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GUIDELINES

RSSDI 2025 NUTRITION GUIDELINES FOR INDIVIDUALS WITH TYPE 2 DIABETES *(Supported by ICMR - National Institute of Nutrition)*

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*Refer to "List of Abbreviations" at the end of the document

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LETTER OF SUPPORT

India has nearly 247 million adults living with diabetes and prediabetes, as per the ICMR-INDIAB 17 report. As national organizations, it is our collective responsibility to ensure they receive the best possible care. Nutrition plays a pivotal role in diabetes management, and there is a pressing need for India-specific dietary guidelines that consider regional dietary patterns and challenges.

Recognizing this need, RSSDI has taken the initiative to develop evidence-based **Diabetes-Specific Nutrition Guidelines** tailored to India's diverse population. These guidelines were formulated with inputs from leading diabetologists, endocrinologists, nutrition experts, as well as senior scientists from ICMR-National Institute of Nutrition. They have undergone rigorous scrutiny at three levels to ensure scientific accuracy and eliminate bias.

We believe that these guidelines will contribute significantly to improving diabetes management, enhancing patients' quality of life, and reducing the risk of complications. Furthermore, by promoting adherence to structured dietary recommendations, these guidelines have the potential to lower medication costs, thereby reducing the overall economic burden of diabetes care.

(Bharati Kulkarni)
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PREFACE

The 2025 RSSDI Consensus Guidelines for Nutritional Management of People with Type 2 Diabetes (T2D) are the culmination of a shared vision—to create a structured, evidence-based, and culturally relevant dietary framework for diabetes management in India.

With the country now home to over 101 million people with diabetes and 136 million with prediabetes, the need for scientifically sound yet practically feasible nutritional recommendations has never been greater. Recognizing this urgent need, the Research Society for the Study of Diabetes in India (RSSDI), undertook this initiative, with the support of ICMR National Institute of Nutrition, to provide a comprehensive guide that aligns with India's diverse food habits, lifestyles, and economic realities.

The conceptualization of these guidelines stemmed and a healthier India from a growing realization that nutrition plays an integral role in diabetes prevention and management. While medications and technological advancements continue to evolve, lifestyle interventions—particularly dietary choices—remain a cornerstone of care. However, India's diverse dietary patterns, socio-economic challenges, and cultural food preferences necessitate a contextualized approach that balances traditional wisdom with modern scientific evidence.

This document serves as a go-to resource for healthcare professionals, dietitians, policy-makers, and individuals with diabetes, offering clear, actionable guidance on meal planning, nutrient distribution, energy balance, weight management, and special dietary considerations. By providing an India-specific, patient-centric, and adaptable nutrition framework, we hope to bridge the gap between research and real-world implementation.

The creation of these guidelines would not have been possible without the collaboration and support of multiple institutions, experts, and dedicated professionals:

- The National Institute of Nutrition (NIN), whose support, scientific inputs, research contributions, and technical expertise have been invaluable in shaping these recommendations.
- The editorial and review committees, whose diligence, commitment, and expertise have ensured the scientific rigor, clarity, and applicability of these guidelines.
- Most importantly, a heartfelt thanks to the authors and contributors of each chapter, who have brought their extensive knowledge, research, and clinical experience to craft a resource that is both authoritative and practical.
- A special acknowledgment to **MEDEVA** for their invaluable contributions in facilitating research, data compilation, and logistical support throughout the development of these guidelines.

This document is a testament to the collaborative spirit of the **RSSDI Consensus Group**, and we deeply appreciate the time, effort, and expertise of every individual who has played a role in its development. As we present these guidelines, we urge healthcare professionals, public health organizations, and educators to adopt and integrate these recommendations into practice. The path forward in diabetes care must be holistic, evidence-driven, and tailored to the needs of the Indian population.

We hope this document serves as an enduring guiding light in the journey toward improved diabetes management, better health outcomes, and a healthier India.

Dr. Vijay Viswanathan	Dr. Sanjay Agarwal
(President, RSSDI)	(Secretary-General, RSSDI)

LETTER FROM THE EDITORIAL COMMITTEE

The 2025 RSSDI Consensus Guidelines for Nutritional Management of People with Type 2 Diabetes (T2D) reflect the collective expertise and dedication of some of the most esteemed minds in diabetes care and clinical nutrition in India. This initiative has been a meticulously planned, evidence-driven effort to provide healthcare professionals with a comprehensive and practical guide to nutrition-based diabetes management. This document addresses the unique dietary habits, metabolic profiles, and socio-economic realities of the Indian population. From macronutrient distribution and glycemic index considerations to meal replacement strategies and culturally relevant food choices, the recommendations herein have been designed with the Indian context in mind.

A defining feature of this document is its interdisciplinary approach. Experts from endocrinology, diabetology, clinical nutrition, public health, and behavioral sciences have collaborated to develop a holistic framework that extends beyond blood glucose control to encompass metabolic health, cardiovascular risk management, and quality of life. By synthesizing global best practices with region-specific evidence, this document ensures that healthcare professionals have access to actionable, practical, and effective dietary interventions.

The creation of these guidelines has been a monumental effort requiring extensive research, clinical expertise, and dedicated collaboration. We extend our deepest gratitude to RSSDI and the National Institute of Nutrition (NIN) for trusting us with this editorial responsibility. The foundation of this document has been the collective effort of all the authors and contributors of individual chapters, their subject-matter expertise, meticulous research, and commitment to scientific accuracy. Each section reflects their dedication to improving diabetes care through nutrition.

It has been a pleasure and privilege working with Dr. Anoop Misra and Dr. V Mohan, whose critical evaluation ensured that every recommendation met the highest standards of scientific rigor and clinical relevance. Heartfelt gratitude to MEDEVA whose role in facilitating research, coordination, and documentation was integral to the seamless execution of this project.

We are confident that these guidelines will serve as a cornerstone for advancing nutritional strategies in diabetes care, ultimately benefiting clinicians, dietitians, researchers, and the millions of individuals living with diabetes in India.

It is now up to healthcare professionals, public health institutions, and policymakers to take these recommendations forward, integrating them into daily practice to create a meaningful impact. Together, we can work towards making India the diabetes care capital of the world and move towards a future where nutrition is recognized as a powerful tool in disease prevention and management.

Best wishes,

Dr NK Singh	Ms Sheryl S Salis	Dr Akash Singh	Dr Rajeev Chawla

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Section 1: Principles of MNT in Type 2 Diabetes Management

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1.1 INTRODUCTION

Type 2 Diabetes Mellitus (T2D) poses a significant public health challenge in India, where the country ranks second globally in the number of individuals living with diabetes.[1] This figure is likely to double in

the next two decades, positioning India as the global epicenter of T2D prevalence. The ICMR-INDIAB national study reports that 101 million people in India have diabetes, and 136 million have prediabetes.[2] The management of T2D necessitates primordial and primary prevention strategies tailored to the Indian demographic and epidemiologic context. This comprehensive management strategy to manage Blood Glucose (BG) levels, weight, and associated comorbidities, including cardiovascular risk factors and sequelae, is critical for mitigating the progression of T2D and reducing the burden of disease on both patients and healthcare systems. (refer to Figure 1.1)

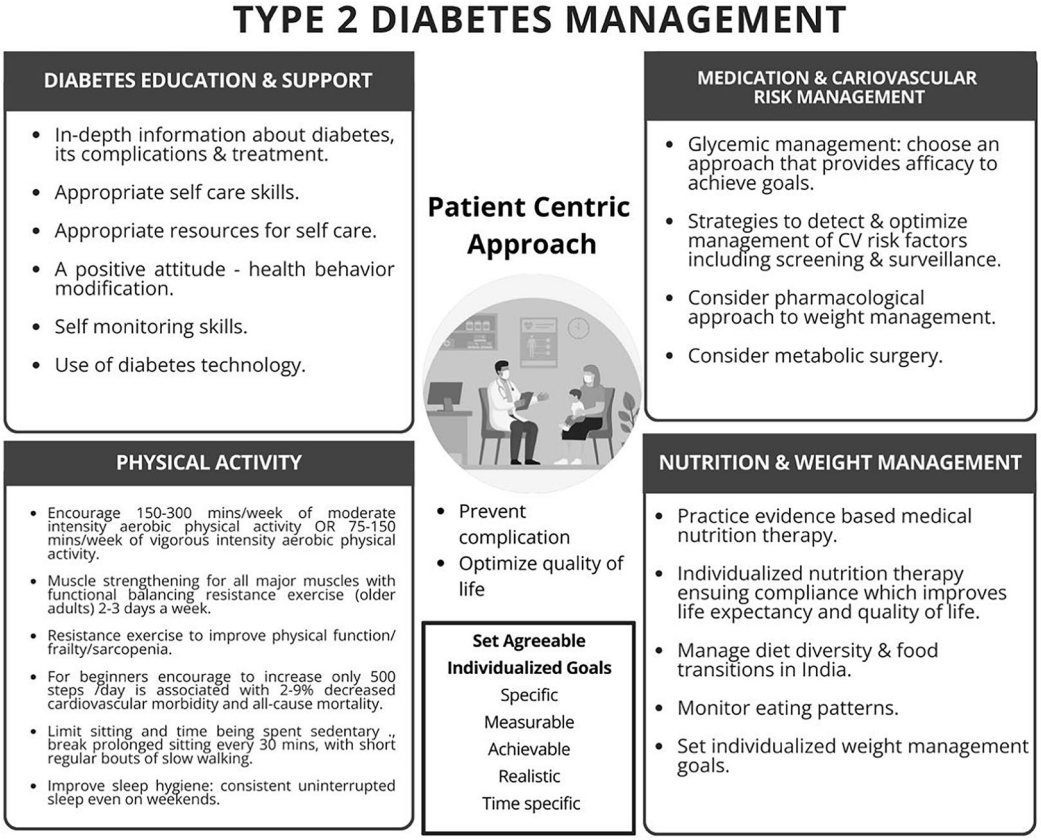

Figure 1.1 T2D Management (Adapted from ElSayed NA, Aleppo G, Aroda VR, Bannuru RR, Brown FM, Bruemmer D et al. 3. Prevention or delay of diabetes and associated comorbidities: standards of care in diabetes— 2023. Diabetes Care. 2023 Jan 1;46(Supplement_1):S41–8.

1.1.1 Objectives and Goals in T2D Management

The 2025 Nutrition Guidelines by the Research Society for the Study of Diabetes in India (RSSDI) are designed to equip healthcare professionals with a robust framework to enhance the management of T2D and mitigate its associated complications. Key elements of diabetes care emphasized in these guidelines include Medical Nutrition Therapy (MNT) for weight control, counselling for tobacco and substance misuse, physical exercise, and psychological support, which are integral to encouraging healthy behaviors. This comprehensive approach is bolstered by Diabetes Self-Management Education and Support (DSMES), ensuring a multidimensional strategy to T2D management that aligns with evidence-based practices.[3-5]

The management of T2D is grounded in a set of objectives that prioritize improving life quality and alleviating symptoms. Key goals[6] include meticulous management of BG levels to prevent severe complications, alongside the identification and treatment of comorbid conditions such as obesity, hypertension, and dyslipidemia.[7] These strategies also aim to thwart microvascular sequelae like retinopathy, neuropathy, and nephropathy, as well as macrovascular complications, including cardiovascular, cerebrovascular, and peripheral vascular diseases. Prevention of infections is also a critical aspect of care. Collectively, these goals provide a cornerstone guiding healthcare professionals to devise personalized treatment plans and empower people with diabetes to lead healthier and more productive lives.

Although T2D is often viewed as a chronic condition, emerging research suggests remission may be possible.[8,9] Primary care-led

weight management for remission of T2D (DiRECT) trial demonstrated that a healthy diet regimen, moderate physical activity, and behavioral therapy led to remission in a significant proportion of individuals. Remarkably, 46% of the research participants achieved remission after a year, underscoring the transformative effect of lifestyle modifications to regulate BG levels and potentially reverse the progression of T2D. These findings highlight the need for a comprehensive diabetes treatment strategy that empowers individuals to take control and manage their health and well-being proactively.[10–14]

1.1.2 Individualized Control of BG, Lipid, and Body Weight

Tight glycemic control, with HbA1c targets ideally below 7%, is crucial in the early stages of T2D, especially for young individuals.[15,16] However, a recent study by Ramachandran *et al.* (2020) suggests that overly aggressive glycemic control in high-risk elderly people with diabetes might not be beneficial and could even increase cardiovascular events.[17,18] Similarly, lipid management and weight control become equally essential aspects of individualized care.[17]
Statin trials, including both primary and secondary prevention trials, have consistently shown the beneficial effect of statins on cardiovascular disease in patients with diabetes.[19] This data highlights the need for medication selection based on ethnicity to optimize lipid control.[20–22]
The PACER trial (high protein, high fat, and moderately low carbohydrate, lacto-vegetarian diet) showed significant improvement in weight loss, body composition, and cardio-metabolic profile as compared to a standard vegetarian diet among obese Asian Indians in north India.[23,24]
A randomized controlled trial showed a Mediterranean diet with extra-virgin olive oil or nuts reduced cardiovascular events in high-risk individuals.[25]
Individualized control of BG, lipids, and body weight is paramount for preventing chronic diseases in India. Recent research delves deeper into personalized approaches, considering factors like gut microbiota, ethnicity, and cultural preferences. Exploring the benefits of traditional practices like yoga alongside dietary modifications holds promise for developing culturally relevant and effective preventive strategies.

1.1.2.1 Prevention or Control of Co-Morbidities

While managing BG levels remain paramount, a growing focus is on preventing comorbidities such as Cardiovascular Disease (CVD), Chronic Kidney Disease (CKD), and neuropathy. Hypertension and dyslipidemia are the most prevalent co-existing conditions, followed by neuropathy and sleep apnea.[26] This aligns with findings from the National Programme for Prevention and Control of Diabetes (NPPCD-2018), which highlighted a high prevalence of hypertension among people with diabetes.[18] This emphasizes the significant threat CVD poses to people with diabetes in India.
Diabetes was identified as the most common cause of CKD, affecting approximately 25% of patients.[27] Additionally, Diabetic Nephropathy (DN), a complication of diabetes, is a major contributor to CKD, with estimates suggesting that 30- 40% of individuals with diabetes may develop this condition.[28-30]
Other comorbidities, such as mental health issues like depression and anxiety, can also be comorbid with diabetes, adding another layer of complexity. Studies haven't been conducted specifically in India on this aspect, but the global trend suggests a need for holistic care that incorporates mental health support.

1.1.2.2 Risk Factors for Comorbidities in People with Diabetes in India

Genetic predisposition: Genetics play a significant role in the development of T2D, and race can also influence its occurrence. However, environmental factors are also crucial in determining its development.

Lifestyle factors: Dietary habits like high intake of refined carbohydrates and unhealthy fats, coupled with physical inactivity, contribute significantly to the risk of co-morbidities in people with diabetes.[19,31]
Socioeconomic factors: Socioeconomic factors like low income, lack of access to healthcare, and limited health literacy can further exacerbate the risk of co-morbidities in people with diabetes.
Understanding the specific co-morbidity profile of people with diabetes in India is crucial for developing effective management strategies.

1.1.3 Significance of a Nutritionist or a Registered Dietitian (RD)

1.1.3.1 Clinical Expertise and Patient Care

Qualified nutritionists and Registered Dietitians (RDs) are pivotal figures in healthcare, specializing in designing nutrition programs to enhance and maintain an individual's health. Their roles extend beyond mere dietary advice, encompassing a comprehensive approach to improving overall well-being. Qualified nutritionists and RDs are instrumental in developing personalized dietary plans for individuals with T2D. The Diabetes in India Nutritional Guidelines Study (DINGS) emphasizes the crucial role of a nutritionist or RD in managing T2D by providing personalized nutrition plans tailored to the unique needs of each individual. These professionals empower individuals to make informed food choices, navigate complex dietary recommendations, and adopt sustainable lifestyle modifications that are essential for effective diabetes prevention and management.[32,33]
Continuous follow-ups with a qualified dietitian or RD are equally important for achieving sustained success in diabetes management.[29,32–34] Regular monitoring and feedback sessions enable healthcare professionals to assess the effectiveness of dietary interventions, track progress, and make necessary adjustments to the nutrition plan. By maintaining a close relationship with people with diabetes over time, these specialists can provide ongoing support, address challenges, reinforce positive behaviors, and offer motivation to stay on track with dietary goals.[35]
Moreover, research suggests that regular follow-up intervals may lead to better clinical outcomes in people with diabetes, indicating the importance of regular follow-ups in maintaining and improving diabetes control. The increasing cost of diabetes care necessitates the reduction of resources used in diabetes care, and extended follow-up intervals may contribute to reducing healthcare costs without negatively impacting diabetes control or individuals' health.

1.1.3.2 Impact on Health Outcomes

The research underscores the positive impact of qualified dietitians on clinical outcomes, medication use, and hospital admissions for individuals with chronic conditions like obesity, diabetes, and lipid metabolism disorders. By focusing on dietary modifications tailored to each individual's needs, qualified dietitians can effectively contribute to glycemic control and improved nutrient intake, thereby reducing the risk of diabetes-related complications and improving overall health outcomes.[36] Their involvement in MNT has been linked to improved health outcomes and reduced healthcare costs, emphasizing the crucial role they play in diabetes management. Moreover, increased contact with qualified dietitians leads to improved HbA1c levels, with the most significant reductions observed in groups with round-the-clock and quarterly touch interventions.[37]

1.1.3.3 Interdisciplinary Collaboration and Improved Behavioral Outcomes

Qualified dietitians/RDs collaborate with healthcare teams, including physicians, nurses, and pharmacists, to ensure holistic patient care. They provide essential education on food-nutrient interactions, dietary plans, and lifestyle modifications, contributing significantly

to individuals' overall well-being. Qualified dietitians/RDs ensure a comprehensive and coordinated approach to patient care by working closely with other healthcare professionals. They can significantly contribute to promoting healthy behaviors that lead to enhanced glycemic control, weight management, cardiovascular health, and potentially the management of comorbidities. They serve as key advocates for providing dietary education and conducting nutrition assessments, which are crucial components in the management of T2D. Hence, their inclusion in multidisciplinary teams is vital for optimizing outcomes.[38]

1.1.3.4 Research and Professional Development

The ability of qualified dietitians/RDs to interpret scientific studies and translate nutritional science into practical advice underscores their commitment to evidence-based practice. Workplace support, mentorship, and personal drive are crucial in sustaining research involvement among qualified dietitians/RDs, highlighting the importance of ongoing professional development in this field.

1.2 MEDICAL NUTRITION THERAPY IN T2D MANAGEMENT

It is imperative to acknowledge the profound impact that MNT has on the health and well-being of people with diabetes. MNT stands as a cornerstone in the management of T2D, offering a personalized and evidence-based approach to nutrition that empowers people with diabetes to actively manage health outcomes. This section aims to delve into the fundamental principles, strategies, and practical recommendations that underpin effective MNT for T2D, aiming to equip both healthcare professionals and individuals with the knowledge and tools necessary to optimize diabetes management through nutrition.

American Diabetes Association (ADA) emphasizes the importance of MNT in the overall diabetes management plan, advocating for regular reassessment of MNT by healthcare providers in collaboration with people with diabetes throughout their lives, with special attention paid to times of changing health status and life stages. International diabetes management collaborative organizations have also recommended MNT to counteract the adverse nutritional transition.[39]

The ADA's 2025 guidelines delineate specific goals for nutritional therapy, which include promoting healthy eating habits and appropriate portion sizes tailored to individual needs and cultural preferences, encouraging the enjoyment of food while limiting unhealthy choices, and providing people with diabetes and caregivers with viable strategies for enhancing dietary quality.[40,41] These guidelines advocate for nutritional practices for people with diabetes that align with those recommended for the general population.

During the initial six months, it is advised that a qualified dietitian/RD conducts between three to six MNT sessions and evaluates the need for further follow-ups. Research indicates that such structured engagements can significantly decrease HbA1c levels by 0.3–2.0% in adults with T2D, concurrently optimizing medication therapy and improving quality of life. For sustained benefits, at least one annual MNT follow-up should be conducted by the dietitian/RD, with evidence showing continued reductions in HbA1c levels for up to two years in adults with T2D.[42] Physicians managing people with diabetes are encouraged to integrate a qualified dietitian/RD into their practice, adopting systematic steps to incorporate MNT into clinical practice, particularly in India. (Figure 1.2)

Let us navigate the intricate interplay between food, metabolism, and health to pave the way for improved outcomes and enhanced quality of life for those affected by T2D. (Figure 1.2)

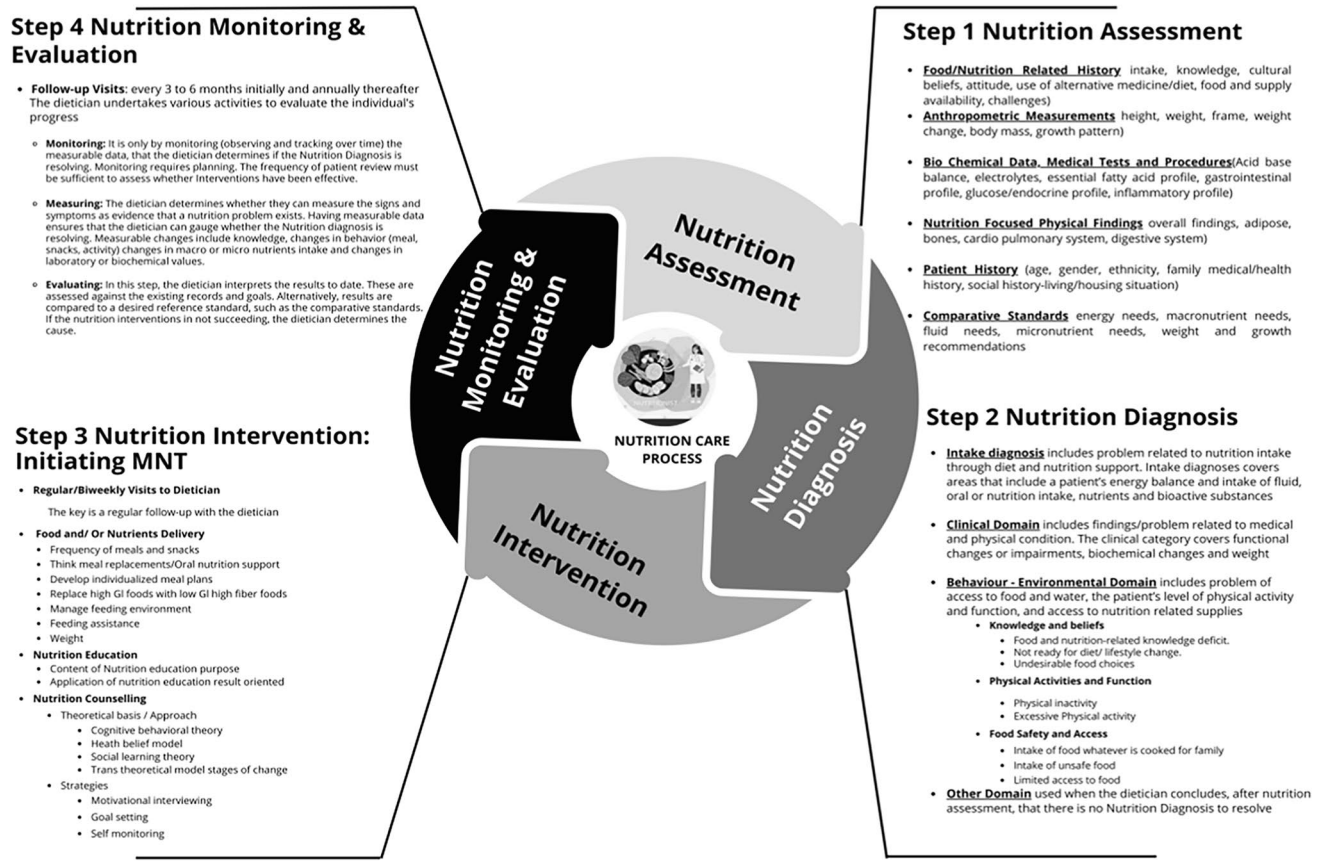

Figure 1.2: Step-wise approach for implementation of MNT. MNT, qualified dietitian/RD. Adapted from the Academy of Nutrition and Dietetics Nutrition Care Process (NCP) model.

Addressing Individual Nutritional Needs Considering Metabolic, Nutritional, and Lifestyle Parameters

Nutritional intervention serves as a cornerstone in both the prevention and management of T2D. However, a *one-size-fits-all* approach to MNT is often ineffective, as the optimal nutritional plan varies significantly between individuals.

A variety of eating patterns (combinations of different foods or food groups) are acceptable for the management of diabetes. Personal preferences such as tradition, culture, religion, health beliefs, routine/lifestyle, economics, and metabolic goals must be considered when recommending one eating pattern over another. Treatment decisions should be founded on evidence-based guidelines tailored to individual preferences, prognosis, and co-morbidities.[43,44]

RSSDI aim to illuminate the importance of tailoring nutritional interventions based on a comprehensive understanding of an individual's metabolic profile, nutritional requirements, and lifestyle patterns. A highly personalized approach is crucial for achieving sustained glycemic control, mitigating risk factors, and promoting overall well-being in those living with T2D.

1.2.1 Nutritional Parameters- Macronutrient Composition

1.2.1.1 Dietary Carbohydrates

To achieve weight loss and reduction in body fat, which includes subcutaneous and visceral fat, either a carbohydrate controlled, or low-fat, calorie-restricted diet may be successful in the short term (up to a year) with careful monitoring and follow-up with the healthcare team. Modest weight loss and reduction of visceral fat improve insulin resistance in people with obesity.

• For weight loss, monitor lipid profiles, renal function, and protein intake (for individuals with nephropathy), and adjust oral anti-hyperglycemic agents as needed. Physical activity and behavior modification are crucial for weight loss and maintenance.

• Weight-reduction drugs may be used for people with diabetes above the target weight range and can help achieve 5–10% body weight loss when combined with lifestyle changes.

• Bariatric surgery may be considered for people with diabetes with a Body Mass Index (BMI) ≥35 kg/m², and it can significantly improve glycemia. The long-term benefits and risks of bariatric surgery for those with pre-diabetes or diabetes are still being studied.

Restricting the consumption of simple carbohydrates, added sugars, and refined and processed foods that can cause rapid BG spikes. Prioritizing complex carbohydrates found in whole grains, legumes, and non-starchy vegetables helps provide sustained energy and dietary fiber, thereby improving glycemic control.[4]

• A carbohydrate intake of 50–55% is recommended for Indians (and Asians), the majority of which should come from complex carbohydrates.

• A diet rich in whole fruits, vegetables, whole grains, legumes, and low-fat milk is recommended for optimal health.

• Monitoring carbohydrates, whether through carbohydrate counting, exchanges, or experienced-based estimation, is an important technique for attaining glycemic control.

- The use of glycemic index (GI) and load (GL) may provide an advantage over just considering carbohydrate amount alone.
- Sucrose-containing meals can be exchanged for other carbs in the meal plan. Sucrose must be restricted to less than 5% of energy. People with diabetes, like the general population, are recommended to eat a range of soluble and insoluble fiber-rich foods. It is recommended by the NIN for the general population to consume 15 g of fiber/1000 kcal or 30 g of fiber/2000 kcal daily. However, there is little data to suggest that people with diabetes should consume more dietary fiber than the general population.
- Sugar, alcohols and nonnutritive sweeteners are safe to consume in moderation; within the Food and Drug Administration's (FDA) recommended daily intake amounts.

The qualified dietitian/RD, in collaboration with people with diabetes, should individualize the macronutrient composition of the healthy eating plan within the appropriate energy intake. Limited research regarding differing amounts of carbohydrate (39–57% of energy) and fat (27–40% of energy) reported no significant effects on HbA1c or insulin levels in adults with diabetes, independent of weight loss. Limited research reports mixed results regarding the effects of the amount of protein (ranging from 0.8- 2.0 g/ kg/day) on fasting glucose levels and HbA1c.[45]

A. **Anthropometric Assessment**

Body Mass Index (BMI): BMI (weight in kg/height in m²) categorizes individuals as underweight, normal, overweight, or obese. Obesity is a significant risk factor for T2D.[46] BMI has limitations as it does not differentiate between muscle and fat mass, nor does it account for the distribution of fat or individual variations in body composition and health.

Waist Circumference (WC): WC assesses central adiposity and associated cardiovascular risk. Increased WC is independently linked to T2D.[47]

Waist-to-height ratio (WHtR): The waist-to-height ratio is a useful measure for assessing central obesity and related health risks, as it accounts for fat distribution more effectively than BMI.

Body Composition Analysis (BCA): Bioelectrical Impedance Analysis (BIA) or skinfold thickness measurements estimate body fat and lean mass, offering insights beyond BMI.[48]

B. **Biochemical Assessment and Metabolic Profile**

A thorough assessment of metabolic parameters is the cornerstone of personalized nutrition planning for T2D. Key indicators include glycemic markers like:

Fasting Blood Glucose (FBG), HbA1c (reflecting average blood glucose **over 2–3 months),** and **postprandial BG** (for insights into glucose spikes after meals)**:** These are primary indicators of glycemic control. FBS and post-prandial BG levels show current glucose levels, while HbA1c reflects average BG control over the past 2–3 months.

Lipid Profile [total cholesterol, Low Density Lipoprotein (LDL), High Density Lipoprotein (HDL), triglycerides): Dyslipidemia is common in T2D. Assess total cholesterol, HDL, LDL, and triglycerides to determine cardiovascular risk.

Renal Function [estimated glomerular filtration rate (eGFR) and urine albumin-creatinine ratio): Monitor serum creatinine and eGFR and urine albumin-creatinine ratio as T2D is a risk factor for DN and assess the need for specific dietary restrictions to mitigate cardiovascular and renal risks.

Liver Function: Evaluate liver enzymes [Alanine Aminotransferase (ALT), Aspartate Aminotransferase (AST)] as T2D increases the risk of Metabolic dysfunction-Associated Steatotic Liver Disease (MASLD).[4] Liver function tests, Fibrosis-4 index (FIB-4) supplemented by a Fibroscan if indicated, provide a more accurate diagnosis of chronic liver disease than assessing only ALT and AST levels. Additionally, Fibroscan is a simple test to confirm the progression of chronic liver disease and cirrhosis.

III. **Clinical Signs and Nutritional Status**

Signs of insulin resistance: Look for acanthosis nigricans (dark, velvety skin patches in body folds), a cutaneous marker of insulin resistance.

Signs of nutritional deficiencies: Examine for signs potentially linked to T2D complications, like pale skin (anemia), angular stomatitis (vitamin B deficiency), or peripheral neuropathy (nerve damage). Individuals living with T2D are at increased risk of micronutrient deficiencies, particularly of vitamin D, vitamin B_{12}, and magnesium, impacting metabolic

control and overall health. Screening for these deficiencies is essential for targeted supplementation.[49]

IV. **Dietary Recall and Lifestyle Factors**

Assessing dietary patterns and food preferences is vital to developing culturally relevant, sustainable nutrition plans.[50] Lifestyle habits play a pivotal role in T2D management. Regular physical activity, encompassing both aerobic and resistance exercise, is essential for enhancing insulin sensitivity and weight management. Sleep patterns are intimately linked with glucose metabolism; insufficient sleep can disrupt hormonal balance and worsen glycemic control. Stress management is particularly important, as chronic stress exacerbates insulin resistance and impedes self-care behaviors. Finally, identifying any comorbidities (e.g., hypertension, dyslipidemia) necessitates integrated dietary adjustments to manage multiple health conditions.[51]

1.2.1.2 Dietary Protein

There is little data to suggest that people with diabetes and normal renal function should change their routine protein intake (15–20% of calories). The quantities and quality of protein intake depend on age, sarcopenia, and renal dysfunction.

- In people with diabetes, dietary protein can boost insulin response without raising plasma glucose levels. Protein-rich foods must not be consumed to treat or prevent acute hypoglycemia, especially at night.
- The long-term implications of consuming more than 20% protein in calories on glycemic control and complications remain unknown. Although such diets may result in short-term weight loss and improved glycemia, it is unclear whether these benefits are sustained over time, and the long-term implications on renal function for people with diabetes remain unknown. Non-vegetarian foods are sources of high-quality protein. However, intake of red meat should be restricted.
- A protein intake of 0.8–1g/kg of body weight/day, or about 15–20% of total calories from protein, is recommended. Higher protein diets may offer some benefits. However, it is recommended to consult a healthcare professional for personalized guidance.

1.2.1.3 Dietary Fat

Fat intake should be limited to less than 30% of the total daily calories.[4] It is recommended to consume about 20–25% percent of fats coming from healthy Monounsaturated Fatty Acids (MUFAs) such as groundnut or mustard oil, nuts, and seeds. This can be achieved by using a combination of at least two vegetable oils, such as groundnut/sesame/rice bran + soybean / mustard oil, and rotating them throughout the week.[4]

- Limit Saturated Fatty Acids (SFA) intake to less than 10%, and in individuals with dyslipidemia/at risk of CVD, limit to <7% SFA of total daily calories. Avoid trans fats, with less than 1% of calories coming from trans fats. Studies have shown a positive association between high saturated fat intake and increased insulin resistance, a hallmark of T2D.[52]
- NIN-ICMR 2024 guidelines recommend not more than 15% of energy coming from visible fat per day. Fried foods should be avoided, with occasional frying in high-smoke-point oils like ghee.[53]
- Omega-3 fatty acids [Polyunsaturated Fatty Acids (PUFA)], known for their benefits in reducing inflammation and supporting heart health, are recommended to be included in the diet through sources such as fatty fish, flaxseeds, and walnuts.
- Oils with high MUFA and PUFA should be used. The use of 2 or more vegetable oils is recommended in rotation.
- For non-vegetarians, 200 g of marine fish, such as salmon, mackerel, trout, and tuna, which are good sources of preferred omega-3 polyunsaturated fatty acids, are recommended to be consumed per week. For vegetarians, dietary sources for omega-3 polyunsaturated fats are nuts (walnuts), seeds (flax, fenugreek, chia, perilla, etc.), soybean, mustard, black gram, cow pea, kidney beans, pearl millet, green leafy vegetables, etc.
- Avoid consuming foods high in saturated fat (butter, coconut oil, margarine, and ghee).
- The use of partially hydrogenated vegetable oils (vanaspati) as the cooking medium should be avoided.
- Reheating and refrying of cooking oils should be avoided.

1.2.1.3 Dietary Cholesterol

- <300 mg/day (for individuals with normal lipid levels/no risk of CVD.
- <200 mg/day (for individuals with dyslipidemia/risk of CVD).

1.2.1.4 Nutritional Parameters- Micronutrient Composition

Ensure adequate dietary fiber intake (25–40 g/day) through whole grains, fruits, vegetables, and legumes. Fiber promotes satiety, improves gut health, and aids in BG management.[54] Screen for and address micronutrient deficiencies, particularly vitamin D and vitamin B_{12}, which are prevalent in the Indian population and influence glucose metabolism.[55–57]

- There is no strong evidence that vitamin or mineral supplementation benefits people with diabetes (relative to the general population) who do not have underlying deficits.
- Routine supplementation with antioxidants, such as vitamins E and C and carotene, is not recommended due to a lack of evidence of benefit and concerns about long-term safety.
- The benefits of chromium supplementation in people with diabetes or obesity have not been fully shown.

1.2.1.5 Nutritional Interventions for Pregnancy and Lactation with Diabetes

- During pregnancy, adequate calorie intake is required to ensure appropriate weight gain. Weight loss is not advised; however, for women with BMI in the overweight and obese category with Gestational Diabetes Mellitus (GDM), moderate calorie and carbohydrate restriction may be appropriate.
- Starvation or Nutritional ketosis should be avoided by providing adequate nutrition.
- MNT for GDM focuses on meal choices that promote healthy weight gain, normoglycemia, and the absence of ketones.
- Because GDM is a risk factor for developing T2D, lifestyle changes with timely follow-ups focused on losing weight and increasing physical activity are advised post-delivery.

1.2.1.6 Nutritional Interventions for Older Adults with Diabetes

- Elderly people with diabetes and obesity may benefit from modest dietary restrictions and increased physical exercise; energy requirements may be lower than for a younger person of comparable weight.
- A daily multivitamin supplement may be useful, particularly for older people with low energy intake.

1.2.1.7 Additional Considerations

Completely avoid sugar-sweetened beverages, as they significantly contribute to excess calorie intake and poor glycemic control. Non-nutritive Sweeteners (NNS) are restricted to Acceptable Daily Intake (ADI) limits. A moderate salt intake of less than 5 grams per day is crucial for maintaining healthy Blood Pressure (BP), which is crucial for individuals with T2D.[4] Practice mindful eating with portion control and a regular meal schedule to maintain stable BG levels.[58] Extreme diets, including low-carbohydrate ketogenic diets, must be planned and executed following consultation with a physician and qualified dietitian and for a short period of time. Meal plans with strategic meal replacements (partial or complete) may be an option under supervision when feasible and required. Alcohol can interfere with the body's ability to regulate BG levels, causing both hypoglycemia and hyperglycemia, leading to unpredictable

glycemic control.[59] Alcoholic beverages are high in calories, contributing to weight gain, a risk factor for T2D complications. Chronic alcohol consumption decreases insulin sensitivity, thereby impeding glucose utilization. Smoking significantly increases insulin resistance, hindering cells' ability to absorb glucose.[60] It also delays wound healing, a major concern for people with diabetes who are prone to foot ulcers and other complications. Smoking is a major risk factor for cardiovascular disease, a leading cause of morbidity and mortality in individuals with T2D.[61]
Following an optimal nutritional plan is a critical component of managing T2D. These evidence-based guidelines emphasize a well-balanced diet rich in whole grains, vegetables, legumes, healthy fats, and moderate protein. Individuals with T2D can improve glycemic control and overall health by lowering their intake of simple carbohydrates, added sugars, unhealthy fats, and salt.

1.2.2 Optimal Nutritional Intervention

This section will outline the latest clinical data for optimal food choices, specific dietary patterns, and nutritional considerations within the Indian context.

1.2.2.1 Individualised Nutrition Prescription

The qualified dietitian/RD should individualize the nutrition prescription and implement evidence-based guidelines in collaboration with people with diabetes. A variety of eating patterns (combinations of different foods or food groups) are acceptable for the management of diabetes. Personal preferences (e.g., tradition, culture, religion, health beliefs with perceived personal goals and economics) and metabolic goals should be considered when recommending one eating pattern over another. Treatment decisions should be founded on evidence-based guidelines tailored to individual patient preferences, prognosis, and co-morbidities.

1.2.2.2 Encourage Healthful Eating Plan for Appropriate-Weight People with Diabetes

For appropriate-weight individuals with diabetes, the qualified dietitian/RD should encourage the consumption of a healthful eating plan with the goal of weight maintenance and prevention of weight gain. A variety of eating patterns (combinations of different foods or food groups) are acceptable for the management of diabetes.
1.2.2.3 Encourage Reduced Energy Healthful Eating Plan for People with Diabetes with overweight and obesity
For people with diabetes who are overweight and obese, the dietitian should encourage a low-calorie, healthy eating plan with an emphasis on nutrient density and diet diversity, aiming at weight loss, maintenance of weight loss, and prevention of weight gain. Studies based on interventions to reduce energy intake reported significant reductions in HbA1c of 0.3–2.0% in adults with T2D and of 1.0–1.9% in adults with Type 1 Diabetes (T1D), as well as optimization of medication therapy and improved quality of life.[62]

1.2.3 Provision of Positive Messages About Food Choices

In India, the land of diverse cuisines, a diagnosis of T2D can feel like a barrier to enjoying the richness of our food culture. However, RSSDI emphasizes that with the right dietary guidance and a positive approach, people with diabetes can transform their relationship with food and thrive with T2D.

From Restraints to Celebration

Celebrating tradition with a twist: Indian cuisine boasts a vast array of vegetables, dals (lentils), and whole grains like brown rice and millets. Explore healthier versions of traditional dishes. For example, use low GI whole-grain rice instead of high GI white rice in biryani.
Spice up your life: Embrace the world of Indian spices! Turmeric, fenugreek, and cinnamon have been shown to possess potential benefits for BG management, adding flavor while promoting health.
Building Sustainable Habits

• **Small steps, big impact:** Significant lifestyle changes can be overwhelming. Start small and focus on forming sustainable habits. Swap sugary drinks for buttermilk (*chaas*) or unsweetened lemon water, or replace evening fried, salted snacks with a handful of unsalted nuts and a piece of fruit.
• **The power of community:** In India, food is a social experience. Studies by Anjana *et al.* (2023) suggest a supportive social environment is vital for successful diabetes management.[2]
• **Find your support system:** Consult a qualified dietician/RD familiar with Indian cuisine. They can personalize a meal plan that incorporates cultural preferences and helps develop healthy substitutions within familiar dishes.
Core guidelines for positive food choices
• **Fresh and local:** Prioritize fresh, seasonal vegetables and fruits from local markets. They are not only packed with nutrients but also burst with flavor.
• **Embrace traditional grains:** Rediscover the health benefits of millets. These ancient grains are rich in dietary fiber and can help with BG control. Choose unpolished over polish for health benefits. However, as per the NIN-ICMR guidelines 2024, not more than 20% to 30% of Cereals should be from millets for adults, and not more than 20% of cereals should be from millets for children (up to 10 years of age)
• **Smart snacking:** Plan healthy snacks like roasted chana with a sprinkle of mixed spices to curb cravings and maintain **BG** levels.
• **Mindful eating practices:** Incorporate ancient wisdom – eat slowly, savor each bite, and stop when comfortably full. This practice, rooted in Ayurvedic principles, promotes mindful eating and prevents overconsumption.
• **Celebrate non-scale victories:** Focus on the positive changes beyond the weighing scale – improved energy, better sleep, and a more vibrant outlook on life. Celebrate these milestones alongside weight management goals.

1.2.3.1 The Burden of Diabetes: A Psychological Toll

Living with diabetes can be emotionally taxing. Studies reveal a significantly higher prevalence of mental health conditions in individuals with diabetes compared to the general population. Depression, anxiety, and eating disorders are particularly common.[63,64] The constant stress of monitoring BG, adhering to dietary restrictions, and managing medication schedules can be overwhelming. Fear of complications, feelings of isolation, and a perceived loss of control can further exacerbate emotional distress.
The connection between psychological well-being and successful diabetes management is backed by robust scientific evidence. A 2017 study published in Diabetes Care found that psychosocial interventions, which address emotional and behavioral aspects of diabetes, led to significant improvements in glycemic control in people with diabetes.[65] Research has also shown that psychological support can enhance medication adherence, improve dietary choices, and increase physical activity levels – all crucial components of effective diabetes management.[66]
There are several mechanisms at play in this positive influence. Psychological support can:
• **Reduce stress:** Chronic stress can raise BG levels, making management more challenging. Support can equip individuals with coping skills to manage stress effectively, leading to improved glycemic control.[67]
• **Boost motivation and self-efficacy:** Psychological interventions can foster a sense of empowerment and self-belief in one's ability to

manage diabetes effectively. This increased self-efficacy translates to better adherence to treatment plans and healthier lifestyle choices.
• **Improve emotional regulation:** Living with a chronic illness can trigger emotional fluctuations. Psychological support helps individuals develop healthy strategies for managing emotions and navigating the challenges of diabetes with greater resilience.
• **Promote problem-solving skills:** Diabetes management often requires navigating complex situations. Psychological support can equip individuals with problem-solving skills to address challenges and make informed decisions regarding their health.

1.2.3.2 Integrating Psychological Support into Diabetes Care

The ADA emphasizes the importance of integrating psychosocial care into routine diabetes management.[68,69] This can involve:
• **Screening for mental health conditions:** Regular screening allows healthcare professionals to identify potential issues early and connect individuals with appropriate support services.
• **Psychotherapy:** Individual or group therapy sessions can provide valuable tools for managing stress, anxiety, and depression.
• **Support groups:** Sharing experiences with others who understand the challenges of diabetes can foster a sense of community and reduce feelings of isolation.
• **Diabetes education:** Educational programs that address the psychological aspects of diabetes, along with self-management skills, can empower individuals to take control of their health.

By embracing a positive and culturally sensitive approach to food choices, people with diabetes can successfully manage T2D and cultivate a sustainable, healthy lifestyle. With small, positive changes and the support of the community, one can turn food into a powerful tool for a thriving life with T2D. Psychological support is not a luxury but an essential pillar in successful diabetes management. By addressing the emotional and behavioral aspects of the condition, we can empower individuals to cope with the challenges, improve health outcomes, and enhance their overall well-being. Integrating psychological support into routine care is a crucial step towards a more holistic and effective approach to managing diabetes.

1.2.4 Provision of Practical Tools for Day-to-Day Meal Planning

Dietary education should be individualized for people with diabetes depending on their abilities, preferences, and management goals on one of the MNT strategies listed below:
• Plate method, portion control, and simplified meal plan
• Food lists (like Choose Your Foods). Monitoring carbohydrate consumption, whether through carbohydrate counting or experience-based estimation, remains an important method for glycemic management. Individuals with T2D who have low health literacy or numeracy difficulties may benefit more from a simple diabetes healthy eating plan strategy, such as portion control or healthy food selections.

1.2.4.1 The Indian Food Exchange List Method: A Culturally Nuanced Approach

NIN-ICMR food exchange lists categorize commonly consumed Indian foods based on their carbohydrate, protein, and fat content.[50] This method resonates with individuals accustomed to a diverse array of staples like rice, lentils (dals), and vegetables. Unlike generic exchange lists, the NIN-ICMR version incorporates these familiar food groups, fostering a sense of ease and ownership in meal planning. The benefits include:

• **Culturally relevant:** Utilizes familiar Indian staples, promoting adherence.[70]
• **Empowers individuals:** Provides choices and control within a structured framework, fostering self-management skills.[71]
• **Simplicity:** Easy to understand and implement, making it suitable for diverse educational backgrounds.[72]

1.2.4.2 The Thali System and Portion Control: A Visual Cue for Balanced Meals

The traditional Indian thali system, a segmented plate with various compartments, offers a practical and culturally relevant tool for portion control. Each compartment can be designated for a specific food group, promoting balanced meals that visually reinforce healthy eating principles. Benefits:
• **Visual aid:** The plate layout provides a clear and relatable cue for appropriate portion sizes.[73]
• **Cultural familiarity:** Leverages established dining practices, enhancing patient buy-in.[74]
• **Adaptability:** Compartment sizes can be adjusted to individual calorie and macronutrient needs.[75]

1.2.4.3 A Synergistic Approach: Combining Methods for Optimal Outcomes

The food exchange list and thali system can be combined to create a comprehensive and empowering strategy. Individuals can utilize the exchange lists to choose appropriate foods within each thali compartment, ensuring balanced and portion-controlled meals. Studies conducted in India have demonstrated the effectiveness of combining dietary education with visual aids like the thali system. Joshi *et al.* (2018)[76] observed significant improvements in glycemic control and dietary behaviors among people with diabetes who received a structured education program incorporating a modified thali system.

Additional Tips for Healthy Indian Diabetes Friendly Meals

• **Focus on whole grains:** Promote options like brown rice, unpolished millets, and whole wheat rotis over refined grains to provide sustained energy and dietary fiber.[77]
• **Incorporate healthy fats:** Include moderate amounts of unsalted nuts (almonds, walnuts, pistachios, peanuts), seeds (flaxseeds, chia seeds, pumpkin seeds, sunflower seeds, sesame seeds), and vegetable oils (mustard oil, groundnut oil) for satiety and essential nutrient intake.[78]
• **Prioritize vegetables:** Encourage a variety of non-starchy vegetables like lady finger, French beans, amaranth, spinach, fenugreek, cabbage, and cauliflower in every meal for essential vitamins, minerals, and fiber.[79]
• **Limit sugary drinks:** Emphasize water consumption and unsweetened beverages like buttermilk and unsalted lemon water to manage BG levels effectively.[80]

Equipping individuals with practical tools like the Indian food exchange list, thali system, and portion control methods empowers them to manage their diabetes through culturally relevant and sustainable meal planning strategies. By combining these tools with personalized guidance from healthcare professionals, individuals can achieve optimal BG control and improve their overall well-being.

1.2.5 Delaying the Complications of Diabetes

Chronic hyperglycemia and glycemic variability, the common metabolic abnormalities in T2D, damage blood vessels and nerves throughout the body. Over time, this damage can lead to a range of complications, including cardiovascular disease, diabetic nephropathy, diabetic neuropathy, and diabetic retinopathy.[81–84] However, the RSSDI emphasizes that optimal management can significantly delay or even prevent the onset of these complications.

Early intervention and optimal management can significantly delay or even prevent the onset of these complications. Studies by Ramachandran *et al.*[84] have shown that intensive glycemic control can significantly reduce the risk of microvascular complications in Indian people with diabetes.[85] Early detection and regular follow-up every three months is crucial. Moreover, regular screening for diabetes complications is recommended by the concerned team of specialists. Strict glycemic control is the cornerstone of preventing complications. Maintaining BG levels as close to normal as

possible is essential, which is influenced by factors like age, comorbidities, and overall health. Reducing glycemic variability through dietary interventions may help prevent micro- and macrovascular complications in T2D individuals.[86–88] Several studies have shown that minimizing glycemic excursions can reduce oxidative stress and inflammation, which contribute to the development of cardiovascular diseases.[87,88] Modern diabetes management strategies, such as improved anti diabetes oral agents, newer insulins, and insulin pump therapy, also aim to address glycemic variability, effectively.[88] Reducing glycemic variability, along with optimizing FBG, postprandial BG, HbA1c, and quality of life, has been proposed as part of a 'glycemic pentad' that should be considered in diabetes management.[88]
Physical activity is another essential component, with a recommendation of at least 150–300 minutes of moderate-intensity aerobic physical activity or at least 75–150 minutes of vigorous-intensity aerobic physical activity or an equivalent combination of moderate- and vigorous-intensity activity throughout the week.
Even small increases in activity levels can significantly improve glycemic control. Weight management is critical, as maintaining a healthy weight or losing excess weight can significantly improve BG control and reduce the risk of complications.[89]
Lifestyle modifications such as smoking cessation, stress management, and adequate sleep are also crucial. Smoking significantly increases insulin resistance and the risk of cardiovascular complications. Quitting smoking is one of the most impactful lifestyle changes. Chronic stress can elevate BG levels, so practicing stress-reduction techniques like yoga, meditation, or deep breathing exercises is beneficial. Adequate sleep, aiming for 7–8 hours of quality sleep each night, is essential, as poor sleep can disrupt BG regulation.

1.3. CONCLUSIONS AND RECOMMENDATIONS

Clinical Pearls of Practice

- Quantity and quality of macronutrients are both important.
- Fat: Intake should be limited (20-25% of total calorie intake); the quality of dietary fats is more crucial.
- Include nuts and seeds in your diet. Use a combination of oils rather than one oil. Avoid consuming higher quantities of saturated fats (ghee/ butter, etc.). Avoid Trans fats (Margarine, Vanaspati, street foods, etc.).
- Protein intake should be maintained at about 15–20% of the total calories. The quantity of protein intake depends on age, sarcopenia, and renal dysfunction.
- Non-vegetarian foods are sources of high-quality protein. However, the intake of red meat/processed meats should be avoided.
- Carbohydrate content should be limited to 50-55% of total calorie intake. Both quantity and quality are important. Complex carbohydrates should be preferred over refined products. Low GI and low GL foods should be chosen.
- Diets rich in whole grains, fruits, vegetables, legumes, and nuts and lower in refined grains, red/processed meats, and sugar-sweetened beverages have been demonstrated to reduce diabetes risk and improve glycemic control and blood lipids in patients with diabetes.
- Several healthy dietary patterns emphasizing the overall diet quality can be adapted to appropriate personal and cultural food preferences and calorie needs for weight control and diabetes prevention and management.
- We recommend abstinence from alcohol. Alcohol consumption may place adults with diabetes at increased risk for delayed hypoglycemia, especially if using insulin or insulin secretagogues.
- The meal plan should be prepared by a qualified nutritionist/dietitian whenever possible. It should be based on Type, Amount, and Frequency (TAF). Regular follow-up with a nutritionist is recommended.

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Section 2: Current Dietary Habits and Their Relevance to Diabetes Management and Prevention

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2.1 INTRODUCTION

Unhealthy lifestyle changes (unhealthy diet and physical inactivity) are the important risk factors for both diabetes progression and poor glycemic control.[1,2] Altered dietary practices have led to a reduced intake of whole grains, pulses, fruits, and vegetables; instead, they have been replaced by a higher intake of refined carbohydrates like white rice and refined wheat flour.

Public health strategies and policy-level decisions involving stakeholders with diet and lifestyle modification as focal points are absolute priorities to prevent and manage the burden of obesity and Type 2 Diabetes Mellitus (T2D) in India. Given the cultural and geographical variations in food consumption patterns in India, it is essential to tailor these strategies to address the specific dietary habits and nutritional challenges of different regions.[3]

In this context, this chapter explores current evidence on the same to discuss ways to improve dietary habits and suggest the need for evidence-based dietary guidelines to prevent and manage T2D.

2.2 CURRENT DIETARY HABITS

Predominantly, Indian diets are plant-based. However, religious and cultural influences shape animal-based diets (including lacto, ovo, lacto-ovo vegetarian, pescatarian, flexitarian, and non-vegetarian). Socio-economic factors such as religion, family size, income, and social class also contribute to this diversity.[3]

In India, large regional and national studies have been collected periodically over decades to assess the dietary intakes of the population and their nutritional status, mainly associated with undernutrition-related malnutrition. Only in the last few decades have obesity-related dietary assessments been included in these studies. These national studies are discussed below.(Table 2.1)

2.2.1 Role of National, Regional, and International Studies

Table 2.1. Role of National, Regional, and International Studies

National Surveys	
National Family Health Survey (NFHS)[4,5]	• Typically conducted at an interval of about 3 years • NFHS provides comparable data on o Population dynamics o Health indicators o On emerging issues in health and family welfare and associated domains. • Dietary practices of children, women, and men • NFHS surveys aid in programs and policymaking for setting the benchmarks
National Nutrition Monitoring Bureau (NNMB)[6]	• The National Institute of Nutrition (NIN) conducts diet surveys to assess the food and nutrient intakes at household and individual levels and to determine their nutritional status • NNMB covers representative segments of the rural/urban/tribal population in the states and regions o To evaluate ongoing national nutrition programs. o To identify the gaps to recommend appropriate corrective measures.
National Sample Survey Office (NSSO)[7]	• Conducts expenditure surveys at periodic intervals in diverse fields, including food consumption surveys across all regions, states, and socio-economic strata of India. • NSSO surveys do not provide direct dietary intakes of the population o It measures the amount of income spent on the purchase of various foods' quantity by individuals of various socioeconomic strata.
ICMR-INDIAB Study[8]	• It is the first large Indian survey conducted nationally o To estimate the prevalence of diabetes at the national and state levels. • The study includes all states and union territories of India, including the National Capital Territory (NCT) of Delhi. • This study highlights the various determinants, including lifestyle factors such as the population's dietary habits and their association with diabetes prevalence and poor glycemic control. • The study findings provide useful first-hand insights for policymakers o To plan programs even at the state level to arrest the growing diabetes epidemic. o Also lays the foundation for the national, regional, and state-level nutrition guidelines to improve overall diabetes care.
Regional Surveys	
Chennai Urban Rural Epidemiology Study (CURES)[9]	• Largest systematic population-based study conducted in urban and rural South India on diabetes and its complications. • CURES was initially planned as a cross-sectional study to evolve later into a longitudinal study (cohort). • The representative Chennai city adult population had been considered in the urban component. • The CURES study was conducted in 3 phases o Detailed dietary assessment was carried out. o Key findings on dietary factors and their associations with the incidence of diabetes and other cardiometabolic entities were widely published.
The Indian Migrants Study (IMS)[10]	• Elucidates the effects of rural-urban migration on obesity and diabetes in India. • Conducted between 2005 and 2007. • Carried out in factory settings from Northern, Central, and Southern India (Lucknow, Nagpur, Hyderabad, and Bangalore). • To evaluate the dietary changes due to rural-to-urban migration in the context of cardiovascular health.
Multinational Study	
Prospective Urban Rural Epidemiology (PURE) Study[11,12]	• A prospective study among 27 countries on over 200,000 participants o To investigate the impact of modernization, urbanization, and globalization. o Health behaviors, including how risk factors develop and influence cardiovascular disease, diabetes, lung diseases, cancers, kidney disease, brain health, and injuries, with India as one of the participating countries. • Dietary habits of the global population further stratified by ethnicity assessed by this study o Sheds light on transition diets and their impact on Non-Communicable Diseases (NCDs) and brings evidence for policymakers on global and regional health matters.

2.2.2 Dietary Intake – Macronutrients

Carbohydrates- Historically, Indians consumed and continue to consume cereal staple-based diets and hence have high carbohydrate intake irrespective of the different regions or dietary patterns that exist in the country. Regarding macronutrients, carbohydrates account for 60–80% of the total ingested calories in Indian diets.[13] The average carbohydrate intake among urban and rural adults was similar (61–62% Energy) irrespective of the status of their glucose tolerance (Normal Glucose Tolerance (NGT) or glucose intolerance

(pre-diabetes or newly diagnosed diabetes-NDD).[14] The '**S**tudy **T**o **A**ssess the dieta**R**y **C**arbo**H**ydrate' content of Indian T2D population (STARCH) was a multicentric study that assessed dietary patterns in individuals with T2D. The dietary assessment in 10 specialty endocrinology/diabetology centers across five regions of India showed a carbohydrate intake of 64% in T2D individuals, which was no different from the carbohydrate intake of individuals without diabetes in these regions. Higher carbohydrate intake (>450 g/day), especially derived from refined cereal grains, is associated with a higher risk for metabolic syndrome and incidence of diabetes.[15,16,17] Higher refined grain dietary intake contributed to a higher intake of refined carbohydrates and Glycemic Load (GL), which were inversely associated with High-Density Lipoprotein (HDL).[18] Carbohydrate intake and the risk of chronic diseases are detailed in Chapter 5 - Dietary Carbohydrates.

Proteins - In NNMB studies, the average protein intake of adults in urban and rural India was 55.4 g and 69 g/day, respectively. Rural South Indian men consume higher protein (51.3 g/day) than rural women (45.8 g/day), and both had lower average daily protein intakes, with proteins accounting for 9.6% of total energy[19] as compared to the World Health Organization (WHO) standards (10–15% of the total energy) required for prevention of NCDs.[10,11] Increasing protein-derived calories to 14–16 % could help in reducing the risk of diabetes across regions, genders, and in both urban and rural populations.[12,14]

Fat - South Indian urban adults reported that dietary fats contributed 24% of total daily calories as median intake. This included nearly 9% energy from Saturated Fatty Acid (SFA), 7% and 6% from Mono- and Polyunsaturated Fatty Acids (MUFA and PUFA).[15] Over the previous two decades, the population's total fat intake has increased considerably in rural (from 31 to 42 g/day) and urban areas (42–53 g/day), respectively. [20] The national ICMR-INDIAB study showed that the fat intake was 26% among urban and 25% among rural adults.[14] The urban south Indian population consumed nearly 33 g of visible fats and oils/day,[21] which was more than the recommended amount given by ICMR-NIN for sedentary males (25 g) and females (20 g).

Fiber - In the south Indian population, the mean dietary fiber intake among rural males was 16.4 g/day and 13.8 g/day in females, whereas fiber consumption among urban adults was 34.7 g/day. In the CURES study, the dietary fiber intake in those with NDD was 29 g/day. Ingestion of dietary fiber over 30 g/day could reduce total and Low-density Lipoprotein (LDL) cholesterol levels.[22] Dietary fiber intake of 15 g/1000 calories reduced the risk of diabetes among the urban population.[17]

The macronutrient intake of the population and clinical studies are summarized in **Table 2.1**.

2.2.3 Micronutrient Intake (Vitamins, Minerals, and Trace Elements)

India is experiencing a period of triple burden of malnutrition, which includes undernutrition, overnutrition, and micronutrient deficiency. Micronutrient insufficiency, which has also been termed as 'hidden hunger'[23] is becoming a public health priority in India.[24,25] Micronutrients such as fat-soluble vitamins (A, D, E), water-soluble vitamins (B_1, B_6, B_{12}), and minerals like calcium, chromium, iron, magnesium, potassium, selenium, vanadium, and zinc play supportive roles in diabetes management. Despite their importance, there is a notable paucity of comprehensive data on micronutrient deficiencies in the Indian population. The limited availability of such data hampers the development of targeted nutritional interventions and public health strategies. Without robust and detailed information, addressing the specific micronutrient needs of diverse demographic groups is challenging, leading to potential gaps in healthcare provision and policy formulation. The average daily intake of several vitamins and minerals in the urban population appears to fall below the Estimated Average Requirement (EAR). Specifically, the intake of vitamin A (124 µg/CU/day), riboflavin (0.8 mg/CU/day), niacin (16 mg), folate (118 µg/CU/day), and vitamin C (29 mg) were all reported to be less than the EAR. Low maternal vitamin B_{12} levels combined with high folate levels might increase the risk of T2D and vitamin B_{12} deficiency, which is observed in 33.4% of offspring.[26] Furthermore, the average daily intake of minerals like calcium (331 mg) and iron (12 mg) also did not meet the EAR in the urban population. According to Awasthi *et al.*, the prevalence of calcium and iron insufficiency was 59.9% and 49.4%, respectively, among urban school-going children and adolescents in India.[27]

Low vitamin D levels have been linked to an increased risk of diabetes. Systematic review and meta-analysis showed improvement in Fasting Blood Glucose (FBG), glycosylated hemoglobin (HbA1c), and insulin resistance with Vitamin D supplementation, especially for those with vitamin D deficiency[28]. Vitamin D deficiency has been observed in 39.7% of Indians, and it is possible that there is an inverse relationship between Vitamin D levels and FBG in ostensibly healthy adults.[29] Experimental investigations suggest that chromium might help regulate BG levels[23]. Conversely, high selenium concentration from supplementation could be linked to increased gluconeogenesis, higher FBG levels, and a potentially increased risk of diabetes.[30] There also seems to be a possible association between low levels of magnesium and insulin resistance.[31] Magnesium deficiency, possibly due to low vegetable intake, has been noted in 44% of individuals with T2D, and diabetes complications and poor glycemic control could be positively associated with low serum magnesium levels.[32,33] Additionally, poor glycemic control might be associated with low zinc levels.[34] Research has highlighted that Coronavirus Disease (COVID-19) patients with lower levels of zinc and selenium tend to experience more severe symptoms and have a higher risk of complications.[35]

2.2.4 Food Groups and Their Quality

Overall diet quality- Research consistently demonstrates that the quality of one's diet greatly influences diabetes management. Anjana *et al.*[36,37] in the CURES urban cohort explained that around 30% of diabetes incidence can be averted by modifying five dietary habits: consuming highly refined cereals, low consumption of fruits, vegetables, dairy products, and including food sources rich in MUFA like those present in edible nuts. Lakshmipriya *et al.*,[16] further developed the Indian Diet Quality Score (IDQS), which assesses an individual's diet across eight food categories (pulses and legumes, dairy and its derivatives, fruits and vegetables, white rice, edible fats and oils, added sugars, added salt, and poultry and eggs) and one category for the type of cooking oil. These categories are associated with the risk of diabetes. The higher overall diet score suggests healthier dietary habits for preventing NCDs and managing T2D. NFHS-4 study[37] developed dietary scores using the healthy and unhealthy food groups and their frequency of intake (daily/weekly/never) and explained the importance of quality of the diet and moderate intake of both healthy and unhealthy foods - milk or curd, pulses or beans, dark green leafy vegetables, fruits, eggs, fish, chicken/meat, fried foods, and carbonated drinks. Both daily consumption and complete avoidance of these food groups were associated with higher risks of diabetes and cardiovascular diseases in men. Therefore, the dietary scoring system can serve as an effective tool for educating the public.

Cereals and millets - Compared to the traditional cereal staple grains today, most grains are refined grains, mainly rich in starch and devoid

of fiber and micronutrients. Studies from both the Indian and Western populations suggest an increased risk of diabetes and poor glycemic control with higher refined grains consumption.[18]

The CURES study found that urban adults consume an average of 333 g/day of refined grains, with higher intake associated with an increased risk of metabolic syndrome. Similarly, the PURE multinational study[38] indicated that higher consumption of carbohydrate diets, primarily from refined grains like white rice, is linked to an elevated risk of diabetes in Asian countries. Substituting brown rice for white rice has been shown to reduce HbA1c and C-Reactive Protein (hs-CRP) levels among overweight adults, particularly those with metabolic syndrome.[21]

Pulses and legumes - Pulses and legumes are the common, less expensive staple protein sources compared to animal proteins, making them accessible to various socioeconomic groups in India. The average pulse consumption is lower than 53 g/day.[18] Pulses and legumes intake >60 g/day showed a significant risk reduction of diabetes and other cardiometabolic risks.[16] This is the only one study, that shows the combination of various dietary ingredients, including pulses and legumes, plays a role in the risk reduction of diabetes. The large national NFHS-3 data suggested that including pulses or beans in the daily diet could reduce the risk of diabetes, especially among women.[39]

Fruits and vegetables - Fresh fruit and vegetable consumption was 265 g/day, less than the Food and Agriculture Organization (FAO)/WHO recommended daily intake of 400 g.[18] A diet high in fruits and vegetables (≥ 400 g/day) can reduce risk factors for cardiovascular disease. The consumption of fruits was 26 g/day in rural and urban 42 g/day, while the intake of vegetables was 74 g/day (rural) and 79 g/day in urban population.[17,40] Rural adults in the CURES study had one-fourth of the WHO consumption of 400 g/day to prevent NCDs.[41] A higher intake of fruits and vegetables was associated with about 48% reduction in cardiovascular disease risk factors.[42]

Milk and milk products - NNMB studies mentioned a mean consumption of 121 g/day and 118 g/day of dairy products by urban and rural, respectively.[43,44] Mohan *et al.*[17] and Lakshmipriya *et al.* showed that dairy intake > 365 g/day could reduce the risk of diabetes. Increased consumption of total dairy (including fermented dairy) of 755 g/day and 300 g of fermented dairy was associated with a lower risk of high FBG compared to a low total dairy intake of < 208 g/day and fermented dairy 11 g/day.[45] The recent global systematic review and meta-analysis highlighted total dairy, fermented dairy, and plain yogurt, all of which were inversely associated with incident T2D.

Animal foods (Meat, poultry, fish, seafood, and egg) - Animal food intake was around 50 g/day only by the urban adults, which accounted for 2·5% of daily calories, 13·9% of protein, and 3·1% of total fat intake.[18] NFHS-3 showed an increased risk of diabetes with daily fish consumption.[46] On the other hand, the large multi-country PURE study showed that those with existing cardiovascular disease would benefit from the consumption of two servings/week (175 g/serving).[47]

Fats and oil - In India, the urban populace consumes more visible fat. When it comes to fat and oil intake, it is recommended with a PUFA n6/n3 ratio of not more than 5:1 to reduce the risk of metabolic syndrome and insulin resistance. Visible fats and oils (including those utilized in cooking, processing, and added at the table) contributed to 12.4 % of the total calorie intake, almost half of the daily fat calories.[9,18] Cooking oils are region-specific. Mustard oil is preferred in the north, northeast, and east regions, sunflowers in the south, and soybean oil in the west. Both urban and rural adults from the CURES study reported sunflower oil (urban 68%; rural 17.2%) is the most popular type of oil used in cooking, followed by palmolein, which is distributed in the public distribution system (urban 22%; rural 40.4%) while traditional oils like groundnut and gingelly are reported higher in rural (41%)[41] than urban (6%).[33] The largest portion of the total fat consumed was made up of visible fats and oils, accounting for 53.3% of daily fat intake. Sunflower oil (n-6 PUFA rich) showed a higher risk for metabolic syndrome as compared to traditional oils like groundnut and gingelly.[41] Although clinical trials with rice bran oil as a main cooking oil[48,49] have shown improvement in blood lipid profile (as it contains rich antioxidants like gamma oryzanol, etc.), this oil has not been reported commonly in epidemiological studies in India.[48]

Nuts and seeds- They are nutrient-dense dietary choices rich in macronutrients-protein, MUFA and PUFA, and dietary fiber. In addition, nuts and seeds are rich in bioactive nutrients, such as polyphenols, which have antioxidant properties.[50] Randomized controlled trials on unsalted, raw nuts like cashews (up to 30 g/day) positively impacted lipid profile, such as increased HDL and decreased systolic blood pressure among T2D participants. Incorporating almonds (43 g/day) into the daily diet for 12 weeks significantly decreased HbA1c, total cholesterol, and LDL cholesterol, particularly aiding prediabetes prevention.[51] Gulati *et al.* found that consuming 20 g of almonds before major meals improved body weight, glycemia, and insulin resistance, potentially reversing prediabetes over three months.[52] Furthermore, almonds increase MUFA intake, decrease carbohydrate calories, and improve insulin sensitivity, reducing diabetes and cardiometabolic risks in Asian Indians.[53,54]

Sugar and salt- Excessive consumption of sugar and salt increases the risk of NCDs. WHO suggests reducing added sugar intake to 10% and further to 5% of total calories for added health benefits to reduce obesity-linked NCDs. The recent dietary guidelines suggested restricting the intake of added salt to a maximum of 5 g/day. The urban cohort study showed that added sugar >5% of total calories was associated with the incidence of diabetes.[16] Compared to rural people, urban residents consumed more sugar and salt. Urban adults' higher salt intake was associated with a higher prevalence of hypertension. Only one in 5 urban adults consume the recommended intake of added salt of <5 g/day.[55]

The consumption of various food groups reported from national and regional studies has been compiled and detailed in **Tables 2.4** and **2.5**.

2.3 ASSESSMENT OF DIETARY HABITS IN CLINICAL SETTINGS

The assessment of dietary intake forms the basis for further focused individualized intervention to improve dietary adherence and manage diabetes effectively. Only half of the individuals with diabetes reported compliance with the diet. Many clinics do not have dietary assessment and advice despite the well-known evidence on the importance of diet in managing diabetes. Hence, the need of the hour is to have a system for meaningful dietary assessment methods that can be employed in all types of clinics, and healthcare givers are well-trained on dietary advice to improve adherence to diet and lead to improvement in glycemic status & reduction of cardiometabolic risk. The most common tools are 24-hour diet recalls and Food Frequency Questionnaires (FFQ), which are used for research and clinical practice. These are briefly discussed below.

2.3.1 Twenty-Four-Hour Intake by Dietary Recall

The 24-hour dietary recall method retrospectively details all meals and beverages consumed in a day, using household measurements. While simple to administer with minimal burden, reliance on one single-day recall may not fully represent the usual habitual intake. Data quality depends on interviewer proficiency, and social desirability bias is a concern. Thus, it's valuable for short-term assessment but requires

supplementation with other methods for a comprehensive understanding of long-term dietary habits.

Food Frequency Questionnaire (FFQ)- An FFQ assesses the usual dietary intake over a specified period, typically the past month or year. It collects information about the frequency and portion size of foods and beverages consumed. FFQs are designed to capture the typical dietary habits rather than specific intake on a particular day. They are relatively easy to administer and are less burdensome for participants compared to methods like food diaries. FFQs usually contain a list of commonly consumed foods/meals. This list can be modified to include specific clinical outcomes and focus only on the foods that are key to managing diabetes. FFQs are validated tools used in epidemiological studies and clinical research to assess dietary intake and help inform dietary recommendations.[56]

2.3.2 Dietary Assessment Aids

Food atlas- Dr. Mohan's Atlas of Indian Foods, serves as a visual aid containing images of typical food portion sizes and household measures. It aims to assist in collecting precise dietary information. Along with various portion sizes of Indian foods (extra small-xs to extra-large-XL), the nutritive value of each portion size is also given.

Portion tools- Portion tools are aids to visually estimate or measure food portions, helping individuals manage their portion sizes and maintain a balanced diet. These tools include measuring cups, spoons, scales, and visual references such as portion-size plates or models. Portion tools provide guidance on appropriate serving sizes for different food groups, helping individuals make healthier food choices and control their calorie intake. They are useful for portion control, weight management, and improving dietary adherence. However, while portion tools can be helpful, they may not always be practical or available in every setting, and individuals may still need to develop awareness and judgment regarding portion sizes to maintain a balanced diet effectively. Despite these limitations, portion tools remain valuable resources for promoting portion control and healthier eating habits.

The 24-hour recall and FFQ data need to be analyzed for an overview of the individual diet and a prescriptive or personalized diet plan. The manual calculation of nutrients from 24-hour recalls or FFQ is tedious and error-prone, underscoring the importance of nutrition databases and software. EpiNu software is one of the food databases developed by the Madras Diabetes Research Foundation (MDRF) to assess the dietary habits of the population/individuals/patients. The software has information on 72 nutrients for more than 2000 cooked, processed, and raw foods. It is essential to orchestrate customized meal plans to meet dietary requirements.(Table 2.2, 2.3,2.4)

2.4 DIETARY GUIDELINES FOR DIABETES MANAGEMENT

2.4.1 Macronutrients

Table 2.2. Dietary Guidelines for Diabetes Management

Carbohydrates	• Based on a recent national study on macronutrient recommendation, utilizing a data-driven optimization method. ▪ Decreasing carbohydrate energy intake to 50-55% could aid in diabetes risk reduction. ▪ Culture-specific cereal staple intake • Brown rice-based diets recommended – They have a 20% lower day-long glycemic response than White rice-based diets in Asian Indians[57] **Note:** For more details on Glycemic Index (GI) and Glycemic Load (GL), refer to chapter 5 on Dietary Carbohydrates.
Proteins	• Protein intake of 15–20% of the total daily calories is recommended by WHO to prevent NCDs. • Increasing protein calories from 10–11% to 14–16% could help risk reduction[14] • Healthier options for protein intake include vegetable sources, pulses and legumes, nuts, low-fat dairy, fish, and lean meats.
Fats	• Fat intake of 20-25% of the total daily calories is encouraged. • Saturated fats should be limited to less than 10% of total daily calories, less than 7% in case of dyslipidemia,[58] with the majority coming from MUFA and PUFA.
Dietary fiber	• A dietary fiber intake of about 15 g/1000 **k**cal and 30 g/2000 **k**cal is recommended.[59]

Table 2.3. Dietary intake of Adults - Population Based Studies among Indian Adults

Population-Based Studies Among Indian Adults for Dietary Intake						
Macronutrient or Food Groups	**Author**	**Year**	**Study Population**	**Method of Data Collection**		**Intake/Key Findings**
Total energy intake	Hemalatha et.al What India Eats Report, ICMR-NIN, 2020	2016	Urban (16 states)	24-hour dietary recall		1943 kcal/day
		2012	Rural (10 states, n = 33261, both sexes)			2081 kcal/day
	Sharma *et al.* 2020	2020	Urban	Based on data from Consumption Expenditure Survey, NSSO 2011–2012.		2169 kcal/day
			Rural			2214 kcal/day
	Anjana *et al.* 2022 The ICMR-INDIAB National Study[14]	2022	Urban	Semi quantitative food frequency questionnaire.	n = 4880	2101 kcal/day
			Rural		n = 13210	2023 kcal/day
Carbohydrates	Hemalatha et.al What India Eats Report, ICMR-NIN, 2020	2016	Urban (16 states, n = 34671, both sexes)	24-hour dietary recall		289 g
		2012	Rural (10 states, n = 33261, both sexes)			368 g
	Sowmya *et al.* 2016[19]	2016	South Indian rural population (n = 6907)	Semi quantitative food frequency questionnaire.	Men, n = 2900	417 g/day
	Chennai Urban Rural Epidemiological Study (CURES)				Women, n = 4007	392 g/day
	Anjana *et al.* 2022 The ICMR-INDIAB National Study[14]	2022	Urban	Semi quantitative food frequency questionnaire.	n = 4880	321 g/day
			Rural		n = 13210	326 g/day
	Joshi *et al.* 2014 (STARCH study)	2014	A total of 796 participants (Asian) were enrolled in this study (385, T2D and 409, non-T2D)	3-day dietary recall and semi quantitative food frequency questionnaire.		The study shows that CHO constitutes 64.1% of total energy from diet in T2D participants, higher than that recommended in India
Proteins	Hemalatha et.al What India Eats Report, ICMR-NIN, 2020	2016	Urban (16 states, n = 34671, both sexes)	24-hour dietary recall		55.4 g/day
		2012	Rural (10 states, n = 33261, both sexes)			69 g/day

	Sowmya *et al.* 2016[19] Chennai Urban Rural Epidemiological Study (CURES)	2016	South Indian rural population (n = 6907)	Semi quantitative food frequency questionnaire.	Men, n = 2900	51.3 g/day
				Women, n = 4007	45.8 g/day	
	Anjana *et al.* 2022 The ICMR-INDIAB National Study	2022	Urban	Semi quantitative food frequency questionnaire.	n = 4880	63.g/day
			Rural		n = 13210	63 g/day
Fats	Hemalatha *et al.* What India Eats Report, ICMR-NIN, 2020	2016	Urban (16 states, n = 34671, both sexes)	24-hour dietary recall		51.6 g/day
		2012	Rural (10 states, n = 33261, both sexes)			36 g/day
	Radhika *et al.* 2011 Chennai Urban Rural Epidemiological Study (CURES)	2011	South Indian Urban population (n = 2042)	Semi quantitative food frequency questionnaire – 222 food items.		33.6 g/day
	Sowmya *et al.* 2016[19] Chennai Urban Rural Epidemiological Study (CURES)	2016	South Indian rural population (n = 6907)	Semi quantitative food frequency questionnaire.	Men, n = 2900	32 g/day
					Women, n = 4007	27.4 g/day
	Anjana *et al.* 2022 The ICMR-INDIAB National Study[14]	2022	Urban	Semi quantitative food frequency questionnaire.	n = 4880	61 g/day
			Rural		n = 13210	59 g/day

Dietary fiber	Radhika *et al.* 2011 Chennai Urban Rural Epidemiological Study (CURES)	2011	South Indian Urban population (n = 2042)	Semi quantitative food frequency questionnaire – 222 food items.		34.7 g/day
	Sowmya *et al.* 2016[19] Chennai Urban Rural Epidemiological Study (CURES)	2016	South Indian rural population, n = 6907	Semi quantitative food frequency questionnaire.	Men, n = 2900 Women, n = 4007	16.4 g/day 13.8 g/day
Cereals and millets	Hemalatha *et al.* What India Eats Report, ICMR-NIN, 2020.	2016	Urban (16 states, n = 34671, both men and women)	24-hour dietary recall	No distinction made between refined and whole grains	293 g/day
		2012	Rural (10 states, n = 33261, both men and women)			394 g/day
	Sowmya *et al.* 2016[19] Chennai Urban Rural Epidemiological Study (CURES)	2016	South Indian rural population, n = 6907	Semi quantitative food frequency questionnaire.	Refined grains intake Men, n = 917 Women, n = 1125	345 g/day 315 g/day
					Whole grains Men ,n = 917 and Women, n = 1125	42 g/day 37 g/day
	Radhika *et al.* 2009 Chennai Urban Rural Epidemiological Study (CURES)	2009	(n = 2042, aged ≥20 years)	Semi quantitative food frequency questionnaire – 222 food items.		Refined grain was 448.8 g/day The prevalence of metabolic syndrome was highest among the highest quartile of refined grain consumption
	Bhavadharani *et al.* 2020 Multinational prospective urban rural epidemiology (PURE) study	2020	PURE participants from 21 countries (n = 132373, aged 35–70 years) follow-up period of	Semi quantitative food frequency questionnaire.		White rice was ≥450 g/day Associated with increased risk of

			9.5 years			diabetes
Pulses and legumes	Hemalatha *et al.* What India Eats Report, ICMR-NIN, 2020	2016	Urban (16 states, n = 34671, both sexes)	24-hour dietary recall		38.6 g/day
		2012	Rural (10 states, n = 33261, both sexes)			42.9 g/day
Fruits and vegetables	Radhika *et al.*2011 Chennai Urban Epidemiological Study (CURES)	2011	South Indian Urban population, n = 2042	Semi quantitative food frequency questionnaire – 222 food items.	Men, n = 917 Women (n = 1125)	274 g/day 256 g/day
Milk and milk products	Hemalatha *et al.* What India Eats Report, ICMR-NIN, 2020	2016	Urban (16 states, n = 34671, both sexes)	24-hour dietary recall		121 g/day
		2012	Rural (10 states, n = 33261, both sexes)			117.9 g/day
Meat and poultry, fish and sea foods, egg	Hemalatha *et al.* What India Eats Report, ICMR-NIN, 2020	2016	Urban (16 states, n = 34671, both sexes)	24-hour dietary recall		32.1 g/day
		2012	Rural (10 states, n = 33261, both sexes)			75.2 g/day
	Sowmya *et al.* 2016[19] Chennai Urban Rural Epidemiological Study (CURES)	2016	South Indian rural population (n = 6907)	Semi quantitative food frequency questionnaire.	**Meat and poultry** Men Women	 4 g/day 3 g/day
					Egg Men Women	 21 g/day 21 g/day
					Fish and sea foods Men Women	 19 g/day 14 g/day

	Radhika *et al.* 2011 Chennai Urban Epidemiological Study (CURES)	2011	South Indian Urban population (n = 2042)	Semi quantitative food frequency questionnaire – 222 food items.	Meat and poultry Men Women	 55 g/day 44 g/day
					Egg Men Women	 12 g/day 15 g/day
					Fish and sea foods Men Women	 21 g/day 18.6 g/day
Fats and oils	Hemalatha et.al What India Eats Report, ICMR-NIN, 2020	2016	Urban (16 states, n = 34671, both sexes)	24-hour dietary recall		30 g/day
		2012	Rural (10 states, n = 33261, both sexes)			16 g/day
	Radhika *et al.* 2011 Chennai Urban Epidemiological Study (CURES)	2011	South Indian Urban population, n = 2042	Semi quantitative food frequency questionnaire – 222 food items		34 g/day
	Sowmya *et al.* 2016[19] Chennai Urban Rural Epidemiological Study (CURES)	2016	South Indian rural population (n = 6907)	Semi quantitative food frequency questionnaire.	Men Women	15 g/day 13 g/day
Sugar and salt	Radhika *et al.* 2011 Chennai Urban Epidemiological Study (CURES)	2011	South Indian Urban population (n = 2042)	Semi quantitative food frequency questionnaire – 222 food items.		22.8 g/day
	Sowmya *et al.* 2016[19] Chennai Urban Rural Epidemiological Study (CURES)	2016	South Indian rural population, n = 6907	Semi quantitative food frequency questionnaire.	Men Women	3.6 g/day 3.7 g/day
Nuts	Radhika *et al.* 2011 Chennai Urban Epidemiological Study (CURES)	2011	South Indian Urban population, n = 2042	Semi quantitative food frequency questionnaire – 222 food items.		23 g/day
	Sowmya *et al.* 2016[19] Chennai Urban Epidemiological Study (CURES)	2016	South Indian rural population, n = 6907	Semi quantitative food frequency questionnaire.	Men Women	4.8 g/day 3.9 g/day

Table 2.4 Dietary Intake of Adults - Clinical Studies Among Indian Adults

Dietary Intake of Adults - Clinical Studies Among Indian Adults						
Nutrients	**Author**	**Year**	**Study Design**	**Study Population**	**Intake/Measurement**	**Key Findings**
Cereals, millets, pulses and legumes	Malik *et al.*[60]	2020	Randomized Controlled Trial (-RCT)	Chennai, south India. (n = 166, aged 25–65 years, overweight (BMI >23 kg/m^2). Interventions included a parboiled brown rice or white rice regimen that provided two ad libitum meals per day, six days per week, for three months, with a two-week washout interval.	The result readings include BG, insulin, glycosylated Hb (HbA1c), insulin resistance (homeostasis model assessment of insulin resistance), and lipids.	A decrease in HbA1c was reported in the brown rice group compared to the white rice group.
	Mohan *et al.*[57]	2014	Randomized crossover study	South Indians (n = 15, overweight (BMI, ≥ 23 kg/m^2) Identical diets were given to subject except for the type of rice and inclusion of legumes (50 g).	Continuous Glucose monitoring and insulinemic responses were assessed.	5-day average incremental area under the curve (IAUC) was significantly lower in brown rice and brown rice with legumes group compared to white rice group.
Milk and milk products	Mohan *et al.*[61]	2023	Systematic analysis	27 prospective cohort studies assessing the effect of dairy products with incident (new onset) T2D.	'Total dairy' and 'total milk' Milk and Cultured milk consumption.	Total dairy products, total fermented dairy, and plain yogurt were inversely associated with incident T2D.
Nuts and oilseeds	Gayathri *et al.*[53]	2022	Randomized control trial	South Indians (n = 352); aged 25–65 years with BMI ≥ 23 kg/m^2 Intervention group was supplemented with 43 g/day Almond for 12 weeks.	The outcome measures include glucose tolerance, serum insulin, glycated hemoglobin, C-peptide, and lipid profile. Insulin resistance (HOMA-IR) and oral insulin disposition index (DIo) were measured.	In Asian Indians with overweight/obesity, daily ingestion of almonds increased MUFA intake while decreasing carbohydrate calories, as well as decreasing insulin resistance, improving insulin sensitivity, and lowering serum cholesterol.
	Mohan *et al.*[62]	2018	Randomized control trial	n = 300 with T2D Intervention group was supplemented with 30 g/day cashew nut for 12 weeks.	The outcome measurements include body weight, BMI, blood pressure, glycemic response, and lipid profile.	Cashew nut supplementation resulted in reduced systolic blood pressure and increased HDL cholesterol.
	Gulati *et al.*[54]	2017	Pre-post intervention study	n = 62 with T2D The 24-week intervention period was preceded by a control diet and exercise run-in period of 3 weeks. Raw almonds (20% of energy intake) were provided to the patients for consumption along with diet and physical activity counselling.	The outcome measurements include anthropometric, glycemic, metabolic parameters, and inflammation markers.	Incorporation of almonds in a well-balanced healthy diet leads to multiple beneficial effects on glycemic and CVDs risk factors in Asian Indian patients with T2D.
	Gulati *et al.*[52]	2023	Randomized control trial	n = 64 with prediabetes in the age 18–60 years. Intervention group was supplemented with 20 g/day almond, 30 minutes before each major meal for 12 weeks.	The outcome measurements include anthropometric, glycemic, and metabolic parameters.	Almond supplementation leads to significant improvement in body weight, WC, glycemia (particularly PPHG), and insulin resistance and shows potential for reversal of prediabetes to normal glucose regulation over 3 months.

2.5 CONCLUSION AND RECOMMENDATIONS

Dietary management plays a crucial role in the management of diabetes. A healthy diet consists of several food groups, such as whole grains, plant proteins or lean proteins, dairy products, nuts, fruits, and vegetables. The emphasis on diversity provides nutrients of concern, reducing the risk of deficiencies and promoting health and wellness. Promoting awareness of dietary diversity and improving nutrition literacy, availability, accessibility, and affordability of diversified, balanced diets at population and individual levels will lead to healthy dietary practices. The above recommendations will impact most of the chronic diseases like diabetes, currently affecting the adult population, which occurs at an early age in Indians.

Clinical Pearls of Practice

- The dietary habits/practices of Indian adults indicate poor diet diversity, leading to nutritional imbalances, inadequacies to obesity, and related chronic diseases.
- Replacing refined grains such as white rice and refined wheat flour with whole grains like whole wheat could reduce the GL of diets and promote better glycemic control.
- Protein intake is low, and evidence shows that high protein intake in the diet could reduce T2D risk and improve glycemic control. Good quality protein intake is relatively low, negatively impacting GL, muscle mass, and metabolic health. Increasing the protein intake (energy share 15-20%) can be beneficial in remission and prevention of T2D.
- Intake of dairy products may contribute good quality proteins and nutrients such as calcium, vitamin D, and B vitamins, reduce the risk of diabetes and hypertension, and improve glycemic control.
- More greens and other vegetables and fruits will boost the micronutrient status and add to the dietary fiber. They also provide antioxidants and anti-inflammatory phytonutrients that improve lipid profile and cardiometabolic health.
- Nuts and seeds are rich sources of micronutrients, protein, and fatty acids such as n-3, n-6, and MUFA adding good quality of fat to the diet and may reduce the risk of diabetes.
- Added sugar and salt need to be reduced.

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Section 3: Energy Balance and Weight Management (Cut-Offs)

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3.1 INTRODUCTION

Obesity has emerged as a worldwide epidemic, steadily increasing in prevalence over the past few decades. This surge in obesity rates coincides with a parallel uptick in Non-Communicable Diseases (NCDs), such as Cardiovascular Diseases (CVD), certain cancers, and Type 2 Diabetes Mellitus (T2D).[1] The well-documented relationship between obesity and these NCDs highlights the need for efficacious weight management strategies.

3.1.1 Obesity and Related NCD Prevalence-Rationale and Evidence

Globally, the prevalence of obesity stands at a staggering 650 million adults, with over 1.9 billion adults classified as overweight, a trend with significant public health implications. According to the World Health Organization (WHO), obesity contributes to 80% of T2D cases, 35% of ischemic heart disease cases, and 20% of certain cancer cases.[2] The rationale behind the association between obesity and NCDs lies in the complex interplay of metabolic dysregulation, chronic inflammation, and hormonal imbalances. Excessive adipose tissue, particularly visceral fat, secretes pro-inflammatory cytokines and adipokines, leading to systemic inflammation and insulin resistance, predisposing individuals to developing T2D and other metabolic disorders.[3]
Epidemiological studies and meta-analyses offer compelling evidence linking obesity to the increased prevalence of NCDs. For instance, a systematic review published in The Lancet reported that each 5 kg/m² increase in Body Mass Index (BMI) was associated with a 29% higher risk of T2D, 10% higher risk of hypertension, and 20% higher risk of Coronary Artery Disease (CAD).[4] Similarly, the INTERHEART study demonstrated that abdominal obesity, measured by Waist-to-Hip Ratio (W-HR), was a stronger predictor of myocardial infarction than overall obesity.[5]

3.1.2 Importance of Maintaining a Healthy Weight in T2D

T2D is a metabolic disorder characterized by insulin resistance and impaired glucose regulation, impacting over 400 million individuals globally. Obesity is considered one of the primary modifiable risk factors for the development of T2D.[6]
For people with diabetes, maintaining a healthy weight is paramount for optimal glycemic control and reducing the risk of complications. Excessive adiposity exacerbates insulin resistance and impairs pancreatic beta-cell function, dysregulating glucose metabolism. Furthermore, obesity is associated with an increased risk of cardiovascular complications, nephropathy, retinopathy, and neuropathy in people with diabetes.[7]
Landmark clinical trials, such as the Diabetes Prevention Program (DPP) and the Look AHEAD (Action for Health in Diabetes) trial, have demonstrated the efficacy of lifestyle interventions, notably weight loss, in preventing T2D onset and improving outcomes in individuals with established T2D.[8,9] These findings highlight weight management as a cornerstone of T2D management and prevention strategies.
Addressing the obesity epidemic and promoting weight management are critical priorities for reducing the burden of NCDs, including T2D. Evidence-based interventions targeting healthy weight maintenance can mitigate the risk of developing T2D and improve overall health and well-being.

3.2 EVALUATION

3.2.1 Assessing individuals Body Weight and Composition

3.2.1.1 BMI Cut-Offs: Diagnosis and Interpretation

Obesity is an excessive accumulation of fat in the body, which can adversely affect an individuals's health. Obesity assessment typically relies on three primary measures widely utilized in clinical practice: BMI, Waist Circumference (WC), and W-HR. BMI, calculated as weight in kilograms divided by height in meters squared (kg/m^2), is fundamental for categorizing thinness and fatness and has consistently shown correlations with increased morbidity and mortality across diverse populations.

In addition to BMI, the assessment of abdominal obesity plays a crucial role in identifying the risk of CVD. Abdominal obesity can be characterized using easily measurable parameters such as WC and W-HR. Although BMI, WC, and W-HR often exhibit strong correlations, combining them offers enhanced precision in identifying individuals at heightened CVD risk compared to relying on any single measure alone to evaluate both generalized and abdominal obesity. Notably, a 2007 Consensus statement for Asian Indians proposed BMI cut-offs for overweight as ≥23 kg/m^2 and obesity as ≥25 kg/m^2.[2,10] These BMI cut-offs have been adopted by the National Institute for Health and Care Excellence (NICE), United Kingdom (UK) for migrant South Asians in the UK as well.[11]

Recent research indicates[12] that each unit increase in BMI among overweight and obese individuals in India is associated with a 1.5% rise in the likelihood of developing T2D, compared to 0.5% in non-overweight individuals. Luke *et al.* investigated this link to explore the connection between BMI status and diabetes, using household data from the India Human Development Survey (IHDS), with 150,000 observations on metabolic conditions such as diabetes, hypertension, and CVD, aimed for national representation. They also incorporated data from the 2015–2016 Demographic Health Survey (DHS), involving 770,000 adults to gather insights from income levels, BMI status, and diabetes prevalence.[13]

After meticulous adjustment for age, gender, caste, locality, and survey period, the study identified a notable positive correlation between BMI and T2D, particularly beyond a BMI threshold of 21.8 kg/m².[12] Hood *et al.*[12,14] analyzed a dataset of 43,880 adult Asian Indian males aged 15 to 54 years, including 5549 individuals from various tribal communities in India, and observed that weight scales close to the squared value of height[15] within this geographically, socio-economically, culturally, and ethnically diverse population. They concluded that BMI effectively normalizes weight for height among Asian Indians. In an accompanying editorial, Misra and Dhurandhar[16] affirmed that this study supports using BMI as a reliable measure for studying health indicators in the Asian Indian population. Consequently, they suggested continuing the current formula for calculating BMI in this demographic group.

BMI is a straightforward and cost-effective method to assess body fat levels, offering standardized thresholds for identifying overweight and obesity. Research indicates a direct correlation between BMI and body fat content.[1] For instance, a comprehensive study conducted within a sizable South Asian population revealed that BMI emerged as a robust predictor of both blood pressure and T2D, conditions strongly linked to cardiovascular mortality.[17] The following BMI cut-off points have been suggested:[10] Normal: 18.5–22.99 kg/m^2, Obesity grade I: 23–24.9 kg/m^2, Obesity grade II: 25–27.5 kg/m^2, Obesity grade III: 27.6–32.4 kg/m^2, and Obesity grade IV: ≥32.5 kg/m^2.

Weight management is a crucial aspect of diabetes care, particularly for people with diabetes, given its profound impact on glycemic control and overall health outcomes. Non-pharmacologic interventions are important in achieving sustainable weight loss in this population. This article aims to elucidate the process of setting weight management goals and explores two key avenues for creating a calorie deficit: dietary modifications and exercise interventions.

3.2.1.2 Waist Circumference as a Measure of Abdominal Obesity

The most widely adopted technique for assessing abdominal obesity involves measuring WC. According to recommendations from the WHO and the International Diabetes Federation (IDF), WC should be measured midway between the lowest ribs and the iliac crest (WC-mid) while standing in a relaxed posture (standing barefoot, comfortably, with eyes facing forward).[18] A meta-analysis of 11 prospective cohort studies involving white adults aged 20 to 83 from Australia, Sweden, and the USA, it was concluded that WC demonstrates a positive correlation with all-cause mortality.[19]

Additionally, Waist-to-Height Ratio (W-HtR) could be an alternative method to measure abdominal obesity (refer to Table 3.1). Another definition of obesity based on an individual's morbidity and functional status is being considered.

Table 3.1. Measures of Abdominal Obesity

	Men	Women
WC Cut-off level[10]	≥90 cm	≥80 cm
W-HtR Cut-off level[20]	>0.5	>0.5

3.2.1.3 Assessment of Body Composition

Body weight is the most frequently used measure of obesity. In general, individuals with high body weights typically have higher amounts of body fat. Various scales are available for measuring weight, and these should be calibrated regularly for accurate weight assessments. Weight changes correspond to body water, fat, and/or lean tissue changes. Weight also changes with age in children as they grow and in adults as they accumulate fat. However, body weight taken without other measures of body size is misleading because a person's weight is highly related to stature (i.e., tall people are generally heavier than short people). Stature is measured easily with a variety of wall-mounted equipment. One way to overcome the lack of specificity in body weight is to use the BMI. BMI is a descriptive index of body habitus encompassing both the lean and the obese.[20]

Different methods for assessing body composition offer unique advantages and applications. Each method is based on distinct physical principles, models, and assumptions (refer to Table 3.2).

Table 3.2. Methods to Measure Abdominal Obesity

Skinfold measurements	• Involves the use of calipers to assess subcutaneous fat thickness at specific sites, providing a cost-effective and portable means of estimating subcutaneous fat patterning and body fat percentage.[21]
Bioelectrical Impedance Analysis (BIA)	• Measures the impedance of electrical currents as they pass through the body, providing estimates of body water, from which body fat and fat-free mass are calculated.[22]
Magnetic Resonance Imaging (MRI) and Computed Tomography (CT)	• Advanced imaging techniques offer detailed insights into body composition, enabling (at specific areas of the body) precise fat, muscle, and bone mass quantification at specific areas of the body.[23]
Dual Energy X-ray Absorptiometry (DEXA) scanning	• It provides accurate assessments of bone mineral density, lean tissue mass, and fat mass distribution, making it a valuable tool in clinical settings and research studies.[24]
Underwater weighing (Hydrodensitometry)	• It involves submerging individuals in water to measure their body density, providing an indirect estimation of body composition through Archimedes' principle.[25]
Air Displacement Plethysmography (ADP)	• Commonly known as the Bod Pod, it utilizes air displacement to determine body volume and subsequently calculates body composition parameters, offering a non-invasive alternative to traditional methods.[26]
Note: • Each method has its strengths and limitations, and the selection depends on precision, accessibility, and specific research or clinical objectives.	

3.2.2 Assessing Caloric Intake and Energy Balance

Precise evaluation of dietary intake is pivotal for comprehending the impacts of diet on human health and disease, as well as for devising nutrition policies and dietary guidelines tailored for individuals, groups, and

communities. Nevertheless, accurately gauging dietary exposures via self-reports poses notable challenges regarding precision and reliability. Conventional approaches to dietary assessment encompass food records, food frequency questionnaires, and 24-hour recalls. However, with the advent of technology, digital and mobile methods have emerged as innovative alternatives to traditional techniques, marking a rapidly evolving domain.[27] Additionally, various screening tools and diet history methods are available to augment the spectrum of dietary assessment methodologies.

The selection of an assessment method hinges on multiple factors, including but not limited to the research query, study structure, participant demographics, and sample size.(Table 3.3)

Table 3.3. Dietary Assessment Methods- Overview and Comparison

Food record	• Participants meticulously document all food items, beverages, and supplements consumed over a specified period. ▪ Typically, 3–4 days, as longer recording periods can compromise accuracy due to increased burden. • The ideal scenario involves weighing and measuring dietary intakes. Participants typically rely on estimates before and after consumption.[28]
24-hour Dietary Recall (24-hour)	• Assesses an individual's food intake over the preceding day o Ideally, multiple 24-hour readings on random, non-consecutive days are collected. ▪ Traditionally conducted via interviewer-administered phone or in-person interviews. ▪ However, it can also be done in person[29] or online, such as through Automated-Self-Administered (ASA-24) methods.[30] ▪ The ASA-24 reduces interviewer burden and costs, allows participants to answer at their own pace, and is cost-effective. However, its feasibility may vary among study populations. • It is useful for quick assessment of recent intake in clinical and intervention studies but relies on accurate recall.
Food Frequency Questionnaire (FFQ)	• They evaluate habitual dietary intake over a designated period, typically a longer time frame. • They inquire about the frequency of consuming various food items, often grouping similar items with comparable nutrient profiles into categories. • FFQs present a cost-effective option compared to 24 hours. ▪ Since participants typically self-administer the questionnaire.
	• They are commonly employed in research studies with large sample sizes. • FFQs may adopt quantitative, semi-quantitative, or qualitative formats.31 • The FFQ involves a retrospective assessment of how often specific foods are consumed within a given timeframe, ▪ Such as daily, weekly, every 15 days, or monthly, depending on participants' ability to estimate intake accurately.
Note: • Each method of dietary assessment has its advantages and disadvantages. • 24 hours is considered the most accurate for assessing food and nutrient intake. • Combining methods are often preferred due to the episodic nature of dietary choices and the potential for measurement errors, requiring participant motivation, honesty, and skilled interviewing by investigators.[31]	

3.2.2.1 Determining Basal Metabolic Rate

Determination of Basal Metabolic Rate (BMR), the amount of energy expended at rest to maintain essential physiological functions, is crucial for understanding individuals' energy requirements. BMR accounts for approximately 60- 70% of Total Energy Expenditure (TEE), making it a cornerstone in deriving energy needs through the factorial method for diverse populations. Various methods exist for estimating BMR, including predictive equations based on factors such as age, gender, weight, and height, as well as indirect calorimetry, which directly measures oxygen consumption and carbon dioxide production.

In practical settings, BMR is often estimated rather than directly measured, utilizing prediction equations based on age, sex, and weight.[32,33] The most extensive analysis of BMR to date, conducted by Schofield *et al.*[34] reviewed approximately 11,000 BMR measurements from the literature and developed predictive equations tailored for males and females. These equations were subsequently adopted in the Food and Agriculture Organization (FAO)/ WHO/ United Nations University (UNU) in a 1985 report.[35] While the Schofield equations accurately predict BMR for many individuals in temperate climates, they may be less precise for populations residing in tropical regions. It's worth noting that most values were derived from North American and European subjects, and subsequent analyses revealed a tendency to overestimate BMR by 10–11% in Asian Indian populations.[36,37,38]

3.2.2.2 Total Energy Expenditure Calculation

As its name suggests, total energy expenditure represents the total amount of energy the body expends within a 24-hour timeframe. TEE is calculated by multiplying the BMR by the Physical Activity Level (PAL).

$$\text{TEE} = \frac{\text{BMR} \times \text{PAL}}{100}$$

In previous reports (such as ICMR-NIN),[39] the energy expenditure for various activities was sourced from FAO/WHO/UNU,[40] based on studies of Western populations. However, research conducted in India indicates that energy expenditure for different physical activities is lower among Indians. This could be attributed to the variability in energy expended for a given activity (Physical Activity Ratio–PAR) across different body weights. Extrapolating the data obtained from heavier individuals can overestimate energy expenditure for those with lower body weights.[41,42,43] Energy expenditure for each physical activity tends to be lower for Indians. Therefore, a recalibration was undertaken using PAR values specific to the Indian population. This adjustment revealed a decrease in PAR from the previously recommended 1.53 (Recommended dietary allowance or RDA)[44] to 1.40 for sedentary populations, with proportionate reductions for other activity levels as well.

3.3 SETTING WEIGHT MANAGEMENT GOALS FOR PEOPLE WITH DIABETES

3.3.1 Non-Pharmacologic Management

Limiting calorie intake and engaging in regular physical activity, even briefly, initiate cellular mechanisms that bolster the body's protective responses. Enhancing metabolic health through weight loss is a primary goal of lifestyle therapy, supported by evidence from reputable trials. For instance, in the UK Prospective Diabetes Study (UKPDS), initial three-month training led to a notable 1% decrease in HbA1c levels among 3867 participants.[45] Similarly, the Look AHEAD trial, involving 5000 individuals with diabetes, demonstrated that intensive lifestyle modifications resulted in a mean weight loss of 4.5 kg over four years, leading to significant improvements in various metabolic parameters.[46,47] Notably, reductions in HbA1c levels, triglyceride concentrations, and blood pressure were directly correlated with the extent of weight loss, emphasizing the importance of weight management in diabetes

management.[47] Glucose metabolism improvements have been observed within a short period of caloric restriction to 600–800 kcal/day, with notable normalization achieved after eight weeks of a restricted diet.[48] Beyond weight, dietary composition and PAL significantly influence metabolism, highlighting the importance of personalized counseling and training in diabetes management.

3.3.1.1 Creating a Calorie Deficit for Weight Loss Using Diet

Dietary modifications represent a cornerstone of non-pharmacologic weight management strategies for people with diabetes. A calorie deficit, achieved through prudent dietary choices, promotes weight loss and improves glycemic control. Research by Franz *et al.*[49] emphasizes the efficacy of various dietary approaches, such as low-carbohydrate diets and Mediterranean-style diets, in facilitating weight loss among people with diabetes.

3.3.1.2 Creating a Calorie Deficit for Weight Loss Using Exercise

Exercise is another vital component of non-pharmacologic weight management interventions for people with diabetes. Physical activity contributes to calorie expenditure and enhances insulin sensitivity and metabolic health. Studies by Colberg *et al.*[50] emphasize the benefits of incorporating both aerobic and resistance training exercises for promoting weight loss and improving glycemic control in people with diabetes. Setting weight management goals and implementing non-pharmacologic strategies are integral to comprehensive diabetes care for people with diabetes. By creating a calorie deficit through dietary modifications and exercise interventions, clinicians can empower people with diabetes to achieve sustainable weight loss and optimize their health outcomes.
Creating a calorie deficit of 500 kcal/day through dietary modifications and exercise has been shown to induce weight loss at a sustainable rate. Research by Wing *et al.*[46] demonstrated that a daily deficit of 500 kcal resulted in an average weight loss of approximately 0.45 kg (1 lb)/ week in people with obesity. Similarly, a meta-analysis by Franz *et al.*[51] found that interventions focusing on achieving a 500 kcal/day deficit through diet and exercise led to significant weight loss over time. This approach aligns with clinical recommendations for gradual weight loss, associated with better long-term weight loss maintenance and improved metabolic health.[47] By creating a modest calorie deficit of 500 kcal/day, individuals can achieve meaningful weight loss outcomes while minimizing the risk of metabolic adaptations and negative health consequences.

3.4 MONITORING AND TRACKING PROGRESS

Monitoring and tracking progress are essential to successful weight management for people with diabetes. Regular weigh-ins and body measurements are valuable indicators of progress toward weight loss goals.[47] Studies have shown that consistent monitoring of weight and body measurements, such as WC, facilitates early detection of changes and helps individuals stay accountable for their weight management efforts (Look AHEAD Research Group, 2014).[52] Furthermore, self-monitoring food intake and physical activity are crucial in promoting adherence to dietary and exercise regimens.[53] By keeping a food diary and recording PAL, individuals can gain insight into their behaviors and make informed adjustments to support their weight loss efforts.

3.4.1 Regular Weigh-Ins and Body Measurements

The practice of regular weigh-ins and body measurements has emerged as an important component in understanding and managing various aspects of human health. These routine assessments provide valuable insights into changes in body composition, weight trends, and potential health risks associated with fluctuations in these metrics.[54] By systematically tracking individual's weight and body measurements over time, researchers can analyze correlations between these factors and many health outcomes, including obesity, metabolic disorders, CVD, and overall mortality rates.[55] Moreover, regular monitoring fosters awareness and accountability among individuals regarding their health behaviors and lifestyle choices, empowering them to make informed decisions toward achieving and maintaining optimal health.[56] As such, incorporating regular weigh-ins and body measurements into research protocols facilitates the evaluation of intervention effectiveness and promotes preventive healthcare practices to improve population health outcomes.

3.4.2 Self-monitoring of Food Intake and Physical Activity

Self-monitoring of food intake and physical activity has emerged as a fundamental strategy for promoting healthy behaviors and managing weight-related concerns.[53,57] This approach involves individuals systematically recording and tracking their dietary intake, PAL, and other relevant lifestyle factors using various mobile applications, wearable devices, or traditional pen-and-paper methods.[58] By actively monitoring their behaviors, individuals gain insight into their eating patterns, portion sizes, energy expenditure, and overall adherence to health goals. Research indicates that regular self-monitoring fosters increased awareness, accountability, and motivation, leading to improved dietary choices, enhanced physical activity engagement, and better weight management outcomes.[53] Furthermore, self-monitoring is a cornerstone in behavioral intervention programs to prevent and manage chronic diseases such as obesity, diabetes, and CVD.[59] Overall, integrating self-monitoring practices into research protocols facilitates the evaluation of intervention effectiveness and empowers individuals to take proactive steps toward achieving and maintaining optimal health and well-being.

3.5 CONCLUSIONS AND RECOMMENDATIONS

Addressing the obesity epidemic and promoting weight management is vital to mitigating the prevalence of NCDs such as T2D, CVD, and certain cancers. The complex interplay between metabolic dysregulation, chronic inflammation, and hormonal imbalances underscores the need for effective weight management strategies. Evidence from epidemiological studies and landmark clinical trials, such as the DPP and the Look AHEAD trial, highlights the importance of lifestyle interventions, particularly weight loss, in preventing T2D and improving health outcomes. Assessment methods like BMI, WC, and advanced body composition techniques are crucial for evaluating obesity and setting realistic weight management goals. Ultimately, maintaining a healthy weight through Medical Nutrition Therapy (MNT) and physical activity is essential for optimal glycemic control and reducing the risk of complications in people with diabetes. Regular monitoring and self-tracking enhance adherence to weight management plans, promoting long-term health and well-being.

Clinical Pearls of Practice

- Obesity rates have soared globally, paralleled by an increase in T2D, highlighting the urgency of effective weight management strategies.
- The relationship between obesity and NCDs is well-documented, with excess adipose tissue contributing to metabolic dysregulation and inflammation, increasing the risk of conditions such as T2D.
- Landmark trials like the DPP underscore the importance of lifestyle interventions, including weight loss, in preventing and managing T2D.
- BMI and WC are key metrics to assess obesity and identify individuals at risk of T2D.
- Understanding individual's energy requirements through measures like BMR TEE informs personalized weight management strategies.
- Non-pharmacologic interventions such as dietary modifications and exercise play a crucial role in achieving sustainable weight loss and improving metabolic health in people with diabetes.

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Section 4: Macronutrients

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4.1 INTRODUCTION

The global burden of Type 2 Diabetes Mellitus (T2D) has risen dramatically, particularly in regions like Asia, where dietary patterns are heavily carbohydrate dependent. Traditional diets rich in whole grains, fruits, vegetables, and legumes have been replaced by high intakes of energy-dense, nutrient-poor foods, coupled with low physical activity levels, leading to obesity and insulin resistance and driving diabetes prevalence. Addressing the association between dietary habits and diabetes prevalence is critical for implementing preventive measures and promoting healthier eating behaviors in India. Dietary macronutrients significantly influence glycemic control and overall health. Carbohydrates impact Blood Glucose (BG) levels directly, requiring careful

monitoring, while proteins and fats contribute to satiety and metabolic functions. Effective management of T2D necessitates a focus on dietary interventions, particularly macronutrient distribution, to regulate BG levels and mitigate the risk of complications.[1] A well-structured diet is critical for controlling BG levels and preventing the progression of T2D, with the American Diabetes Association (ADA) emphasizing the importance of macronutrient balance.[2]

4.1.1 Indian Diet

The STARCH study showed that 64.1 ± 8.3% (95% CI 63.27 to 64.93) of total calories came from total carbohydrates.[3] This is higher (Δ4.1% above the upper limit of 60%) than that recommended by the guidelines. Postprandial hyperglycemia is a major challenge while managing diabetes in our populations. While carbohydrate intake is notably high among individuals with diabetes in India, the proportion of calories from fats also plays a significant role in overall dietary quality and metabolic outcomes. Different types of fats (saturated, monounsaturated, polyunsaturated) have varying effects on insulin sensitivity and cardiovascular health. Dietary fiber is a crucial component of a diabetes management plan, as it helps regulate BG levels and improves overall metabolic health.[4] Studies emphasize the benefits of higher dietary fiber intake in reducing glycemic variability and lowering the risk of Cardiovascular Disease (CVD) among individuals with diabetes.[5]

4.2 CARBOHYDRATES

4.2.1 Importance of Managing Carbohydrate Intake

Carbohydrates are the primary macronutrient influencing BG levels. In T2D, excessive intake, especially of refined carbohydrates, significantly contributes to hyperglycemia and poor glycemic control. Indian diets typically derive 65–75% of their energy from carbohydrates; managing carbohydrate intake is crucial for controlling postprandial glucose levels and overall glycemic stability.[1] Managing carbohydrate intake, especially in terms of quality and quantity, is essential to prevent spikes in BG levels, a common issue in T2D management.[6]

Simple carbohydrates, such as sugars and refined grains, are metabolized quickly, causing rapid spikes in BG levels. In contrast, due to their fiber and nutrient content, complex carbohydrates from whole grains, fruits, vegetables, and legumes offer a slower, more sustained glucose release. Sugar substitutes, commonly called artificial sweeteners or non-nutritive sweeteners, provide sweetness without the calories and carbohydrates of sugar, offering an alternative for managing carbohydrate intake.

4.2.2 Glycemic Index (GI) and Glycemic Load (GL)

The GI and GL are essential tools for understanding the impact of carbohydrate-containing foods on BG levels. GI measures how quickly a food raises BG, while GL considers both the GI and the carbohydrate content in a serving. High-GI foods, such as white rice, are common in Asian diets and contribute significantly to the glycemic burden. Substituting these with lower-GI alternatives, like brown rice, can reduce glycemic response by 20%, making it a practical approach for individuals with T2D.[1] Low-GI and low-GL foods are preferred in the diet of individuals with T2D to minimize BG spikes and improve long-term glycemic control.[7] *(Figure 4.1)*

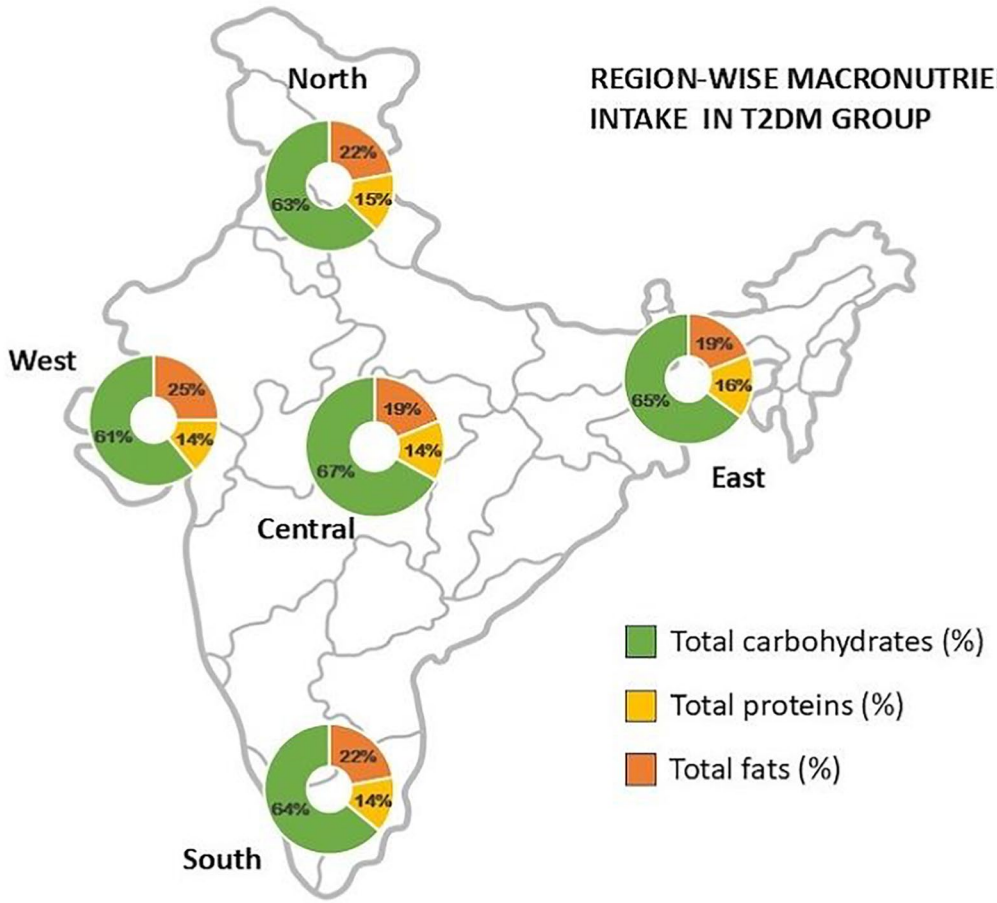

Figure 4.1 Region-wise Macronutrient Intake in T2D Group (Adapted from: Joshi SR, Bhansali A, Bajaj S, Banzal SS, Dharmalingam M, Gupta S, et al: a STARCH study. BMJ Open. 2014 Oct 31;4(10):e005138. doi: 10.1136/bmjopen-2014–005138.)

4.2.3 Recommendations for Carbohydrate Distribution

• Carbohydrate is the body's primary energy source; therefore, it is important to understand the role of dietary carbohydrates with reference to their type, classification, quality, and source to facilitate mindful consumption.
• For individuals with T2D, focusing on a diet that emphasizes low-GI carbohydrates, including whole grains, legumes, and vegetables, is recommended to lower the overall GL and manage BG levels effectively.[1]
• Carbohydrate consumption should be reduced from current 65–75% of daily diet composition to about 50–55% along with sufficient proteins (15–20%), a majority of which may be sourced from legumes and pulses, low fat dairy eggs, lean meat and fish and the remaining 20–25% percent from healthy monounsaturated fats such as groundnut or mustard oil, nuts, and seeds.
• Carbohydrate intake should be distributed evenly across meals to avoid large fluctuations in BG levels. This approach, coupled with a focus on complex carbohydrates rich in dietary fiber, supports better glycemic control.[6]

4.3 PROTEINS

4.3.1 Role of Protein in BG Regulation

Protein has a minimal direct impact on BG levels, making it a valuable component in the diet of individuals with T2D. Proteins can help stabilize BG levels by enhancing satiety and reducing the glycemic impact of carbohydrate-rich meals.[1] Dietary protein helps in muscle synthesis and improves insulin sensitivity. Additionally, protein intake can stimulate insulin secretion, which may aid in better glucose control, particularly in meals with mixed macronutrients.[8] Protein intake increases satiety and supports weight management, which is essential in managing T2D. High-protein diets may improve leptin sensitivity and glucagon secretion, modulating appetite and satiety. People with diabetes have a higher prevalence of sarcopenia, and protein optimization for such patients is vital to their health. The sequencing of food intake, emphasizing protein-rich foods at the beginning of meals, has been shown to attenuate postprandial glucose fluctuations.

4.3.2 Recommended Protein Intake and Sources

• The recommended protein intake for individuals with T2D is around 15–20% of the total daily caloric intake.
• Protein sources should primarily include lean meats, fish, eggs, legumes, and low-fat dairy products.
• Plant-based proteins lower the risk of T2D and offer a sustainable option for diabetes management or prevention. Vegetarians and vegans may need to carefully plan their diets to meet protein Recommended Dietary Allowances (RDAs) due to potential low protein bioavailability. Combining legumes and grains, nuts, and grains can help improve protein quality.
• Adequate protein intake with every meal has been suggested, as it helps lower postprandial glucose spikes by flattening the glycemic response of food.
• In cases where kidney complications are present, protein intake may need to be adjusted to prevent further kidney damage.[1] In diabetic kidney disease (stages 1–4), protein intake should not exceed 0.8 g/kg of body weight daily.[9] A moderate increase in protein intake from lean sources like poultry, fish, legumes, and low-fat dairy is recommended, with an emphasis on balancing protein needs with kidney function considerations.[10]
• Meal order whereby starting the meal with a protein source such as *paneer* (cottage cheese), eggs, chicken, fish, beans, or tofu may also be recommended to reduce post-meal glycemic response.
• In people with diabetes and sarcopenia, the recommended protein intake is about 1–1.2 g/kg of body weight/day, along with physical activity and protein supplements as needed.[11]

4.4 FATS

4.4.1 Impact of Dietary Fats on Insulin Sensitivity

Dietary fats, particularly unsaturated fats, are crucial for improving insulin sensitivity and managing T2D. Unsaturated fats help improve lipid profiles and insulin sensitivity, while saturated and trans fats are associated with increased insulin resistance and should be minimized.[1] A high intake of saturated and trans fats is linked to worsened insulin resistance, making the quality of fats a critical factor in T2D management.[12]

4.4.2 Types of Fats: Saturated, Unsaturated, and Trans Fats

• **Saturated Fats:** Found in animal products and certain oils, saturated fats can worsen insulin resistance and should be limited to less than 10% of total daily caloric intake due to their association with increased Low-Density Lipoprotein (LDL) cholesterol and other cardiovascular risks. In the case of dyslipidemia, the saturated fat content must be restricted to less than 7% of the total daily caloric intake[12]
• **Unsaturated Fats:** Found in nuts, seeds, and fish, unsaturated fats should make up a larger portion of the fat intake. These fats are beneficial for heart health and improving insulin sensitivity, making them a preferred choice in the diet of individuals with T2D.[13]
• **Trans Fats:** Trans fats, commonly found in processed foods, are harmful and should be avoided entirely due to their negative impact on cardiovascular health and insulin sensitivity.[1,12]
4.4.3 Recommendations for Healthy Fat Intake
• Total fat intake should range from 20- 25% of daily calories.
• Saturated fats should be limited to less than 10% of total daily calories, less than 7% in case of dyslipidemia, and trans fats should be minimized to improve insulin sensitivity and reduce cardiovascular risk.[1,2]
• A diet rich in monounsaturated and polyunsaturated fats is recommended for individuals with T2D. This can be achieved by using healthier cooking oils like olive or mustard oil and including sources like nuts, seeds, avocado, and fatty fish in the diet.

4.5 MACRONUTRIENT RATIOS

4.5.1 Optimal Macronutrient Ratios for Diabetes

The optimal macronutrient distribution for managing T2D should be individualized but generally includes approximately 50–55% carbohydrates (primarily low-GI), 15–20% protein, and 20–25% fat (emphasizing unsaturated fats). This balanced approach helps achieve better glycemic control and reduce the risk of complications.[1] The ADA suggests similar ratios but emphasizes the need for individualization based on the patient's usual intake and metabolic goals.[6]

4.5.2 Optimal Macronutrient Ratios for Pre-Diabetes

Maintaining balanced macronutrient ratios similar to those recommended for T2D is crucial for individuals with pre-diabetes. However, a greater emphasis is placed on weight management and preventing the progression to T2D. A diet with a slightly lower carbohydrate content and higher protein and fat intake may be beneficial for improving insulin sensitivity and overall metabolic health.[1,14]

4.5.3 Popular Dietary Patterns and their Implications

• **Very Low-Calorie Diet (VLCD):** VLCDs have been proven to induce remission in some individuals with T2D, particularly when combined with lifestyle changes. However, concerns about the sustainability of such diets and their applicability in Indian settings, where dietary patterns are deeply rooted in cultural practices, remain significant.[1]
• **Low-carbohydrate diet:** Effective for short-term glycemic control, low-carbohydrate diets reduce carbohydrate intake to improve BG

levels. However, long-term safety and adherence to carbohydrate-rich diets like those in India are uncertain, requiring careful planning to avoid nutritional deficiencies.[1,15]

• **Mediterranean diet:** This diet is rich in unsaturated fats, whole grains, and lean proteins, and has been shown to improve glycemic control and reduce cardiovascular risk in individuals with T2D. It emphasizes the intake of healthy fats and low-GI carbohydrates, making it a suitable option for managing T2D.[16]

4.6 PRACTICAL CONSIDERATIONS

Managing T2D effectively requires practical strategies for meal planning, including portion control, choosing low-GI foods, and ensuring a balanced intake of macronutrients. Regular monitoring of BG levels is essential for adjusting dietary intake and maintaining glycemic control. Practical tips include incorporating a variety of food groups into each meal, using whole foods over processed ones, and maintaining a consistent eating schedule to avoid BG fluctuations.[1,2]

4.7 CONCLUSION AND RECOMMENDATIONS

A balanced macronutrient distribution tailored to individual needs is crucial for managing T2D. Emphasizing low-GI carbohydrates, adequate protein intake, and healthy fats can lead to better glycemic control and reduce the risk of complications. When designing dietary interventions, it is essential to consider the cultural relevance and sustainability of the diet, particularly in regions with traditional dietary practices like India. The goal should be to create a diet plan that is not only effective but also sustainable in the long term.

Clinical Pearls of Practice

- Customized macronutrient distribution is crucial to optimize glycemic control and lower the risk of complications among adults with diabetes.
- The acceptable macronutrient distribution ranges are 50-55% of your daily calories from Carbohydrates, 20-25% from fats, and 15–20% from protein.
- To lower the overall GL and manage levels effectively, it is recommended that individuals with T2D focus on a diet that emphasizes low-GI carbohydrates, including whole grains, legumes, and vegetables.
- Carbohydrate intake should be distributed evenly across meals to avoid large fluctuations in levels. This approach, coupled with a focus on complex carbohydrates rich in fiber, supports better glycemic control.
- Adequate protein intake with every meal helps lower postprandial glucose spikes by flattening the glycemic response of food.
- Meal order whereby starting the meal with a protein source such as paneer, eggs, chicken, fish, beans, or tofu may also be recommended to reduce post-meal glycemic response.
- Saturated fats should be limited to less than 10% of total daily calories, less than 7% in case of dyslipidemia, and trans fats should be minimized to improve insulin sensitivity and reduce cardiovascular risk.
- A diet rich in monounsaturated and polyunsaturated fats is recommended for individuals with T2D. This can be achieved by using healthier cooking oils like olive or mustard oil and including sources like nuts, seeds, avocado, and fatty fish in the diet.
- Recommend easily available and cost-effective nutrients.

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Section 5: Dietary Carbohydrates

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5.1 Introduction

Carbohydrates, essential macronutrients, play a pivotal role in human metabolism by serving as the primary energy source. These compounds are instrumental in regulating Blood Glucose (BG) and insulin metabolism, contributing to cholesterol and triglyceride metabolism, and

aiding fermentation. The carbohydrates undergo enzymatic breakdown within the digestive tract upon ingestion, converting into glucose - the fundamental energy currency for cellular activities. Excess glucose, beyond immediate energy requirements, is sequestered in the liver and muscles as glycogen for future energy needs.

'Carbohydrates' encompass diverse nutrients, including sugars, fruits, vegetables, fibers, and legumes.[1] Their impact on BG levels is significant, with distinct effects. High-fiber, complex carbohydrates are associated with gradual increases in post-prandial BG levels, unlike rapid surges induced by refined carbohydrates. Therefore, understanding the quality and quantity of dietary carbohydrates is the crucial predictor of effective glycemic response, especially in managing the predisposition of people with diabetes to obesity or insulin resistance.[2] The effect of dietary carbohydrate intake on glycemia occurs due to the conversion of carbohydrates into glucose, a potent stimulus for insulin secretagogue. Therefore, the quantity and quality of carbohydrates in one's diet are imperative for optimal health.[3]

5.2 Classification, Quality, and Sources of Dietary Carbohydrates

5.2.1 Classification of Dietary Carbohydrates

There are numerous ways of classifying carbohydrates, which differ with regard to their effect on health outcomes. Primarily, carbohydrates are categorized based on their degree of polymerization into monosaccharides, disaccharides (sugars), polyols, oligosaccharides (such as malto-oligosaccharides and non-digestible oligosaccharides), and polysaccharides (comprising starch and non-starch polysaccharides), reflecting their structural complexity and dietary significance. Moreover, carbohydrates are categorized based on their digestibility in the small intestine, characterized by their chain length into simple (digestible) and complex (non-digestible) carbohydrates or dietary fiber, which includes all or some components of the non-digestible carbohydrates. Dietary carbohydrates can also be classified according to their chemical structure, digestion, and effect on BG levels.

5.2.2 Quality and Sources of Dietary Carbohydrates

The quality of carbohydrates refers to their nutritional value and the impact on health associated with different types of carbohydrates. It is a critical aspect of dietary choices, especially among people with diabetes.

• Complex carbohydrates, often termed high-quality carbohydrates, are characterized by their nutrient density and fiber content. These are associated with numerous health benefits, including better weight management, improved cardiovascular health, and reduced risk of developing chronic diseases.[4] Due to their high fiber content, complex carbohydrates contribute to satiety or a feeling of fullness, reducing the likelihood of overeating.[5]

• Conversely, refined carbohydrates, often termed low-quality carbohydrates, are commonly found in processed foods, such as white rice, added sugars, bread made with refined flour, and carbonated beverages, which have high sugar content and lack fiber and essential nutrients. Processing these foods strips them of nutritional value. Such foods contain quickly digestible carbohydrates that could contribute to weight gain, impede weight loss efforts, and increase the risk of diabetes mellitus and Cardiovascular Diseases (CVD).[4]

5.2.3 Sources of Dietary Carbohydrates

Nutrient-dense sources of carbohydrates play a vital role in a balanced diet, offering many health benefits due to their rich composition of fiber, vitamins, minerals, and other vital nutrients.[6] Whole grains like brown rice, quinoa, barley, and whole wheat provide complex carbohydrates, fiber, vitamins, minerals, and phytonutrients,[7] contributing to their nutritional value. Legumes, including beans, lentils, chickpeas, and peas, are recognized not only as excellent sources of carbohydrates but also as exceptional sources of protein, fiber, vitamins, and minerals.[8] This rich nutrient profile highlights the need to incorporate these food groups into the diet for optimal health. (Figure 5.1)

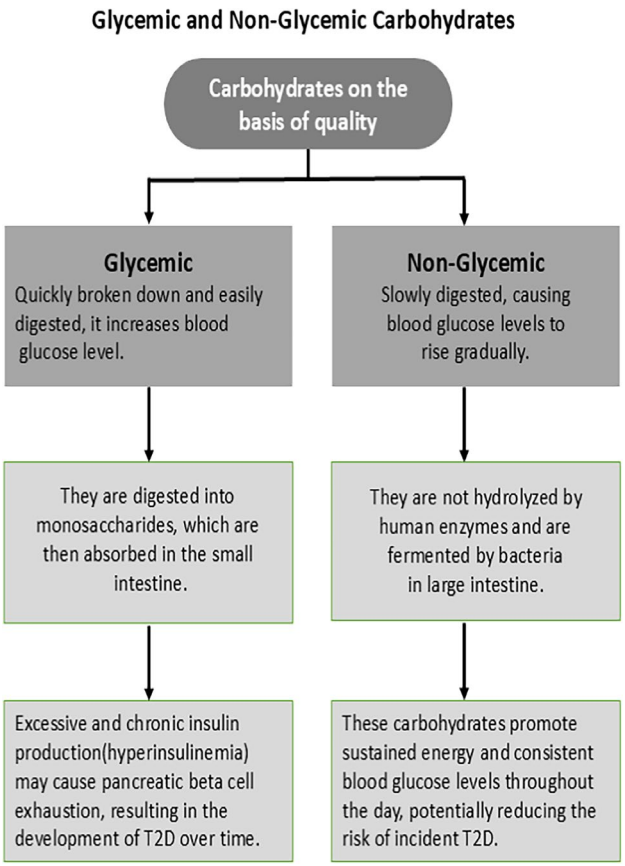
Figure 5.1 Sources of Dietary Carbohydrates (Adapted from International Tables of Glycemic Index and Glycemic Load Values: Fiona S. Atkinson, RD; Kaye Foster-Powell, RD; Jennie C. Brand-Miller, PHD)

Conversely, consuming low-quality, extensively processed, or refined carbohydrates presents health risks. White rice, refined flour, bread, sweetened beverages, and carbonated drinks are significantly depleted of fiber and essential nutrients. These foods contain quickly digestible carbohydrates that could contribute to weight gain and increase the risk of Non-communicable Diseases (NCDs) such as diabetes and heart disease.[4]

5.2.4 Glycemic and Non-Glycemic Carbohydrates

Figure 5.2 shows glycemic and non-glycemic carbohydrates

Figure 5.2 Classification of carbohydrates, based on their quality (Adapted from Hardy DS, Garvin JT, Xu H. Carbohydrate quality, glycemic index, glycemic load and cardiometabolic risks in the US, Europe and Asia: A dose–response meta-analysis. Nutrition, Metabolism and Cardiovascular Diseases. 2020 Jun 9;30(6):853-71.)



5.2.5 Glycemic Index (GI) and Glycemic Load (GL)

The GI is critical in assessing carbohydrates and their distinct effects on BG levels. This index offers a quantifiable measure of the rate at which carbohydrates are metabolized during digestion and subsequently absorbed into the bloodstream. Foods characterized by high GI are readily broken down, leading to increased BG levels and insulin responses following the intake. On the contrary, foods with a low GI exert a slower and smaller effect on BG levels as their slower digestion and absorption contribute to sustained energy levels and potentially reduce the risk of developing chronic conditions like diabetes and CVD.[9] Carbohydrates with high GI are processed and refined foods that are generally lower in nutritional quality, as they are devoid of essential nutrients and fiber, which are eliminated during food processing.[10] The absence of these critical dietary components in high-GI foods underscores the importance of selecting low-GI alternatives that retain their nutrient and fiber content, thereby supporting better glycemic control and overall health. (Table 5.1)

Table 5.1. Categorization of GI[11]

Low GI	Medium GI	High GI
<55	**56–69**	**>70**
• Non-starchy vegetables • Sweet potatoes • Legumes • Carrots • Peas	• Brown and basmati rice • Raw pineapple • Sweet corn • Quick oats	• Carbonated drinks • Bakery products • White rice • Dosa • Idli

Glycemic Load (GL) is an advanced metric incorporating the GI and carbohydrate amounts in a typical serving size. By evaluating the quality and quantity of carbohydrates in a food serving, GL furnishes a more practical assessment of a food item's impact on post-prandial glucose concentrations. GL is determined by multiplying GI with the amount of carbohydrate (in g) per serving:
This metric offers a nuanced and practical approach to managing BG levels through diet. It considers portion sizes critical for individual seeking to optimize their glycemic control, enhancing the effectiveness of nutritional strategies to improve BG stability and overall metabolic health.(Table 5.2, 5.3, 5.4)

$$GL = \frac{GI\% \times \text{Amount of Carbohydrate (in grams) per serving}}{100}$$

Table 5.2. Categorization of GL[12]

Low GL	Medium GL	High GL
<10	11–19	>20

5.2.6 GI Testing and Studies from India

Table 5.3. GI Testing and Dietary Implications in the Indian Context

Primary energy source in India	• Carbohydrates. • A popular Indian staple is white rice. White rice contributes to nearly half of the daily caloric intake. o It has a high glycemic response and is linked to a higher risk of Type 2 Diabetes Mellitus (T2D).[13]
Cultural significance of traditional foods	• Vital to cultural heritage and dietary habits. • GI testing of these foods helps to integrate cultural dietary preferences with health recommendations to promote dietary patterns that are culturally relevant and health-conscious.
GI **testing methodology**	• Often performed on individual foods. • GI for meals or diets o Calculated using a weighted total of the ingredients, the formula's ability to estimate a meal or diet's GI is uncertain.[14]
Importance of testing techniques	• GI testing o A useful tool for comparing different carbohydrate sources, and to make this comparison meaningful, GI values must be calculated using rigorous and consistent techniques throughout testing events.[15] • GI testing is a foundation for further research and education on nutrition and dietary patterns in India.[16]
Dietary carbohydrates and health risks	• Their high consumption has been linked to an elevated risk of NCDs because of high GI and GL. • Indian cuisine recipes vary by region, carbohydrate profiles, and glycemic properties. • Carbohydrate content in many foods may undergo transformation during processing/preparation techniques, and such modifications may synergistically affect the post-meal glycemic response to the food.[16]
Impact of GI on dietary research and education	• Understanding the GI of traditional Indian foods informs initiatives focused on reducing the prevalence of diet-related diseases and promoting healthier eating habits.
Research evolution and dietary considerations	• Evolving studies highlight the importance of GI in the Indian environment. o The GI value of foods should be considered when choosing carbohydrates in any diet. o The amount of carbohydrates consumed affects BG levels and insulin responses.[17]
Strategies to lower GI	• Consumption of intact whole grains cooked along with intact whole-grain legumes and vegetables may help to lower GI.[16]

Table 5.4. GI Values for Indian Foods[16–20]

Food	Glycemic Index	Classification
Broken wheat upma[16]	52	Low
White chickpea sundal[16]	24	Low
White peas sundal[16]	30	Low
Whole wheat flour roti[17]	45	Low
Adai[16]	66	Medium
Finger millet extruded snack[18]	65	Medium
Finger millet or vermicelli upma[18]	66	Medium
Fenugreek paratha[16]	60	Medium
Parboiled brown rice[19]	58	Medium
Sorghum idli[16]	61	Medium
Wheat dosa[16]	62	Medium
Decorticated finger millet with a lower degree of polish, upma[18]	85	High
Dosa white rice	71	High
Finger millet flakes upma[18]	82	High
Finger millet stiff porridge ball[16]	98	High
Maize roti[16]	75	High
Pearl millet roti[16]	70	High
Ponni[20]	70	High
Sona masuri[20]	72	High
Sorghum roti[16]	84	High
Surti kolam[20]	77	High
Wheat flakes snacks, chiwda[16]	73	High
White rice[19]	80	High
Under milled rice[19]	73	High

Note: For more details on GI and GL, refer to the chapter of GI and GL of mixed meals in *RSSDI Nutrition Guidelines for T1D*.

5.3 Carbohydrates Intake and Chronic Diseases

Carbohydrate intake significantly influences chronic disease risk, with implications for diabetes, obesity, and CVD. The impact of carbohydrates on health depends on the type and quality of carbohydrates consumed. Strategically balancing carbohydrate intake - prioritizing whole, high-quality sources while adhering to moderate consumption levels can mitigate the risk of chronic diseases.

5.3.1 Current Trends in Carbohydrate Intake

In many South Asian nations, carbohydrates account for 70–80% of the total caloric intake,[21] with diets in India particularly deriving two-thirds of these carbohydrate calories from grain staples. This pattern has remained unchanged over the last three decades.[22] A balanced diet is essential for good nutrition throughout the lifecycle.[23] Historically, early human populations primarily relied on plants and plant parts to fulfill their hunger and occasionally supplemented their diets with small animals.[24] Over the last few decades, there has been a significant lifestyle transformation in modern populations from physically demanding jobs and agrarian diets to sedentary routines characterized by overconsumption of calorie-dense beverages and processed foods. Notably, an increase in the intake of refined carbohydrates and foods containing added sugars has contributed to the burgeoning epidemics of T2D, diabetes, hypertension, stroke, and Coronary Artery Disease (CAD).[22] Until the early 1970s, traditional diets in India and other Asian nations predominantly featured less processed (milled) or polished grains, as they were hand-pounded. Remarkably, over the subsequent four to five decades, as hand-pounded or under-milled rice was increasingly replaced with fully milled white rice, the prevalence of diabetes in India's urban areas escalated from 2% in the 1970s to 25% in 2015, and in rural areas from 1% to 14–16%.[21] Concurrently, the urban population has become more sedentary and engages in less physical exercise than required.[25] Despite this, the average total carbohydrate intake remains high, with urban India consuming an average of 289 g/day, compared to 368 g/day in rural areas.[26] While India now produces large quantities of rice and sugarcane, there is a deficiency in millet production, coarse grains, pulses, fruits, and vegetables.[27]

The quality of carbohydrates consumed has thus emerged as a critical concern, with a growing preference for diets rich in whole, unprocessed foods over refined and sugary alternatives. This approach is advocated to promote better glycemic control, sustained energy, and overall nutritional adequacy.[28] Individualized Medical Nutrition Therapy (MNT) is increasingly recognized as vital and widely accepted, with carbohydrate intake tailored to individual metabolic health, exercise level, personal preferences, and dietary goals. Such tailored approaches enhance dietary adherence and optimize nutritional outcomes.[29]

5.3.2 Carbohydrates and T2D

Carbohydrate needs vary among people with diabetes based on age, weight, activity level, metabolic status, and treatment regimen. The diabetes epidemic is largely driven by a rapid epidemiological transition characterized by shifts in dietary habits and reduced physical activity, as evidenced by the increased prevalence of diabetes in metropolitan areas. Although the frequency of microvascular complications of diabetes, such as retinopathy and nephropathy, is lower in Indians, the prevalence of early CAD is markedly higher compared to other ethnic groups.[30]

For people with diabetes, the regulation of BG levels becomes paramount to prevent short-term complications like hyperglycemia and long-term complications such as CVD, neuropathy, and retinopathy.[31] The quality and quantity of ingested carbohydrates significantly impact BG levels. Dietary fiber, a carbohydrate found in plant-based foods such as fruits, vegetables, whole grains, legumes, and nuts, plays a vital role in diabetes management. Fiber slows carbohydrate digestion and absorption, resulting in a more gradual release of glucose into the bloodstream. This helps stabilize BG levels and may improve insulin sensitivity.

The consumption of rice (carbohydrates) was possibly one of the numerous variables behind the diabetes epidemic.[21] Although rice is a staple in Asian Indian diets, encouraging reductions in consumption may be impractical. Instead, substituting white rice with brown rice enhances the quality of the cereal staple in the diet and can help reduce 24-hour glucose and fasting insulin responses among overweight Asian Indians and those with metabolic syndrome.[13]

Simple carbohydrates, such as sugars and refined grains, are metabolized quickly, causing rapid spikes in BG levels. In contrast, due to their fiber and nutrient content, complex carbohydrates from whole grains, fruits, vegetables, and legumes offer a slower, more sustained glucose release.[32] Sugar substitutes, commonly called artificial sweeteners or non-nutritive sweeteners, provide sweetness without the calories and carbohydrates of sugar, offering an alternative for managing carbohydrate intake.

Research, including findings from the Chennai Urban Rural Epidemiological Study (CURES) by Mohan *et al.*[33], indicates that high dietary carbohydrates and GL are associated with an increased risk of T2D. In contrast, higher dietary fiber consumption is associated with a reduced risk. Indian diets, predominantly high in polished grains, are deficient in healthy carbohydrate sources such as whole grains, fruits, and vegetables.[33] Incorporating whole grains and legumes in diets can enhance protein and dietary fiber intake, improve glycemic response, and thus help prevent Coronary Heart Disease (CHD).[34] A recent multinational prospective cohort study spanning five continents supports these findings, demonstrating a significant association between high-GI diets and an increased risk of diabetes (highest quintile vs. lowest quintile; hazard ratio of 1·15, 95% confidence interval 1·03–1·29). Moreover, individuals in the top quintile of GL had a higher likelihood of developing T2D compared to those in the lowest quintile (hazard ratio 1·21, 95% confidence interval 1·06–1·37).[35]

5.3.3 Carbohydrates and Cardiovascular Health

Numerous genetic and lifestyle factors contribute to the etiology of CHD, affecting both the atherosclerotic and thrombotic processes that underpin the disease's clinical symptoms. Dietary factors can influence these processes directly or indirectly through various CVD risk factors. Adults who were overweight or obese were randomly assigned to one of the four diets, reduced-fat high-fiber, for 12 weeks. Higher protein content (25 % total energy intake) with either high or low GI was found in the third and fourth diets, while higher carbohydrate content (55% total energy intake) was found in the first two diets. In the first diet, the GL was highest, and in the fourth diet, it was lowest. They concluded that diets high in protein and low in GI also promote body fat decrease. On the other hand, a low-GI, high-carbohydrate diet was most effective in reducing cardiovascular risk.[36] Diets with a low-GI have been linked to decreased post-prandial glycemic levels, serum cholesterol, C-reactive protein, and blood pressure. A diet with a low GI and GL had a lower risk of CVD and death compared to those who followed a diet with a higher GI and GL.[37]

Prospective trials have indicated that cereals rich in non-starch polysaccharides offer protection against CHD. There is no evidence linking sucrose directly to CHD development. The cornerstone of dietary recommendations aimed at lowering CHD risk primarily advocates consuming more carbohydrate-rich foods, particularly cereals, vegetables, and fruits high in non-starch polysaccharides, at the expense of fat. For those who are overweight or obese, it is crucial to minimize overall fat intake and promote the consumption of carbohydrate-containing foods. Concerns exist that consuming more carbohydrate-containing foods at the expense of fat may result in a drop in High-Density Lipoprotein (HDL) and an increase in Very Low-Density Lipoprotein (VLDL) and triglyceride levels in the bloodstream. However, there is little indication that this occurs when carbohydrate intake rises due to increased eating of vegetables, fruits, and adequately processed cereals over time.[38]

It is also known that carbohydrate intake influences blood lipid profiles, a CVD risk factor. A high-carbohydrate diet may promote atherosclerosis development and other vascular disorders, ultimately leading to mortality. Understanding food trends of various cultures is essential for designing effective chronic disease prevention measures. Studies have found that high carbohydrate intake was linked to an increased risk of total mortality, whereas total fat and specific types of fat were linked to a lower risk of total mortality. Notably, total fat and specific fat types were not linked with CVD, Myocardial Infarction (MI), or CVD mortality; however, saturated fats had an inverse relation with stroke.[39] Whole grains, for example, are connected with a lower risk of CVD, whereas sugary beverages are associated with an increased risk. High fructose and sucrose consumption were associated with negative effects on blood lipids.[40] (Table 5.5)

Table 5.5. Different Types of Carbohydrates and CVD Risk

Food/Nutrients	Key Findings	References
Refined carbohydrates	High intake is associated with increased BG levels, insulin resistance, and a higher prevalence of metabolic syndrome, contributing to CVD risk.[41,42]	• Misra *et al*. 2011 • Deepa *et al*. 2011
Added sugars	Excessive consumption is linked to obesity, T2D, and elevated CVD risk factors such as hypertension and dyslipidemia.[43,44]	• Mohan *et al*. 2010 • Yadav *et al*. 2015
Whole grains	Consumption of whole grains such as brown rice and whole wheat is associated with improved lipid profiles and reduced risk of CVD.[45,46]	• Radhika *et al*. 2009 • Anjana *et al*. 2015
Fruits and vegetables	High intake improves cardiovascular health through reduced inflammation and improved lipid profiles.[22,47]	• Bhardwaj *et al*. 2013 • Gupta *et al*. 2015
Dietary fiber	High fiber intake from whole foods helps lower LDL cholesterol and control BG, reducing CVD risk.[48,49]	• Snehalatha *et al*. 2010 • Sudha *et al*. 2013
Glycemic Index and Load	Diets with low GI and GL are associated with a reduced risk of CVD due to better BG and insulin control.[33,50]	• Mohan *et al*. 2009 • Radhika *et al*. 2010
Urban vs. Rural diets	Urban diets higher in refined carbohydrates and processed foods are linked to higher CVD risk, while rural diets with more whole foods show lower CVD risk factors.[51,52]	• Joshi *et al*. 2012 • Reddy *et al*. 2007
Nutrient-dense carbohydrates	Emphasis on nutrient-dense carbohydrates like millet and pulses can reduce CVD risk due to their high fiber, vitamin, and mineral content.[53,54]	• Kurpad *et al*. 2006 • Shetty 2002

5.4 Tips to Reduce Carbohydrates in the Meal Plan

Using mathematical modeling and a large data set from the ICMR-INDIAB study, Anjana and colleagues[55] showed that even a modest reduction in carbohydrates in Indian diets from the present 60–70% to 50–55%, increase in protein to 20%, preferably from vegetable sources such as pulses or lean meat and healthy fats comprising 20–25% can help both in prevention and remission of T2D. Nita Forouhi endorsed this in a commentary in the same journal. Thus, it is unnecessary to make drastic

changes in the diet, such as a very low carbohydrate diet or keto diet, to address the rising burden of T2D in India.[56] The Institute of Medicine defined an Appropriate Macronutrient Distribution Range (AMDR) for carbohydrates as 45–65% of total calories. The energy content of digestible carbohydrates, including sugars and starches, is usually accepted to be 4 kcal/g. Thus, dietary recommendations include carbohydrate-rich foods such as cereals, vegetables, fruits, legumes, nuts, seeds, and milk products. Carbohydrate foods are rich in fiber and other nutrients.[7] Entire grains, legumes, vegetables, fruits, nuts, and seeds are all examples of 'healthy carbs' that can be incorporated into the diet.

Conversely, 'bad carbohydrates' such as refined cereals like white rice and white bread, sugar-sweetened drinks or fruit juices, cookies, and pastries should be avoided. Finally, it's all about balance; moderation is the key to a good diet.[34] Here are some strategies for lowering carbohydrates in the meal plan: (Table 5.6)

Table 5.6. Strategies for Reducing Carbohydrates in Meal Planning

Nutrients	Strategies
Whole grains	Choose whole grains like brown rice, quinoa, barley, and oats. They have complex carbohydrates, higher fiber, and nutrients, helping regulate BG and promoting satiety.
Non-starchy vegetables	Opt for non-starchy vegetables such as cabbage, cauliflower, gourds, and green leafy vegetables. They are low in carbohydrates and high in fiber, helping reduce carbohydrate intake.[57]
Pulses, legumes, and non-vegetarian protein	Include pulses, legumes, lean meat, poultry, and fish. They are low in carbohydrates, help in feeling full, and prevent muscle loss during weight management.[42]
Healthy fats	Use healthy fats from nuts, seeds, avocados, and olive oil. These fats add flavor and satisfaction without significantly increasing carbohydrate intake.[58]
Balanced diet	Ensure a balanced diet with nutrient-dense carbohydrates, proteins, and healthy fats to support physical and mental well-being.
Carbohydrate counting	Track carbohydrate intake at each meal and snack. One starch choice = one fruit or milk choice (about 15 g of carbohydrates). Nutrition labels provide portion size and content.
Limit processed foods and sugary snacks	Reduce intake of processed foods and sugary snacks, which are high in carbohydrates and low in nutrients, to improve overall health.[59]
Portion control	Pay attention to portion sizes, especially for carbohydrate-rich foods like grains, fruits, and starchy vegetables, to manage carbohydrate intake effectively.
Avoid added sugars	Be mindful of foods and beverages with added sugars like aerated drinks, candies, cookies, and pastries, which can lead to weight gain and increase the risk of chronic diseases.
Combine carbohydrates with protein and healthy fats	Combine carbohydrates with protein and healthy fats to balance meals and satisfy hunger. For example, pair whole-grain dosa with eggs or legume gravy, or have nuts before meals.
Sugar substitutes	Use sugar substitutes (artificial sweeteners) within Acceptable Daily Intake (ADI) limits as alternatives to sugar to manage BG levels and reduce calorie intake.

5.5 Conclusion and Recommendations

• Understanding dietary carbohydrates, significance, classification, quality, and sources is paramount for promoting overall health and preventing chronic diseases. Carbohydrates are the body's primary energy source, influencing BG levels and metabolic processes.
• Individuals can make informed dietary choices by differentiating between simple and complex carbohydrates, considering factors like GI and GL, and distinguishing natural from added sugars. The impact of carbohydrates on chronic diseases such as diabetes, obesity, and CVD underscores the importance of mindful carbohydrate consumption.

- In summary, striking a balance between carbohydrate quantity and quality and adopting a holistic approach to nutrition is essential for promoting long-term health and vitality. Through education, awareness, and informed decision-making, individuals can harness the power of dietary carbohydrates to optimize health outcomes and enhance overall quality of life.

• The take-home message for Indians (and Asians) is to reduce carbohydrate intake from 65–75% to 50–55 % and to consume enough proteins (15–20%), the majority of which should come from vegetable sources such as legumes and pulses or lean meat and the remaining 20–25% percent from healthy monounsaturated fats such as groundnut or mustard oil, nuts, and seeds.[34] Such adjustments are proposed to optimize dietary composition for individuals with T2D, aiming at achieving remission and mitigating the risk of disease progression.[59] This would make our diets more nutritious and sustainable in the long run.[34]

Clinical Pearls of Practice

- To mitigate health risks and support optimal well-being, advise patients to opt for high-quality carbohydrates such as whole, unprocessed sources - fruits, vegetables, and whole grains.
- Tailored nutritional approaches are emphasized for dietary intake of macronutrients.
- To reduce carbohydrate intake and maintain nutritional adequacy
- Incorporation of lean proteins, healthy fats, and non-starchy vegetables is recommended.
- The pertinence of portion sizes must be reiterated and reinforced.
- Recent trends include awareness of added sugars and a focus on whole, nutrient-dense foods.

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Section 6: Dietary Proteins

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6.1 INTRODUCTION

6.1.1 Introduction–Dietary Protein Intake in Indians

With the increasing burden of the triple threat–obesity, diabetes, and hypertension in India- there is a clear need to reassess Medical Nutrition Therapy (MNT) to emphasize protein's critical role.[1,2] The typical diet of Asian Indians, characterized by high intake of refined carbohydrates, saturated and trans fats, salt, and sugar, coupled with low intakes of protein, fiber, and omega-3 Polyunsaturated Fatty Acids (PUFA), exacerbates the risk of developing diabetes.[1] The '**S**tudy **T**o **A**ssess the dietary **C**arbo**H**ydrate' *(Starch)* study and subsequent nutritional analyses across India have revealed a consistent pattern: a disproportionate consumption of carbohydrates and an inadequate protein intake among people with diabetes.[3] This imbalance created by high Glycemic Load (GL) is linked to an elevated risk of diabetes.[4] It highlights the deficiency in meeting dietary protein recommendations among the Indian population, in which only 5% of the rural and 18% of the urban population were consuming the recommended food groups.[5] A focus on carbohydrates and fats has historically overshadowed the role of protein in the dietary management of people with diabetes. Yet, integrating high-quality protein sources into the diet is crucial for moderating postprandial glucose levels and improving overall health outcomes in people with diabetes.

The evolution of dietary patterns towards refined grains, sugar, and processed foods further complicates the nutritional landscape, especially for India's sizable vegetarian population, which relies heavily on cereal grains, pulses, and legumes for protein.[6] Many Indians with diabetes struggle with suboptimal control of glycemic levels, blood pressure, and lipids. The main challenge lies in ensuring protein quality and meeting the requirements for all essential amino acids. Out of the twenty amino acids necessary for bodily functions, nine are essential and cannot be synthesized by the body. Therefore, consuming a variety of foods is crucial to obtain these nine essential amino acids. Lysine,

threonine, tryptophan, and methionine are often limited in plant-based foods. However, vegetarian diets that properly combine cereals, pulses, nuts, and seeds can provide all essential amino acids. Adding milk and dairy products to the daily diet can further improve protein quality. Nonvegetarian sources such as fish, poultry, meat, and eggs have high biological value protein.[2]

6.1.2 Importance of Dietary Protein in Diabetes

Modern MNT guidelines for people with diabetes in India are beginning to prioritize protein, advocating for an intake that constitutes approximately 15–20% of total caloric consumption. This adjustment aims to address not only the prevention and management of diabetes but also the associated risk of sarcopenia.[4] While non-vegetarian foods provide high-quality protein, the consumption of red meat should be moderated.[7] Ultimately, a balanced diet rich in high-quality protein is essential for managing diabetes and promoting general health, highlighting the need for tailored nutritional interventions based on individual requirements and health conditions.

6.1.3 The Rationale of Dietary Protein in Diabetes

The intricate role of dietary protein in managing Diabetes Mellitus (DM) underscores the complexity of nutritional strategies critical for optimizing metabolic health. (Table 6.1)

Table 6.1. Importance of Dietary Proteins for Type 2 Diabetes Mellitus (T2D)

Function	Description
Muscle protein synthesis	• Dietary proteins enhance muscle synthesis and insulin sensitivity, which is crucial for diabetes management. • Amino acids like leucine, isoleucine, and glutamine promote muscle growth and facilitate glucose uptake by muscle tissues, aiding glycemic control.[8]
Satiety and weight management	• Protein intake increases satiety and supports weight management, which is essential in the management of DM.[9] • Protein consumption boosts diet-induced thermogenesis by 20–30%, significantly more than carbohydrates (5–10%) or fats (0–5%). This greater diet-induced thermogenesis by protein consumption potentially leads to weight loss.[10] • Specific proteins trigger gastrointestinal hormones such as cholecystokinin and Glucagon-Like Peptide-1 (GLP-1), reducing appetite and increasing feelings of fullness.[11] • High-protein diets may improve leptin sensitivity and glucagon secretion, modulating appetite and satiety.
Plant vs. animal protein sources	• The choice between plant and animal protein sources is vital in managing DM. A high-protein diet benefits weight loss and improves glycemic control.[12] • Plant-based proteins lower the risk of T2D and offer a sustainable option for diabetes management or prevention.[13] • Vegetarians and vegans may need to carefully plan their diets to meet protein Recommended Dietary Allowances (RDAs) due to potential low protein bioavailability.[14]

6.2 CLASSIFICATION AND FUNCTION

6.2.1 Protein Classification–Complete vs Incomplete Protein

Table 6.2. Dietary Proteins

Complete proteins	• Contain all of the essential amino acids in adequate proportions required by the human body. • Examples ○ Eggs, flesh foods, milk and milk products, soybean.

Incomplete proteins	• Are limited to one or more essential amino acids.
	• Examples
	  ○ Wheat and rice are deficient in lysine and threonine.
	  ○ Pulses are deficient in methionine.
	  ○ Using a combination of pulses and cereals (grains) like dal and rice helps to overcome the deficiency of amino acids in either one.

6.2.2 Physiological Effects of Protein

The mechanisms by which dietary protein helps improve glycemic control are complex and not fully elucidated. Dietary protein helps in muscle synthesis and improves insulin sensitivity.[15] Several amino acids, such as leucine, isoleucine, and glutamine, improve muscle growth. The release of the GLP-1 hormone by protein intake stimulates insulin release and helps control glycemic conditions. The sequencing of food intake, emphasizing protein-rich foods at the beginning of meals, has been shown to attenuate postprandial glucose fluctuations, underscoring the importance of meal composition in managing glycemic excursions in people with diabetes.[16] Starting the meal with a protein source such as paneer, eggs, chicken, fish, beans, or tofu has been shown to reduce post-meal glycemic response; hence, meal order also matters.[17]

To address the nutritional needs of vegetarians with T2D, incorporating various protein-rich plant foods, such as legumes, nuts, and seeds, is vital to ensure a comprehensive amino acid profile. Soy products and other plant-based protein supplements can also aid in meeting protein requirements while supporting glycemic control and overall health. Combining legumes and grains, nuts, can help improve protein quality. Protein intake also improves satiety and aids in weight loss.[16] This is naturally affected by the protein source, quality, time, and amount consumed. Some proteins can stimulate the release of gastrointestinal hormones like cholecystokinin and GLP 1, which decrease appetite by acting at the hypothalamus level (refer to Figure 1).[8] High protein intake may increase sensitivity to leptin at the hypothalamic nucleus level, decreasing appetite and inducing satiety.[9] It can also increase glucagon secretion and modulate the GH/IGF-1 pathway, activating the TOR/S6K and RAS/cAMP/PKA signaling cascades.[14]

A meta-analysis compared the effects of high-protein diets (25–32% of total energy intake) *vs.* standard intake on weight control and other metabolic variables in people with diabetes. The studies lasted 4–24 weeks. The results favored high-protein diets with more significant weight loss (2 kg) and a slight reduction in HbA1c (0.5%). Sir Van Nielen *et al.*[12] showed that animal- and plant-based dietary proteins might have differing impacts on the risk of T2D development.[13] This research underscores the importance of considering the quantity, quality, and source of dietary protein in diabetes progression.

6.2.3 Role of Dietary Protein on Glycemia

Table 6.3. Proteins and Their Role in Glycemic Control

Types of Proteins	Role in Glycemic Control
Dairy protein	• Contains fast-acting whey and slow-acting casein protein, beneficial for weight loss and muscle mass improvement when combined with physical activity,[18,19] especially beneficial for people with diabetes.
Whey	• Higher leucine concentration (50-70%) than soy or casein.[20] • Leucine stimulates muscle protein synthesis.[21] • When taken with meals or with a high Glycemic Index (GI) meal, they increase meal-stimulated insulin release & reduce postprandial glucose levels. It also increases satiety, aiding in weight loss.[22,23] • A 20 g dose reduces glucose significantly compared to 5 and 10 g doses.[24]
Casein	• Co-ingestion with carbohydrates or leucine enhances insulin response and reduces post-prandial Blood Glucose (BG) rise associated with carbohydrate intake in T2D.[25,26]
Soy	• Low in carbohydrates and high in protein compared to other plant sources, such as dals and legumes.[27] • Improves fasting glucose and serum insulin levels, insulin resistance, Low-Density Lipoprotein (LDL) - cholesterol, and C-reactive protein levels in diabetes.[17] • Enhances muscle mass and strength alongside exercise, managing T2D and associated sarcopenia.[28]
Egg and flesh foods	• High protein content and virtually no carbohydrate in eggs, lean chicken, and fish increase protein intake without raising carbohydrates when taken within the recommended amounts.
	• Replacing carbohydrates with protein-rich foods aids long-term weight maintenance and benefits people with diabetes in a high-carbohydrate-consuming country like India.[1] • Incorporating eggs or fish with whole grains, fruits, and vegetables is effective in diabetes management.[29,30]
Pea protein	• Peas provide dietary fiber and protein and are low in calories. • They are high in vitamins A, C, K, zinc, potassium, magnesium, folate, iron, and several B vitamins.

Table 6.4. Dietary Protein Recommendations by Various Scientific Bodies

Condition	Organization	Protein Recommendation (% Energy)
Diabetes	Research Society for the Study of Diabetes in India, RSSDI (2022)[15]	15% calories from protein
Diabetes	Indian Council of Medical Research (ICMR) guidelines for T2D (2018)[31]	12–15% calories from protein
Diabetes	American Diabetes Association (ADA)2024 [32-33]	No specific recommendation
Diabetes	Nutrition therapy for adults with diabetes or prediabetes: a consensus report. Diabetes Care 2019 [34] / Canadian Diabetes Association Clinical Practice Guidelines[35] (2024)	14–20% calories from protein or 1–1.5 g/kg of body weight
Diabetic Kidney Disease (DKD)	Kidney Disease Outcomes Quality Initiative (KDOQI) Nutrition Guidelines 2020 [36,37]	0.6–0.8 g/kg of body weight/day
Sarcopenia	The International Clinical Practice Guideline for Sarcopenia,[38] International Conference on Frailty and Sarcopenia Research (ICFSR) (2018)[34,38,39]	1–1.2 g/kg of body weight/day

6.2.4 Dietary Protein and Remission/Prevention of Diabetes

Macronutrient recommendations using a data-driven optimization model in the latest ICMR-INDIAB (2022) study have highlighted the reduction in dietary carbohydrate and increase in protein intake for both T2D remission and for prevention of progression to T2D in those with prediabetes and standard glucose tolerance.[1] A moderate-protein diet of 18–20% can be a safe option for people with diabetes and obesity, focusing on the source and quality of proteins and looking for plant sources rather than animal protein (refer to Table 6.4).

6.3 SOURCES AND PRACTICAL ASPECTS

6.3.1 Sources of Dietary Protein

Table 6.5. Sources of Dietary Protein in the Indian Diet and their Macronutrient Content [Indian Food Composition Table]

Source	Amount	Protein (g)	Fat (g)	Carbohydrates (g)	Energy (kcal)
Cow milk	150 mL	4.8	6.7	7.4	110
Curd	100 g (51/2 tbsp)	3.1	4.5	3.0	60
***Paneer* (Cottage cheese)**	50 g	9.4	7.4	6.2	13
Processed cheese	25 g (1 cube cheese)	5.8	3.5	0.6	85
Greek yogurt	85 g	6.1	6.8	4.0	55
Egg	One whole/two egg whites	Whole–6.5	11.0	0.0	Whole–90
		White–6.0	0.2		White–30
Chicken/fish	100 g	18–21	3.6	0.0	100
Soybean	25 g	9.4	5.8	2.5	95
Soya chunks	30 g (3/4 cup)	15.6	0.2	9.9	100
Soy paneer (Tofu)	100 g	9.4	9.0	2.3	95
Pulses/lentils green gram, kidney beans, chickpeas)	30 g (one fistful, raw)	7.0	1.6	14.0	100
Wheat	100 g	10.59	1.47	64.7	323.7
Bajra	100 g	10.96	5.43	61.78	350
Jowar	100 g	9.97	1.73	67.68	336

6.3.2 How to Increase Dietary Protein Intake

Table 6.6. Ways to Incorporate Protein at Every Meal

Meal	Protein Source
	*Either steamed or made into patties
Breakfast (7–14 g protein)	One cup curd/50 g paneer/One cup skimmed milk/One egg/One cup sprouts*/One cup kidney beans*/Chickpeas*/Soybean*/Green gram*
Lunch (7–20 g protein)	One cup curd/One cup dal*/Sprouts*/50 g paneer/One cup soya granules*/100 g chicken or fish
Evening (6–7 g protein)	One cup chana* chaat/Sprouts* chaat/One egg omelet
Dinner (7–20 g protein)	One cup curd/One cup dal*/Sprouts*/50 g paneer/One cup soya granules*/100 g chicken or fish

Table 6.7. Protein Complementation

Food	Limiting amino acid	Complement
Beans/legumes	Methionine	Grains, dairy
Grains	Lysine, threonine	Legumes, dairy
Nuts	Methionine	Grains, dairy
Dairy, soy, legumes, and seeds- Sesame, pumpkin, hemp	Leucine	-
Meat, fish, poultry, eggs, cheese, lentils, nuts, and seeds	Isoleucine	-
Poultry, milk, yogurt, ricotta cheese, cottage cheese, raw spinach, raw parsley, and cabbage	Glutamine	-

6.3.3 Implementing Dietary Protein and Protein Supplements

Protein intake in India is poor; however, considering its health benefits, people with diabetes should include adequate protein in their diets, particularly high-biological-value proteins. It is difficult to adequately meet the dietary protein requirement in a typical Indian vegetarian menu. Incorporating a good quality protein source in every meal would help to meet the requirements and improve overall protein intake. Table 6.5 enlists protein sources in the Indian diet and its macronutrient content.[4] These protein sources need to be evenly distributed in all the main meals to meet the protein requirement and obtain the benefit of postprandial glucose control. Milk and milk products, dals, and pulses are good protein sources to increase protein intake in a vegetarian diet. However, these are also sources of carbohydrates, and their addition implies an increase in the total carbohydrate content of a meal. Milk and milk products such as paneer and curd can only be used up to a limited quantity in T2D as they are also sources of Saturated Fatty Acid (SFA).

Adding lean chicken, fish, or egg is a good way to increase the meal's protein content for a non-vegetarian menu. However, the frequency and quantity of nonvegetarian foods would determine the adequacy of protein consumption. Animal protein sources such as lean meats (fish, poultry) are low or devoid of carbohydrates. They are a good source of high-biological-value protein. The inclusion of these sources in a meal can improve protein intake without increasing carbohydrates. Hence, they are one of the recommended sources of protein for people with diabetes. Here, caution is necessary, as these are also sources of cholesterol and SFAs, and nonvegetarian preparations in Indian households often have rich gravies or are fried and, therefore, are high in visible fat. Table 6.7 elucidates examples of ways to incorporate protein in every meal.

Bridging the protein gap with dietary supplements for diabetes

Diabetes Specific Nutritional Formulas (DSNF) are a combination of macro and micronutrients designed to help bridge nutritional gaps and aid in the nutritional management of diabetes. These supplements typically have a low GI/ low GL and contain slowly digestible complex carbohydrates, healthy fats, dietary fiber, and specific micronutrients, which provide additional benefits over standard nutrition formulas, thereby helping to improve postprandial BG levels and glycemic control. DSNF can be a convenient way to improve protein intake and provide essential vitamins and minerals when the regular diet cannot meet the requirements, especially for those with specific dietary needs or malnutrition. These formulas can be used as oral supplements or tube feeds, making them versatile for different patient needs. However, they must be prescribed at the discretion of the healthcare professional after careful assessment of the individual's dietary intake and clinical requirements.

6.4 CONCLUSION AND RECOMMENDATIONS

Standard protein intake can account for 15–20% of daily energy intake.[12] In diabetic kidney disease (stages 1–4), protein intake should not exceed 0.8 g/kg of body weight daily.[36,37] Dietary protein is necessary to synthesize maternal, fetal, and placental tissues. Most guidelines of various scientific bodies[40] suggest that protein should account for 20% of total calories in Gestational Diabetes Mellitus (GDM) (refer to Table 6.4). Adequate protein intake with every meal has been suggested as it helps lower postprandial glucose spikes by flattening the glycemic response of food. Special considerations are needed before starting a high-protein diet (>30% of daily energy intake) in people with diabetes and obesity. Many factors must be considered, such as age, body composition, physical activity, and comorbidities, as evidence of albuminuria or changes in the glomerular filtration rate.

Clinical Pearls of Practice

Condition	Considerations

For people with diabetes	• Rationale: Incorporating dietary proteins is important for enhancing
	  ○ Muscle protein synthesis
	  ○ Increasing post-prandial satiety
	  ○ Aiding in weight management
	  ○ Improving insulin sensitivity
	• Considerations: Age, presence of sarcopenia, and renal function.
	• Monitor
	  ○ Presence of albuminuria (<30 mg/g).[41]
	  ○ Estimated Glomerular Filtration Rate (eGFR): 0.6–0.8 g/kg/day for eGFR[37] <45 mL/min/1.73 m².
	  ○ Sarcopenia: Use SWAG-SARCO questionnaire.[42]
	  ▪ Amount of protein: A dietary protein intake of 15–20% of total caloric consumption.
	• Quality of protein: Complete proteins with high biological value are recommended. Although proteins of animal sources such as eggs, meat, chicken, and poultry are complete proteins. Proteins derived from plant sources have been shown to improve insulin resistance, diabetes, and even cardiovascular risk in the long term and should be promoted.
	• DSNFs may be prescribed at the discretion of healthcare professionals after careful assessment of the individual's dietary intake and clinical requirements.

For Sarcopenia in diabetes	• People with diabetes have a higher prevalence of sarcopenia.
	  ○ Assessment (SWAG-SARCO) and prevention are key.
	  ○ Recommended protein intake[34]
	  ▪ 1–1.2 g/kg of body weight/day, along with physical activity.
	  ▪ Protein supplements may be useful in this scenario.

For DKD	• Protein intake for stages 1–4 DKD: 0.6–0.8 g/kg of body weight/day • A low-protein diet minimizes intraglomerular pressure and reduces strain on the kidneys.[43] • Individualized advice considering severity, progression of Chronic Kidney Disease (CKD), albuminuria status, presence of sarcopenia, and overall nutritional status.[44] ○ Target: 0.6–0.8 g/kg/day for eGFR <45 mL/min/1.73 m².[37]
For Chronic Liver Disease (CLD)	• Recommended protein intake to prevent and reverse muscle loss in sarcopenic patients: 1.2–1.5 g/kg of body weight/day. • Early stages before cirrhosis have similar guidelines for people with diabetes.[45]
For GDM	• Recommended protein intake: minimum 71 g/day (20-25% of total energy intake.[40]

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Section 7: Dietary Fats

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7.1 INTRODUCTION

Dietary fats have experienced a broad shift in perception, transitioning from being widely demonized to being recognized as essential nutrients. Comprising 15–30% of the human body, fats play a crucial role beyond their association with obesity and heart disease; they are vital components of various physiological processes.[1] Historical dietary trends that favored low-fat, high-sugar, and high-carbohydrate diets have contributed to an increase in metabolic disorders such as insulin resistance, Type 2 Diabetes Mellitus (T2D), and obesity.[2] The evolving acknowledgment of the importance of dietary fats within a balanced diet represents a significant paradigm shift in nutritional perspectives in India. According to a study conducted in India, it was observed that the fat

intake is higher in urban India (51.6 g/day) as compared to rural (36 g/day) India, especially highest in the northern urban population (24%) as compared to the urban areas of other regions.[3] This change underscores the necessity for a nuanced approach to fat consumption, recognizing its indispensable role in maintaining health and preventing disease.

7.2 WHAT ARE DIETARY FATS?

Fats, recognized as crucial macronutrients, are essential as they provide energy. Beyond their nutritional value, fats enhance the taste and texture of food. Chemically, fats are organic substances that are insoluble in water but soluble in organic solvents. Hence, dietary fats are crucial in cellular structure and fat-soluble nutrient absorption. They are categorized into Monounsaturated Fatty Acids (MUFA), Polyunsaturated Fatty Acids (PUFA), Saturated Fatty Acids (SFA), and trans-fatty acids, each with distinct effects on health. While Essential Fatty Acids (EFA) in PUFA benefit health, trans-fats, formed during industrial oil processing or on reheating the oil, can be harmful. Cholesterol, primarily found in animal fats, is vital for human life as it contributes to cell membrane integrity and hormone synthesis. However, it's not a required nutrient since the body can produce it.[4]

7.2.1 Classification of Dietary Fats

Dietary fats vary in form and are categorized based on the number and position of double bonds within their hydrocarbon chains.[5] For the classification of dietary fats, refer to Table 7.1.

Table 7.1. Classification of Dietary Fats

Category	Classification	Description
Saturated fatty acids	No double bonds	• Contains no double bonds in the hydrocarbon chain.
Unsaturated fatty Acids	Have double bonds	• Contains one or more double bonds in the hydrocarbon chain. • It can be further subdivided based on the bond characteristics.
MUFA	One double bond	• Fatty acids with a single double-bond within the hydrocarbon chain.
PUFA	More than one double bond	• Fatty acids with multiple double bonds. • Generally considered beneficial and safe.
Cis Fats	Cis-oriented double bonds	• Naturally occurring fats with cis-oriented double bonds.
Trans Fats	Trans-oriented double bonds	• Usually synthetic and contain trans-oriented double bonds.
Omega-3 Polyunsaturated Fatty Acids	Double bond, three carbons from the terminal	• It contains a double bond three carbons away from the terminal carbon of the chain.
Omega-6 Polyunsaturated Fatty Acids	Varies	• Typically involves a different position of double bonds compared to omega-3 PUFAs.
Cholesterol	Four hydrocarbon rings and a hydroxyl group	• Uniquely shaped 27-carbon molecule containing a hydrocarbon tail, a hydroxyl group, and a core sterol nucleus composed of four hydrocarbons rings.[6]

7.2.2 Types and Sources of Dietary Fats

Dietary fats are a crucial component of a balanced diet and come from various sources, each contributing differently to our health. Refer to Table 7.2 for sources of dietary fats.

Table 7.2. Sources of Dietary Fats

Sources of Dietary Fats[1,7,8,9,10,11,12]	
Types of Fats	**Sources**
Saturated Fatty Acids	Coconut oil (90.8%), ghee (61.9%), butter (51.3%), palm kernel oils (28%), cheese (17.6%), egg yolk (9.5%), whole milk (2.7%), red meats, processed meats (sausages, ham, and bacon).
Monounsaturated Fatty Acids	Olive oil (77%), rapeseed oil (72.8%), olive oil (68.2%), mustard oil (66.9%), macadamia (59.2%), groundnut (peanut) oil (53.7%), hazelnuts (45.6%), sesame (gingelly) oil (41.2%), almonds (38.3%), cashews (27.9%), peanut butter (25.4%), pistachios (18.9%), peanuts (18.3%), canola oil (17.5%), sesame seeds (16.1%), safflower oil (11.6%) olives (7.6%), avocado.
Omega-6 Polyunsaturated Fatty Acids	Safflower oil (79%), sunflower oil (62.2%), corn oil (53.52%), sesame oil (40.9%), soybean oil (42.9%), walnuts (36.2%), rice bran oil (33.1%), sunflower seeds (25.5%), sesame seeds (19.1%), groundnut oil (18.2%), cottonseed oil (1.9%).
Trans Fats	Margarine (20.6%), vanaspati/*dalda* (2%), bakery products (biscuits, cakes, donuts, pastries), ready-to-eat (processed) foods, deep-fried foods (chips, *samosas*, french fries), and sweets (*jalebi, gulab jamun*, etc.).
Omega-3 PUFA	Mustard Oil (41.9%), flaxseeds (12.9%), walnuts (8.71%), mustard seeds (3.34%), fenugreek seeds ((1.08%), soybean oil (0.87%), black gram (kala chana) (0.60%), kidney beans (rajma) (0.55%), cowpea (lobia) (0.20%), chia seeds, eggs, tofu, oily fish (salmon, tuna, herring, sardines, mackerel).
Cholesterol	Brain (1.3–1.6%), egg yolk (1.08%), butter (0.2%), ghee (0.25%), liver (0.55%), shrimp (0.16%), milk and milk products, red meats, poultry, cheese.

7.3 FUNCTIONS OF DIETARY FATS

Fats serve as a crucial energy source for the body, yet the type and quantity of fats consumed daily are instrumental in determining health outcomes. Among all FAs, only PUFAs, such as linoleic acid and alpha-linolenic acid, qualify as EFAs.

This classification is due to the human body's inability to synthesize the omega-3 and omega-6 branches, necessitating dietary intake. These EFAs are precursors for the synthesis of Long-Chain Fatty Acids (LCFAs) such as Arachidonic Acid (AA), Eicosa Pentaenoic Acid (EPA), and Docosahexaenoic Acid (DHA), which are critical components of cell membranes, particularly in neurons, muscles, and immune cells.[13] The digestion and absorption rates of fats are contingent on the length of the fatty acid chain. For example, AA is a precursor for signaling molecules such as prostaglandins, thromboxanes, and leukotrienes. EPA modulates inflammation and coagulation, while DHA is essential for brain development and function.[14]

Short-chain and Medium-Chain Triglycerides (MCT) are rapidly digested and absorbed into the portal circulation, akin to carbohydrates, whereas LCFAs are absorbed into the lymphatic system via chylomicrons.[15] High total fat intake is associated with an increased risk of obesity, and high intakes of saturated and trans fats have been linked to a greater risk of Cardiovascular Disease (CVD). The multifaceted

role of fats includes providing energy, facilitating the absorption of fat-soluble vitamins, protecting organs, offering thermal insulation, enhancing food palatability, and supporting growth. Fats are also integral to the structural integrity of cell membranes, regulation of platelet adhesiveness, and maintenance of vascular homeostasis and are essential for gastric secretion, gastrointestinal motility, lung physiology, reproduction, neuronal excitability, and the synthesis of steroids and bile acids.[4,16]

Studies have also proven that nuts rich in MUFA help reduce the risk for obesity, Metabolic Syndrome (MetS), and Congenital Heart Disease (CHD).[17] Similarly, a study also observed that the use of cooking oils such as canola oil and olive oil had been seen to improve the liver span and reduce the grade of fatty infiltration in addition to improving insulin sensitivity in male Asians with Metabolic Dysfunction Associated Steatotic Liver Disease (MASLD).[18] Carbohydrates are the preferred energy source over fats in human metabolism, a mechanism critical for maintaining Blood Glucose (BG) levels within a strictly regulated homeostatic range. Carbohydrate consumption primarily enhances its oxidation, with minimal impact on fat synthesis under standard dietary conditions. However, the palatability of fats and their relatively modest effect on satiation can lead to passive overconsumption, potentially resulting in weight gain unless balanced by increased energy expenditure.[19]

Specific fatty acids and high-fat diets can induce adverse metabolic reactions beyond their caloric content, elevating inflammatory mediators such as tumor necrosis factor-alpha and various interleukins, as observed in human and animal studies. These diets are associated with heightened oxidative stress and inflammatory responses post-consumption, hormone resistance, and several features of MetS.[20] Integrating high-quality fats into the diet can enhance the structural integrity of cell walls, improving their capacity to metabolize insulin and thereby more effectively regulate BG levels. Optimal fats can stimulate fat burning, reduce hunger, and decrease fat storage, highlighting the importance of selecting high-quality fats to support weight management and counteract the deleterious effects of excessive sugar intake and unhealthy fats.[21]

7.3.1 Daily Dietary Fat Recommendations

Understanding the daily recommendations for fat intake is essential for maintaining a balanced and healthy diet. Health organizations, such as the World Health Organization (WHO) and the American Heart Association (AHA), provide guidelines to help people with diabetes manage their fat consumption. Refer to Table 7.3 for dietary fat guidelines from various scientific bodies.

Table 7.3. Dietary Fat Guidelines from Various Scientific Bodies

Dietary Fat Guidelines from Various Scientific Bodies[3,16,17,22]	
Scientific Bodies	**Recommendations**
American Diabetes Association, 2024	• Total fat intake should range from 20-35% of daily calories. • Saturated fats should be limited to less than 7% of total daily calories, and trans fats should be minimized. • Include healthy MUFA and PUFA, such as those found in nuts, seeds, avocados, and oily fish.[23]
European Society of Diabetes and Nutrition, 2023	• Total fat intake should not exceed 35% of total daily energy intake. • Saturated fats should be limited to less than 10% of total daily calories.[24] • Reduce trans-fat intake to as low as possible. • Encourage the consumption of foods rich in omega-3 PUFAs.
World Health Organizatio n, 2023	• Total fat should not exceed 30% of total daily energy intake. • Limit SFA to less than 10% of total energy and trans-fatty acids to less than 1%. • Promote the replacement of saturated fats with unsaturated FA.[25]
Indian Council of Medical Research, 2024	• Total fat intake should be 20–30% of total calories. • SFA ≤10% of energy and 7% in people with hypercholesterolemia. • Include MUFA and PUFA-rich oils. • Promote the use of alternating oils or blended oils.[26]
Consensus dietary guidelines for healthy living and prevention of obesity, metabolic syndrome, diabetes, and related disorders in Asian Indians, 2011	• No more than 30% of daily energy should come from fat. • No more than 10% of daily energy should come from SFAs. • SFAs should comprise no more than 7% of daily calories for people with Low-Density Lipoprotein Cholesterol (LDL-C) levels >100 mg/dL. • Limit cholesterol intake to 200–300 mg/day.[27]

Over the past several decades, considerable research has been devoted to elucidating the relationship between dietary fat intake and CVD. This extensive body of research has established that the pronounced emphasis on reducing fat intake has paradoxically undermined public health, contributing to a marked rise in overweight and obesity rates due to excessive consumption of carbohydrates and SFA.[28,29] It is now recommended that total fat intake should not exceed 30% of total caloric intake. Consuming foods high in SFA, such as butter, coconut oil, margarine, and ghee, should be avoided to mitigate health risks associated with high SFA intake.[30] Refer to Table 7.4 for current recommendations for dietary fat intake in Indians.

Table 7.4. Current Recommendations for Dietary Fat Intake in Indians

Current Recommendations for Dietary Fat Intake in Indians [25,26,27][30,31,32]	
Scientific Bodies	**Recommendations**
Saturated Fatty Acid	• <10% calories/day (<7% for individuals with dyslipidemia/at risk of CVD).[30]
Linoleic Acid	• 2.5–9% of total energy.[31]
Alpha-linolenic Acid	• >0.5% of total energy.[31]
ALA/ALNA	• <10 (preferably in the ratio of 5:1).[32]
Long-chain Omega-3 Polyunsaturated Fatty Acid	• 200 mg/day.[32]
Dietary Cholesterol	• <300 mg/day for individuals with normal lipid levels/no risk of CVD. • <200 mg/day for individuals with dyslipidemia/risk of CVD.[33,34]

7.3.2 Considerations for the Selection and Use of Cooking Oils

The manufacturing process of oil is a critical factor in its dietary recommendation. Refined oils, characterized by high purity and lower cost, tend to contain higher levels of SFA. In contrast, cold-pressed oils, though produced through a more labor-intensive and costly process, offer a shorter shelf life.[35,36] It is crucial to consider the use of oil in cooking, particularly frying. The nutritional properties discussed pertain to oil in its raw form. However, when oils are heated during cooking, they undergo various chemical reactions, some of which can generate toxic oxidized products that are detrimental to health. This underscores the importance of understanding the smoke point of cooking oils. The smoke point, the temperature at which oil begins to produce a continuous stream of smoke, is a critical indicator of the oil's suitability for frying. Oils with a higher smoke point are generally more appropriate for deep frying, whereas those with a smoke point below 200°C are less suitable for such cooking methods.[37] Table 7.5 shows the commonly used oils in India.

Table 7.5. Types of Commonly Used Oils in India

Types of Commonly Used Oils in India	
Oils	**Characteristics of Oil**
Mustard oil	Mustard oil is commonly used in North India due to its pungency. It is a major source of MUFA. Its rich composition, including optimal ratios of omega-3 and omega-6 PUFAs, oleic fatty acid, linoleic acid, alpha-linolenic acid, and erucic acid, offers multifaceted health benefits. Notably, alpha-linolenic acid's inhibition of platelet adhesion minimizes the risk of heart failure, while its antioxidant properties mitigate cancer risk. The smoke point of Mustard oil is 254 °C.[38,39]
SFA:5.7	
MUFA:66.9	
PUFA:27.2[11]	
Groundnut oil	Groundnut oil is prevalent in Indian cuisine and boasts a high MUFA content that supports cardiovascular health. Research indicates its consumption can lower BG, curb lipid peroxidation, and bolster antioxidants in T2D. Groundnut oil, known for its oxidative stability and high smoking point, is a great choice for cooking and frying needs.[40] The smoke point of groundnut oil is 225°C.[41]
SFA: 19.2	
MUFA:53.7	
PUFA: 26.9	
Sesame oil or Gingelly oil	Sesame is packed with beneficial compounds like lignans, tocopherols, and phytosterols. Its balance of oleic and linoleic fatty acids is crucial for human health. Sesame seeds offer antioxidant properties, lower cholesterol, regulate blood lipids, and protect the liver and kidneys. It also promotes cardiovascular health by reducing bad cholesterol and increasing good cholesterol levels. Additionally, it provides anti-inflammatory and anti-tumor benefits, making it a valuable addition to a healthy diet.[42,43] The smoke point of sesame oil is 242°C.[44]
SFA: 16.4	
MUFA:41.2	
PUFA: 42.3	
Rice bran oil	Rice bran oil, derived from rice bran, offers rich
SFA: 23.6	nutritional benefits due to its high phytosterol content. Rice bran polysaccharides have shown promise in boosting immunity, lowering BG, and combating tumors. Research indicates that peptides found in rice bran can also reduce BP and cholesterol, offering potential benefits against cancer and diabetes.[45] The smoking point of rice bran oil is 232°C.[41]
MUFA:43.7	
PUFA: 32.6	
Coconut oil	Coconut oil is one of the most used edible oils used in South India. The benefits of its use are buried because it contains high SFA. However, it is abundant in MCT (65%), directly absorbed into the liver through the intestine, and does not involve the cholesterol biosynthesis pathway.[38] Consumption of coconut oil has been shown to significantly increase LDL-C levels in studies.[46] The smoke point of unrefined coconut oil is 205 °C.[37]
SFA: 90.8	
MUFA:7.2	
PUFA: 1.9	

Olive oil	Olive oil contains MUFA and antioxidant phenols, which help improve cardiovascular health by reducing oxidative stress, inflammation, and endothelial dysfunction. It also aids in lowering blood pressure. Consuming olive oil can also protect against metabolic disorders by reducing lipid and Deoxyribonucleic acid (DNA) oxidation, improving lipid profiles, and mitigating insulin resistance.[47,48] The smoke point of olive oil, virgin olive oil, extra virgin olive oil, and pomace olive oil is 208°C, 175°C, 206°C, and 190°C, respectively.[49]
SFA: 14%	
MUFA:77%	
PUFA: 9%	
Canola oil	Canola oil (CO) is rich in oleic acid, ALA, and phytochemicals and is a good source of PUFAs, including linoleic acid and MUFAs. ALA, an omega-3 PUFAs in CO, can be converted to DHA and EPA in the body. CO intake may improve total cholesterol, LDL cholesterol, Apo B/Apo A1 ratio, and triglyceride levels. Some studies also suggest CO consumption lowers fasting glucose and insulin levels.[51]
SFA: 6.6%[50]	
MUFA: 17.5%	
PUFA: 9.2%[50]	
Vanaspati	As hydrogenated oil has a high melting point and a long shelf life, it is often referred to as trans-fat or vanaspati and is frequently added to meals. Any refined edible vegetable oil that has hydrogenated is called vanaspati. These days, vanaspati is frequently seen in Indian markets as hydrogenated, solidified vegetable oil. A less expensive option than milk-based clarified butter is vanaspati ghee. It is often used as an ingredient in biscuits, cookies, and other processed foods.[52] Trans Fatty Acids (TFAs) increase LDL-C and lower High-Density Lipoprotein (HDL) cholesterol, raising the risk of coronary heart disease. They are also linked to atherosclerosis, inflammation, and inducing cell apoptosis.[53]
SFA: 61.6%	
MUFA: 33.6%	
PUFA: 4.7%	

On average, an individual should consume three leveled teaspoons or one leveled tablespoon of visible fat per day. To get the most health benefits, utilizing the proper combination, rotating oils, or using commercially available blended oils that include balanced fatty acids is advisable.[54]

7.4 DIETARY FATS- PATTERNS OF FAT AND METABOLIC HEALTH

Dietary fats are pivotal in modulating metabolic health, particularly in managing T2D. The type and quantity of fats consumed can significantly influence BG levels, insulin sensitivity, lipid profiles, and overall metabolic function. Refer to Table 7.6 for the role of dietary fats in modulating metabolic health.

Table 7.6. The Role of Dietary Fats in Modulating Metabolic Health in T2D Management

The Role of Dietary Fats in Modulating Metabolic Health in T2D Management		
Aspects of Metabolic Health	**Influence of Dietary Fats**	**Key Points**
Insulin sensitivity	Modulation by type of fats	• MUFA and PUFA (found in olive oil, nuts, and fatty fish) enhance insulin sensitivity by improving cell membrane fluidity and facilitating efficient insulin sensitivity.[55] • SFA and trans fats (common in processed foods) impair insulin sensitivity, negatively affecting glycemic control. • The type of dietary fat consumed is directly correlated with insulin action in the body.[56,57]
Blood glucose regulation	Postprandial glycemic impact	• Diets rich in unsaturated fatty acid lead to lower postprandial BG levels than diets high in SFA, which are attributed to slower gastric emptying and gradual glucose absorption. • This results in more stable BG levels throughout the day.[57]
Lipid profiles	Improvement of cardiovascular risk markers	• PUFA and MUFA improve lipid profiles by reducing LDL-C and increasing HDL cholesterol.[58] • Omega-3 PUFAs-Icosapentyl Ethyl (IPE) is a highly purified, stable ethyl ester of EPA, which has been shown to reduce triglyceride levels, further lowering cardiovascular risk.[59]
Inflammation reduction	Anti-inflammatory effects	• Omega-3 PUFAs possess anti-inflammatory properties that can reduce systemic inflammation. • Reduced inflammation improves endothelial function, reduces insulin resistance, and lowers the risk of cardiovascular complications.[60,61,62]
Weight management	Role in energy balance and satiety	• Fats are calorie-dense but contribute to satiety, potentially reducing overall calorie intake. • Medium-chain triglycerides[63] are metabolized differently, leading to increased energy • expenditure and reduced fat accumulation, aiding in weight management for T2D.[64,65]

7.4.1 Choice of Dietary Fats- Which, how, and how much?

Choosing the right dietary fats involves understanding which types to include, how to incorporate them into your diet, and determining the appropriate amounts. Health organizations provide guidelines to help individuals make informed decisions about fat consumption (refer to Table 7.7).

Table 7.7. Guidelines for Dietary Fat Selection and Consumption in T2D Management

Guidelines for Dietary Fat Selection and Consumption in T2D Management	
World Health Organization[25]	• **Choice of fats** • Prioritize Unsaturated Fatty Acids (USFA) from plant sources: Olive oil, sunflower oil • Limit SFA from animal sources and trans fats. o **How to use** USFA ♣ For cooking, dressing, and spreads. o Avoid frying with USFA to prevent oxidation. • **Recommended quantity** o Total fat: Less than 30% of total daily energy intake. o SFA: Less than 10% of total energy. o Trans fats: Less than 1% of total energy.
American Diabetes Association[23]	• **Choice of fats** o Focus on MUFA and PUFA. ♣ Olive oil, sunflower oil o Reduce intake of SFA. o Eliminate trans fats from the diet. • **How to use** o To balance glucose levels. ♣ Incorporate healthy fats in each meal. o Reduce SFA intake ♣ Use oils for cooking instead of solid fats. • **Recommended quantity** ● Total fat ♣ Less than 20–35% of total daily energy intake. o SFA ♣ Less than 7% of total energy. o Trans fats ♣ Less than 1% of total energy.
European Society of Diabetes and Nutrition Guidelines[24]	• **Choice of fats** o Emphasize on olive oil, nuts, seeds, and fatty fish for healthy fats. o Avoid fats high in SFA and trans fats. • **How to use** o Utilize healthy fats ♣ In cooking and salads. o To minimize fat degradation. ♣ Prefer baking or steaming over frying. • **Recommended quantity** o Total fat: No more than 35% of total daily energy intake. o SFA: Less than 10% of total energy. o Recommended to use USFA fats to replace SFA and trans fats.
Indian Council of Medical Research[54,66]	• **Choice of fats** o Emphasize on MUFA and PUFA-rich cooking oils like rice bran, mustard oil, and nuts. o Limit fats high in SFA and trans fats. • **How to use** o Alternate between MUFA & PUFA rich oils ♣ Switch oils while cooking and salad dressings. o To optimize glucose control and mitigate CVD risk ♣ Choose nuts & cooking oils rich in MUFA. • **Recommended quantity** o Total fat ♣ 20–30% of total energy intake. o SFA ♣ 10% of total energy for normal people and 7% for people with high lipid levels. o Trans fats ♣ Less than 1% of total energy. o n-3 PUFA ♣ 0.6–1.2 % energy/day. o n-6 PUFA ♣ 3% energy/day.[54]

Consensus dietary guidelines for healthy living & prevention of obesity, metabolic syndrome, diabetes, and related disorders in Asian Indians[27]	• **Choice of fats** o Emphasize on ♣ PUFA-rich foods–fish, walnuts, flaxseeds, canola oil, etc. o Limit the use of SFA-rich foods & avoid trans fats. o Optimal ratio of LA: ALA–5:10. • **How to use** o Alternate between MUFA & PUFA rich oils. ♣ Switch oils while cooking and salad dressings. o Prefer vegetable oils along with ALA-containing oil containing high LA levels along with oil containing moderate or low LA levels. o Groundnut/sesame/rice bran + soybean. • **Recommended quantity** o Total fat: Not more than 30% of total energy intake. o SFA: Not more than 10% of total energy and not more than 7% in people with high lipid levels. o Trans fats: Less than 1% of total energy. • ALA o 1–2 % of total energy. • PUFA o 5–8 % of total energy. • MUFA o 10–15 % of total energy.

Table 7.8 outlines nutritional recommendations for dietary fats for people with diabetes, offering guidance on incorporating various fat sources such as egg yolk, oily fish, seeds and nuts, ghee, coconut oil, and different types of oils into a balanced diet.

Table 7.8. Nutritional Recommendations for People with Diabetes

Nutritional Recommendations for People with Diabetes	
Egg yolk	• It can be part of a healthy diet for people with diabetes. • Monitor overall dietary cholesterol and SFA intake. • ADA has no explicit restriction on egg consumption. • Moderation is advised, typically around 1 whole day within a balanced diet.[67]
Oily fish	• Good source of protein and PUFA.[68] • Low in SFA. • Rich in omega-3 fatty acids, hence cardioprotective. • AHA recommends consuming 2 servings (100 g) of oily fish (salmon, tuna, herring, sardines, mackerel) twice/week.[69,70]
Seeds and nuts	• Such as flaxseed, chia seeds, almonds, peanuts, walnuts, and pistachios. • Provide PUFA and MUFA, fiber, and bioactive compounds. • Have been shown to improve lipid profiles and glycemic control in T2D. • A handful (~30 g) daily as part of a balanced diet.[71,72]
Ghee (dairy) and coconut oil	• Rich in SFA. • Emphasize the importance of context and overall dietary patterns. • Traditional guidelines recommend limiting SFA intake. • Use sparingly, focusing on USFA instead.
Oils (filtered, refined, cold-pressed)	• Selection criteria: Based on processing levels, nutritional content, and shelf life. • Cold-pressed oils: Less processed, retaining more nutrients and antioxidants, but shorter shelf life. Examples: cold pressed sunflower, cold pressed rapeseed. • Focus on USFA, such as olive oil (which can be used for salad dressing), sunflower oil, and groundnut oil. • Usage should align with dietary fat recommendations, emphasizing moderation and variety.

7.4.2 Effects of supplements such as omega-3 PUFAs, MCT oils, LC-PUFA

Nutritional strategies for managing chronic diseases increasingly recognize the significance of specific dietary fats and supplements. Omega-3 fatty acids, MCT oils, and LC-PUFAs, including Conjugated Linoleic Acids (CLAs) and omega-9 fatty acids, are crucial for their bioactive roles in modulating lipid profiles, enhancing metabolic health, and reducing inflammation (refer to Table 7.9).

The current data have indicated that the consumption of omega-3 PUFA by Indians is just about 20–50 mg/day.[73] Mustard, soybean, and canola oil contain reasonable quantities of omega-3 FAs and

alpha-linolenic acid. Although mustard and soybean oil have a peculiar flavor that is unacceptable to many, North India still uses and relishes mustard oil. Canola oil (rapeseed oil) is a good option, but it is expensive and not readily available since attempts to cultivate it in India have not been very successful.[32]

Table 7.9. Nutritional Recommendations for People with Diabetes- Dietary Fat Supplements

Nutritional Recommendations for People with Diabetes- Dietary Fat Supplements	
Omega-3 PUFAs	• Sources include fish oil and algae. • Improve cardiovascular health and lipid profiles and have anti-inflammatory effects. • At least two servings of fatty fish per week or supplements.
Medium-Chain Triglycerides, Oils	• Sources include coconut oil (14%), butter (9.2%), palm kernel oil (7.2%), and supplements. • Supports weight management and insulin sensitivity. • Integrate into total dietary fat intake in moderation without exceeding caloric needs; further research is ongoing.
Low chain-polyunsaturated fatty acids and Conjugated Linoleic Acids	• Sources include dairy products, beef, omega-3 and omega-6 PUFAs. • It is essential for cellular health and may improve diabetes risk factors. • There is mixed evidence for weight management and insulin sensitivity; moderation is advised.
Omega-6 PUFAs	• Include Linoleic acid, arachidonic acid.[74] • Sources include Safflower oil, sunflower oil, cottonseed oil, corn oil, soybean oil, groundnut oil, rice bran oil, sesame oil, walnuts, sesame, and sunflower seeds. • It lowers LDL & cholesterol levels, thus reducing the risk of CVD.[74]
Omega-9 PUFAs	• Sources include olive oil and vegetable oils. • Improves insulin sensitivity, heart healthy. • Use a preferred source of dietary fat and replace SFA and trans fats where possible.

Inadequate intake of quality fats can have significant implications for health and well-being.

7.5 CONCLUSION AND RECOMMENDATIONS

Dietary fats are a crucial diet component for people with diabetes, serving a multifunctional role in enhancing metabolic health. The strategic selection of healthy fats, specifically MUFA and PUFA, over their SFA and trans-fat counterparts is critical. Such choices enhance insulin sensitivity, improve lipid profiles, regulate BG levels, reduce inflammation, and support weight management. This highlights the necessity for personalized Medical Nutrition Therapy (MNT) planning and underscores the importance of educating people with diabetes about healthy fat options within their nutritional management strategies. Using the principles of MNT for T2D management, a balanced intake of dietary fats is paramount, with priority given to USFA fats. Supplements such as omega-3 FAs may confer additional benefits, particularly enhancing cardiovascular health. Tailoring MNT to the needs of people with diabetes is crucial, considering their overall health, dietary preferences, and specific metabolic objectives. Professional consultation with a healthcare provider or dietitian is indispensable in offering tailored guidance and ensuring that MNT effectively supports the management of T2D.

Clinical Pearls of Practice

- Total fats should constitute 20-25% of total daily calories.
- SFA intake should be less than 10% of the total calories and <7% in people with high lipid levels.
- Trans fat should be limited to less than 1% of total calories, although it is best to avoid it altogether.
- Dietary cholesterol intake should be less than 300 mg/day for individuals with normal cholesterol levels and less than 200 mg for individuals with dyslipidemia or CVD risk.
- The intake of n-3 PUFA should be between 0.6-1.2% of energy/day, while n-6 PUFA should make up 3%.
- High-quality fat sources include eggs, flaxseeds, chia seeds, sunflower seeds, pumpkin seeds, nuts including walnuts, groundnut oil, mustard oil, oily fish- sardines, tuna, mackerel.
- Recommendation of oil combinations in Indian Diets (1:1 proportion):
  - Groundnut/sesame/rice bran/cottonseed + mustard
  - Groundnut/sesame/rice bran/cottonseed + canola
  - Groundnut/sesame/rice bran/cottonseed + soybean
  - Safflower/Sunflower + Mustard

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Section 8: Micronutrients

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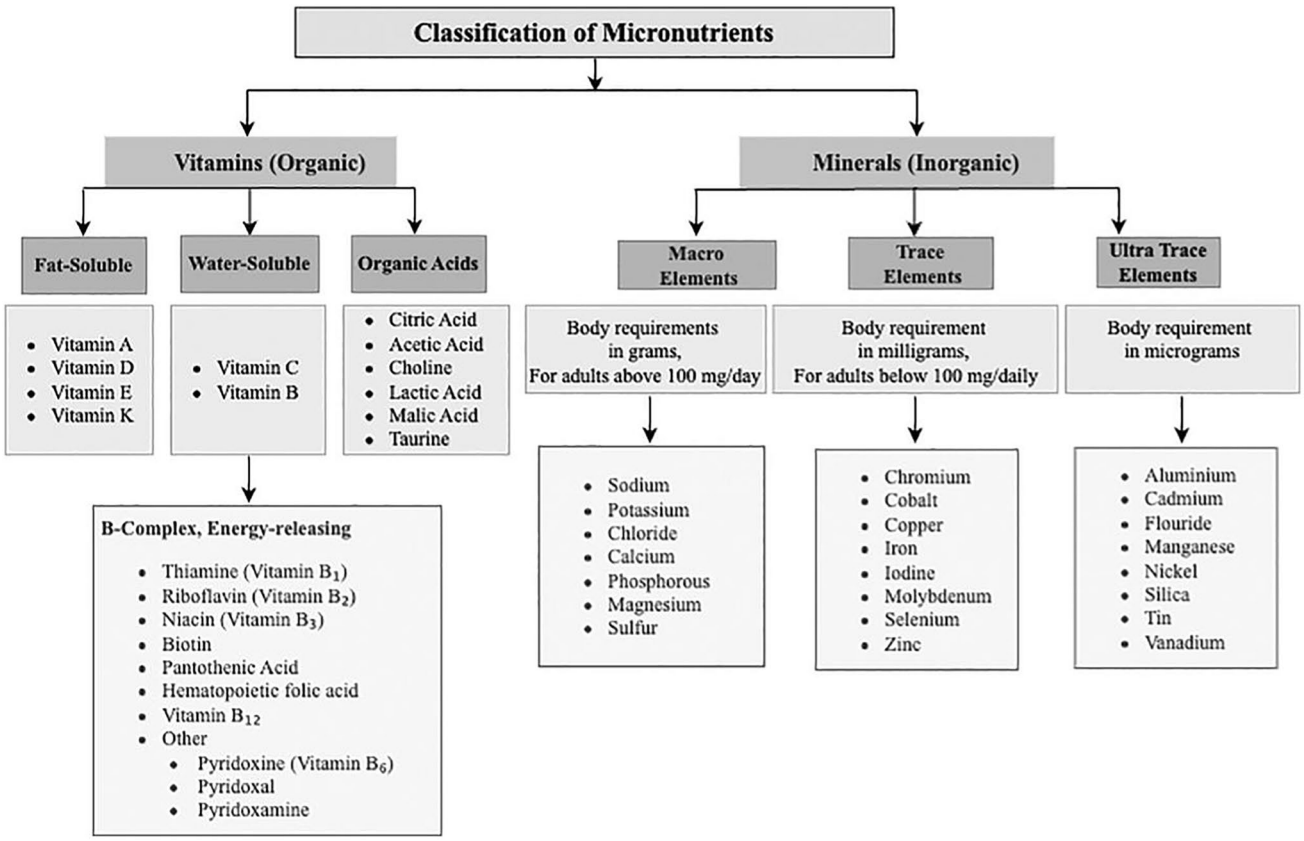
8.1 INTRODUCTION

Micronutrients are often neglected in nutritional counseling for people with diabetes. Although required in smaller quantities, micronutrients support essential bodily functions and cellular processes. Emerging evidence indicates their potential to impact the quality of life among people with diabetes directly. Conventionally, micronutrients encompass vitamins and minerals (refer to Table 8.1).

8.1.1 Classification of Micronutrients

FIGURE 8.1 Classification of Micronutrients[1]



8.1.2 Micronutrients and Natural Sources

Table 8.1. Micronutrient Sources and Recommended Dietary Allowances (RDA)[2]

Micronutrients		Natural Sources
Vitamins	**Vitamin A**	Dairy products, eggs, fish, organ meats, dark green leafy vegetables. For example, amaranth (Red or Green), spinach and chard, orange-fleshed sweet potatoes, carrots, squashes/pumpkins, yellow maize, mangoes, papayas.
	Vitamin C	Citrus fruits - Indian gooseberry (amla), guava (pink and white), orange, sweet lime, lemon, bell peppers, berries, tomato, dark leafy vegetables, cashew fruit, kiwi, strawberry, brussels sprouts, broccoli, raw mango.
	Vitamin E	Nuts and seeds, spinach, broccoli, kiwi fruit, mango, sunflower, safflower, and soybean oil.
Vitamins	**Vitamin B**	Whole grains, eggs, lean meats, milk, green vegetables like spinach (*palak*), green sorrel (*ambat chuka*), agathi leaves, nuts, legumes, oats, bananas, plums, avocados, and potatoes.
	Vitamin K	Amaranth leaves, drumstick leaves, colocasia leaves, pumpkin leaves, mustard leaves, spinach, kale, avocado, broccoli, soybeans, edamame (frozen), okra (lady's finger), orange pumpkin, baby corn, fresh peas, pine nuts, walnuts, custard apple, pear, pomegranate, strawberry, jackfruit ripe, lotus root, gingelly seeds (*til*), mushroom, eggs, poultry.
	Vitamin D	Fortified foods, fatty fish (trout, salmon, tuna, and mackerel), beef liver, egg yolks, yogurt, and tofu.
	Vitamin B_{12}	Fish, meat, poultry, eggs, milk, and other dairy products, clams, oysters, and beef liver.
Minerals	**Calcium**	Dairy products, leafy greens, fortified plant-based milk, milk products, finger millet (*ragi*), tofu, beans, dark green leafy vegetables, sesame seeds, cauliflower greens, coconut dry, amaranth (*rajgira*), and horsegram (*kulthi*).
	Iron	Bajra, amaranth, red lentil (whole, dal), bengal gram, rajma, chickpea, cowpea, horse gram, dill leaves, amaranth leaves (red, green), drumstick leaves, soy granules and chunks, onion seeds, and garden cress seeds.
	Sodium	Table salt, salty processed foods, canned soup, dry fish, pickles, and poppadoms (papads).
	Phosphorus	Dairy products, meat, beans, milk and milk products, cheese, cereals, legumes, cocoa, all nuts, animal products, and egg yolk.
Minerals	**Potassium**	Broccoli, tomatoes, soybean (matured, raw), lima beans, banana, apricots, and potatoes.
	Magnesium	Nuts, seeds, and leafy greens.
	Zinc	Red meat, poultry, seafood, nuts, whole grains, legumes, soybean, eggs, black and white sesame seeds, pumpkin seeds, and pine nuts.
	Selenium	Brazil nuts, seafood, whole wheat bread, sunflower seeds, brown rice, beans, lentils, eggs, fish, chicken.
	Copper	Organ meats, nuts, seeds, avocado, white onion, seaweed.
	Iodine	Iodized salt, egg, carrot (red, orange), tomato, and seaweed.
	Sulfur	Dry lotus stem, cauliflower, green gram (dal, whole), brussels sprouts, peas (roasted, dry), horse gram, moth beans, bengal gram (whole/dal), red gram dal, black gram dal, foxtail millet, fenugreek leaves, cowpea, finger millet (ragi), buckwheat, pearl millet (Bajra), kesari dal, drumstick & its leaves, whole wheat, maize (tender, dry, flour), rice flakes, and rohu.
	Chloride	Table salt, salty processed foods, sago.

8.1.3 Micronutrient Deficiency in People with Diabetes

In people with diabetes, low levels of magnesium and iron are frequently observed.[3] A study utilizing data from the Comprehensive National Nutrition Survey (CNNS) demonstrated precise interactions between micronutrients and lipids, implicating complex multidimensional pathways involving deficiencies in folate, vitamin B_{12}, ferritin, zinc, hemoglobin, and iodine, which should be considered when devising Medical Nutrition Therapy (MNT) for people with diabetes.[4] Another study from Tunisia found that a lower vitamin D intake was associated with an increased risk of Type 2

Diabetes Mellitus (T2D). In comparison, a higher vitamin A and sodium intake were linked to poor glucose homeostasis.[5] Vitamin E, zinc, and selenium have exhibited antioxidant properties with beneficial effects in people with diabetes.[6]. Micronutrient levels during pregnancy, notably concerning Gestational Diabetes Mellitus (GDM), may impact neonatal anthropometrics, as highlighted in a study from Mexico, suggesting potential alternations in one-carbon metabolism-related micronutrients among pregnant women and their neonates.[7,8] Similarly, the role of iron and folate homeostasis during pregnancy has consistently been associated with a higher risk of developing GDM.[9,10] Micronutrient deficiencies have been noted to affect offspring, young children, and people with diabetes (Type 1).[4,11]

Role of micronutrients in complications of diabetes

Several micronutrients, including magnesium, zinc, chromium, iron, and selenium, have been implicated in glycemic control.[12] Micronutrient replacement has also demonstrated efficacy in preventing macrovascular complications of diabetes. A study by Sarmento *et al.* revealed that a high level of α-tocopherol in serum was associated with a 30% lower Coronary Artery Disease (CAD) risk. An inverse association between zinc levels and CAD was observed; levels lower than 14.1 µmol/L were linked to an increased risk for CAD (RR 1.70; 95%CI 1.21–2.38). [13]

Role of micronutrients in diabetes-related comorbidities

In a systematic review and meta-analysis by *Paula et al.*, Vitamin D and C supplementation was associated with reductions in Systolic and Diastolic Blood Pressure (SBP and DBP) among T2D individuals.[14] Furthermore, secondary data analysis in children with obesity revealed associations between iron, folate, vitamin D, and zinc levels and the likelihood of developing childhood overweight and obesity.[15] The Indian chapter of the American College of Physicians (ACP) recently released guidelines for replenishing micronutrients in the Indian population, providing valuable recommendations for clinical practice.[16,17]

8.2. CONCLUSION AND RECOMMENDATIONS

Clinical Pearls of Practice

- Micronutrients are crucial in managing diabetes by supporting various physiological functions and metabolic processes, contributing to energy metabolism, antioxidation, immunity, cellular functioning, growth, and development. Deficiency in these micronutrients can significantly impact the health and quality of life of people with diabetes.
- A healthy, balanced diet that includes all food groups is essential for people with diabetes to maintain optimal health and prevent complications associated with the condition. It should be the primary approach to addressing micronutrient deficiencies in people with diabetes.
- Focus should be placed on incorporating foods naturally rich in key micronutrients, such as leafy green vegetables for vitamin K, citrus fruits for vitamin C, nuts and seeds for vitamin E, and fortified foods for vitamins D and B_{12}.
- Attention should be given to mineral-rich foods, including dairy products for calcium, red meat and beans for iron, nuts and leafy greens for magnesium, and bananas and potatoes for potassium.
- Individuals with T2D should aim to meet their RDAs for vitamins and minerals through a well-balanced diet, supplemented as necessary to address any identified deficiencies.
- Identifying and specifically treating deficiencies in the following vitamins and minerals may improve the health outcomes of people with diabetes: vitamin D, vitamin C, iron, folate, zinc, and selenium.
- Regular monitoring of micronutrient levels, such as iron, particularly in high-risk populations, such as pregnant women with T2D, is essential to identify and address deficiencies early on.
- Clinicians and healthcare providers should provide personalized MNT counseling to people with diabetes, considering their dietary preferences, cultural backgrounds, and medical histories to optimize their overall nutritional status and health outcomes.
- Excessive doses of specific vitamins or mineral supplements, when there is no deficiency, offer no benefit and may even be harmful.

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Section 9: Oral Anti-Diabetic Agents (OADA) Associated Nutritional Considerations

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9.1 INTRODUCTION

Pharmacotherapy is integral to the comprehensive management of Type 2 Diabetes Mellitus (T2D), encompassing a range of OADAs such as insulin secretagogues, biguanides, insulin sensitizers, alpha-glucosidase inhibitors (AGIs), glucagon-like peptide-1 receptor agonists (GLP-1 RAs), Thiazolidinediones (TZDs), and sodium-glucose co-transporter-2 inhibitors (SGLT-2i).[1,2] While instrumental in glycemic control, they may also have some nutrient interactions potentially leading to deficiencies or other side effects. This necessitates proactive measures to mitigate such risks and optimize therapeutic outcomes. This section delves into the following topics: the interplay between Oral Anti-Diabetic Agents (OADAs) and nutritional interactions leading to deficiencies, considerations regarding Medical Nutrition Therapy (MNT) with specific OADAs, long-term impacts on critical health parameters, and strategies for managing side effects associated with certain medications.

9.2 OADA-ASSOCIATED NUTRITIONAL CONSIDERATIONS

The nutritional deficiencies and considerations associated with OADA are discussed below, followed by MNT recommendations, which are summarized in the clinical pearls at the end of the section.

9.2.1 Metformin and Nutritional Deficiencies

Metformin is typically the initial pharmacotherapeutic choice for managing T2D. 20–30% of individuals undergoing metformin therapy encounter gastrointestinal adverse effects, including anorexia, nausea, abdominal pain, and diarrhea.[3] Extensive evidence indicates a dose-dependent reduction in vitamin B_{12} levels among people with diabetes using metformin, prompting the American Diabetes Association (ADA 2025) guidelines to advocate annual monitoring of vitamin B_{12} levels in individuals who have been taking metformin for more than 4 years or at a risk for vitamin B_{12} deficiency for other reasons (e.g., vegan dietary pattern, previous gastric/small bowl surgery etc.).[3] Supplementation with vitamin B_{12} has demonstrated efficacy in ameliorating depleted levels in this population.[4] Alterations in other B vitamins, vitamin D, and magnesium levels may also occur depending on the dosage and duration of metformin treatment.[5]

9.2.2 Sulphonylureas and Obesity

By stimulating insulin, sulphonylureas augment anabolism and the propensity for obesity due to elevated insulin levels. They may result in severe hypoglycemia, contributing to obesity.[6,7] Meta-analyses reveal that when combined with other treatments, sulphonylureas are associated with a weight gain of 2–2.3 kg compared to placebo,[8–10] potentially augmenting the risk of Cardiovascular Diseases (CVD).[11] Advocating calorie restriction is crucial for people with diabetes on sulphonylureas to prevent further weight gain and mitigate associated health risks. Before initiating low carbohydrate eating patterns, it is essential to adjust the dose of sulphonylureas appropriately to prevent hypoglycemia.[12]

9.2.3 Alpha-glucosidase Inhibitors (AGIs)

9.2.3.1 Dietary Considerations for People on AGIs

AGIs have unpleasant gastrointestinal side effects, such as flatulence, diarrhea, abdominal pain, and bloating, which at times necessitate discontinuation of the medication.[13,14] Consuming sugar-sweetened beverages and maintaining a high carbohydrate intake can exacerbate gastrointestinal complaints due to increased fermentation.[15,16] In people with diabetes on AGIs, it is encouraged to restrict the intake of foods known to increase flatulence, such as legumes and cruciferous vegetables like cauliflower, cabbage, broccoli, and brussels sprouts.[17] AGIs are explicitly recommended for managing postprandial hyperglycemia resulting from high carbohydrate intake and to delay the digestion and absorption of dietary carbohydrates by inhibiting brush-border α-glucosidase.[18] Therefore, extremely low carbohydrate diets are discouraged during AGI treatment, as this diet may precipitate hypoglycemia. AGIs are contraindicated in individuals with Irritable Bowel Syndrome (IBS), Inflammatory Bowel Disease (IBD), partial bowel obstruction, and severe renal or hepatic disease.[19]

9.2.3.2 Hypoglycemia Management

Mild to moderate hypoglycemia in individuals taking AGI should be managed with simple carbohydrates such as glucose, glucose tablets, or fruit juice. It is not advisable to use disaccharides or polysaccharides (such as sucrose, candy, or aerated drinks) as the inhibitory effects of AGIs on α-glucosidase can delay the hydrolysis and absorption of these carbohydrates.[20,21]

9.2.4 Sodium-Glucose Transporter-2 Inhibitors (SGLT-2i)

9.2.4.1 Regulating Dietary Carbohydrates

SGLT-2i enhances the excretion of glucose in the urine, resulting in notable reductions in Blood Glucose (BG) levels in people with diabetes.[22] Additionally, they have been shown to reduce blood pressure and, by several other mechanisms affecting cardio-renal parameters, influence CVD risk favorably and promote weight loss, thus rendering them a preferred choice for individuals with diabesity, concurrent hypertension, and heightened cardiovascular disease risk.[23,24]
A low carbohydrate diet (<50 g/day) combined with SGLT-2i may induce lipolysis, potentially leading to Diabetic Ketoacidosis (DKA).[25–27] Factors contributing to DKA risk with SGLT-2i use include intercurrent illnesses, surgery, decreased carbohydrate intake, dehydration, excessive alcohol intake, or decreased insulin dosage.[28] Prolonged fasting, such as intermittent fasting or low carbohydrate availability within a low-carbohydrate diet, may further exacerbate the risk of DKA.[19] Moreover, the increased excretion of glucose raises the likelihood of secondary urinary tract infections and mycotic genital infections.[15,29] Individuals taking SGLT-2i are at a heightened risk of dehydration.[24]

9.2.4.2 Association with Sarcopenia

SGLT-2i offers several benefits, including weight loss attributed to glucose excretion and fluid depletion.[30] However, they also appear to induce changes potentially relevant to skeletal muscle dysfunction, such as increased lipolysis and ketogenesis.[31] The elevation in glucagon levels prompted by SGLT-2i stimulates gluconeogenesis, potentially promoting lipolysis in adipose tissue and proteolysis in skeletal muscle, resulting in sarcopenia.[32] Numerous clinical trials have consistently demonstrated a reduction in the Skeletal Mass Index (SMI) of 0.02–0.23 kg/m^2 or 1.9–2.9%, and Skeletal Muscle Mass (SMM) of 0.57–1.37 kg with SGLT-2i, which may pose concerns, particularly in people with diabetes, the elderly, and those with lower body mass.[33–38] However, contradictory findings exist, with some trials indicating improvements in grip strength,[39] an increase in appendicular SMM (+2.2%),[40] and others reporting no significant changes in SMI and SMM. Monitoring SMM and ensuring sufficient protein and calcium intake are crucial in individuals undergoing SGLT-2i therapy, given its dual effect of lowering BG levels and inducing weight loss.[41–43]

9.2.5 Thiazolidinediones (TZD)

9.2.5.1 Risk for Fluid Retention

Glitazones have the propensity to induce fluid retention, potentially increasing the risk of heart failure in susceptible individuals.[44] Monitoring for signs of fluid retention, including pedal edema and weight gain exceeding 3 kg, is advisable.[45]

9.2.5.2 Risk for Osteoporosis

TZDs in people with diabetes have been associated with an elevated risk of fractures and reduced bone mineral density, impacting bone turnover.[46,47] This decrease in bone mass appears to be more pronounced in women, who are inherently more susceptible to bone loss and fractures compared to men.[48,49] The ADA 2025 guidelines advise individuals with diabetes, particularly those at an increased risk of fractures, to ensure they meet the recommended daily intake of calcium (1,000–1,200 mg/day) and vitamin D. This can be achieved through dietary sources or supplements as needed to support bone health.[50]

9.2.6 Glucagon-Like-Peptide-1 Receptor Agonists (GLP-1 RAs)

9.2.6.1 Association with Sarcopenia

In people with diabetes, GLP-1 RAs have demonstrated significant weight loss over a study duration of 24 weeks, with reductions in fat mass while preserving skeletal muscle mass, suggesting a protective effect against sarcopenia.[51] However, the impact of GLP-1 RA use on skeletal muscle strength remains uncertain. Studies in mice have yielded conflicting results, with some indicating adverse effects on bone tissue material properties[52–54] and others showing positive or neutral effects on muscle mass and strength.[55,56] Given GLP-1's role in bone homeostasis, along with parathyroid hormone, consideration of its effect on bone health is crucial when selecting GLP-1 RAs as pharmacotherapy to prevent or mitigate fractures[57] and bone disorders in at-risk people with diabetes, who are predisposed to sarcopenia.[58,59]

9.2.6.2 Associated Gastrointestinal Side Effects

GLP-1 RAs are linked with gastrointestinal adverse events, such as nausea, vomiting, diarrhea, abdominal pain, constipation, and pancreatitis.[60,61] Adopting a "start low, go slow" approach when initiating GLP-1 RAs may mitigate the occurrence of these events. Reported rates of nausea, vomiting, and diarrhea associated with GLP-1 RAs exhibit variability based on cultural background and eating behaviors.[62] Notably, individuals with higher baseline emotional eating scores may exhibit reduced sensitivity to GLP-1 RA treatment, while restrained eating behavior could heighten sensitivity to its therapeutic effects.[63] (Table 9.1)

Table 9.1. Recommendations to Minimize Severity of Gastrointestinal Adverse Events with GLP-1 RAs[64]

Improve eating habits to minimize side effects associated with GLP-1 RAs	• Eat slowly and in small portions. • Avoid lying down after having a meal. • Stop eating if you feel full. • Increase meal frequency. • Avoid using a straw while drinking to prevent bloating. • Avoid eating too close to bedtime.
Adapt food composition to the individual's requirements	• Choose easy-to-digest, low-fat foods. • Ensure good hydration status and space fluid intake throughout the day. • Avoid sweets, high-fat dressings, spicy foods, and canned foods.
Additional recommendations for individuals complaining of nausea	• After 30 minutes have passed since the last GLP-1 RA dose, consume foods such as apple, mint, ginger root/ginger-based non-sugary drinks, which will help ease the symptoms of nausea. • Avoid strong smell.
Additional recommendations for individuals complaining of vomiting	• Space out fluid intake and avoid drinking fluids with meals. • Eat smaller amounts of food in more frequent meals.

Additional recommendations for individuals complaining of diarrhea	• Increase fluid intake (water, lemon, and a teaspoon of bicarbonate). • Avoid the use of isotonic drinks intended in the context of sports activities. • Avoid dairy products, coffee, laxative juices/meals, alcoholic drinks, soft drinks, very cold or very hot foods, and products with sweeteners ending in "ol" (sorbitol, mannitol, xylitol, maltitol), including candy and gum. • Avoid (or temporarily reduce intake of) foods with high fiber content, such as grain and seed products, such as grain cereals, nuts, seeds, barley, whole grain bread, vegetables such as beans, cabbage, cauliflower, garlic, lentils, mushrooms, onions, peas, skinned fruits, apricots, blackberries, cherries, mango, nectarines, pears, plums. • Consume chicken/veg broth, rice, carrots, ripe fruit without skin.
Additional recommendations for individuals complaining of constipation	• Ensure the amount of fiber in the diet is adequate. • Increase physical activity. • Ensure the meals consumed are healthy and well-balanced. • Increase water intake by consuming unsweetened beverages like lemon water, buttermilk, etc.
Additional recommendations when GLP-1 RA side effects are unusually severe or/and persistent	• In case of persistent nausea and/or vomiting, avoid water during meals instead; advise to have them between 30 and 60 min before and/or after meals.

9.3 DRUG-NUTRIENT INTERACTIONS

Drug-nutrient interactions encompass the chemical, physical, physiological, or pathophysiological connections between a drug and a nutrient. These interactions are often clinically significant and can arise from various origins. Improper identification and management of drug-nutrient interactions may lead to negative outcomes and diverse consequences.[65] Drugs can impact an individual's dietary intake, nutrient digestion, absorption, distribution, metabolism into active forms, function, catabolism, and excretion.[66,67] (Table 9.2)

Table 9.2. Key Drug-Nutrient Interactions in Commonly Prescribed Medications

Metformin	• Metformin's impact on vitamin B_{12} status is discussed in section 9.2.1.
Proton Pump Inhibitors (PPIs) and Histamine-Selective H2 Receptor Antagonists (H2RAs)	• Commonly prescribed for Gastric Esophageal Reflux Disease (GERD). • It can affect magnesium and vitamin B_{12} levels independently. • Studies suggest that concurrent use of metformin with H2RAs or PPIs may exacerbate vitamin B_{12} deficiency.[68] o Signs of diabetic neuropathy, which are often underdiagnosed and may be attributed to a vitamin B_{12} shortage linked to metformin and polypharmacy.[5]
TZD[68]	• Affects calcium and vitamin D levels. • They cause adipogenesis to rise and osteoblast development to fall in mesenchymal stem cells. • Studies indicate that people with diabetes receiving anti-diabetes medications already have insufficient calcium, vitamin D, or magnesium levels, which are three elements essential for healthy bones.[53,69]
Lipid-lowering drugs, statins	• Cramping and muscle soreness are common side effects of statins. • Healthcare providers should identify at-risk people with diabetes based on medical history, medications, and specific medical issues.[70]

CONCLUSION AND RECOMMENDATIONS

Clinical Pearls of Practice

OADA Associated Nutritional Considerations	
Metformin	• Watch for vitamin B_{12} deficiency with long-term use of metformin.
Sulfonylureas	• Increased risk for obesity. • Calorie restriction should be advised as adjuvant o To avoid low-carbohydrate diets, ketogenic diets, and prolonged fasting. o Adjustments in dosage are required before commencing low-carbohydrate diets to mitigate hypoglycemia.
AGIs	• To avoid low-carbohydrate diets, ketogenic diets, and prolonged fasting. • Moderate carbohydrate intake is advised to optimize drug efficacy and prevent hypoglycemia. o Restrict the intake of flatus (or gas) -forming foods.
SGLT2i	• To avoid low-carbohydrate diets, ketogenic diets, and prolonged fasting. • Ensure adequate fluid intake in order to mitigate the risk of urinary tract infections and dehydration. • Emphasize sufficient protein and calcium intake to preserve and prevent the loss of SMM.
TZDs	• Ensure adequate intake of calcium, vitamin D, and protein to mitigate the risk of osteoporosis. • Monitor for signs of fluid retention, such as pedal edema and weight gain of more than 3 kg. • Sodium intake is to be restricted to the recommended amounts of <2300 mg/day.
GLP-1 RAs	• Emphasize adequate intake of protein to maintain and prevent loss of skeletal muscle mass. • Recommend comprehensive dietary education to mitigate gastrointestinal side effects to optimize the superior impact of these medications on glycemic control and weight reduction.
Other Drugs in Diabetes and Associated Nutritional Considerations	
For drugs commonly prescribed to people with diabetes	• Healthcare professionals must meticulously assess, monitor, and manage drug-nutrient interactions. • Medications frequently prescribed for T2D can interact with specific nutrients, impacting absorption, metabolism, or effectiveness. o Monitoring nutrient levels and providing guidance on dietary modifications is advised to enhance treatment outcomes and mitigate adverse effects.

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Section 10: Alcohol

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10.1 INTRODUCTION

Alcohol, an integral aspect of societal and cultural norms globally, is of considerable scientific interest due to its complex interplay with human physiology and health outcomes.[1] Despite its widespread consumption, the intricate mechanisms underlying alcohol metabolism and its effects on metabolic regulation remain active areas of investigation within the scientific community. This chapter elucidates the multifaceted relationship between alcohol consumption and health, with a particular focus on its implications for glycemic control in Type 2 Diabetes Mellitus (T2D).[2]

Understanding the mechanisms of alcohol absorption is crucial for comprehending its effects on various physiological processes, including glycemic regulation. (Table 10.1) Upon ingestion, ethanol, the primary component of alcoholic beverages, is rapidly absorbed into the bloodstream via the gastrointestinal tract. This absorption occurs directly through the mucous membranes lining the stomach and intestines, allowing quick circulation entry.[3] Gastric alcohol dehydrogenase and intestinal alcohol dehydrogenase facilitate alcohol absorption in 30–120 minutes after ingestion, based on the amount of alcohol consumed and individual metabolism.[4,5,6] This is when alcohol reaches its peak blood concentration. Alcohol elimination primarily occurs through exhalation, urine, and sweat. (Figure 10.1)

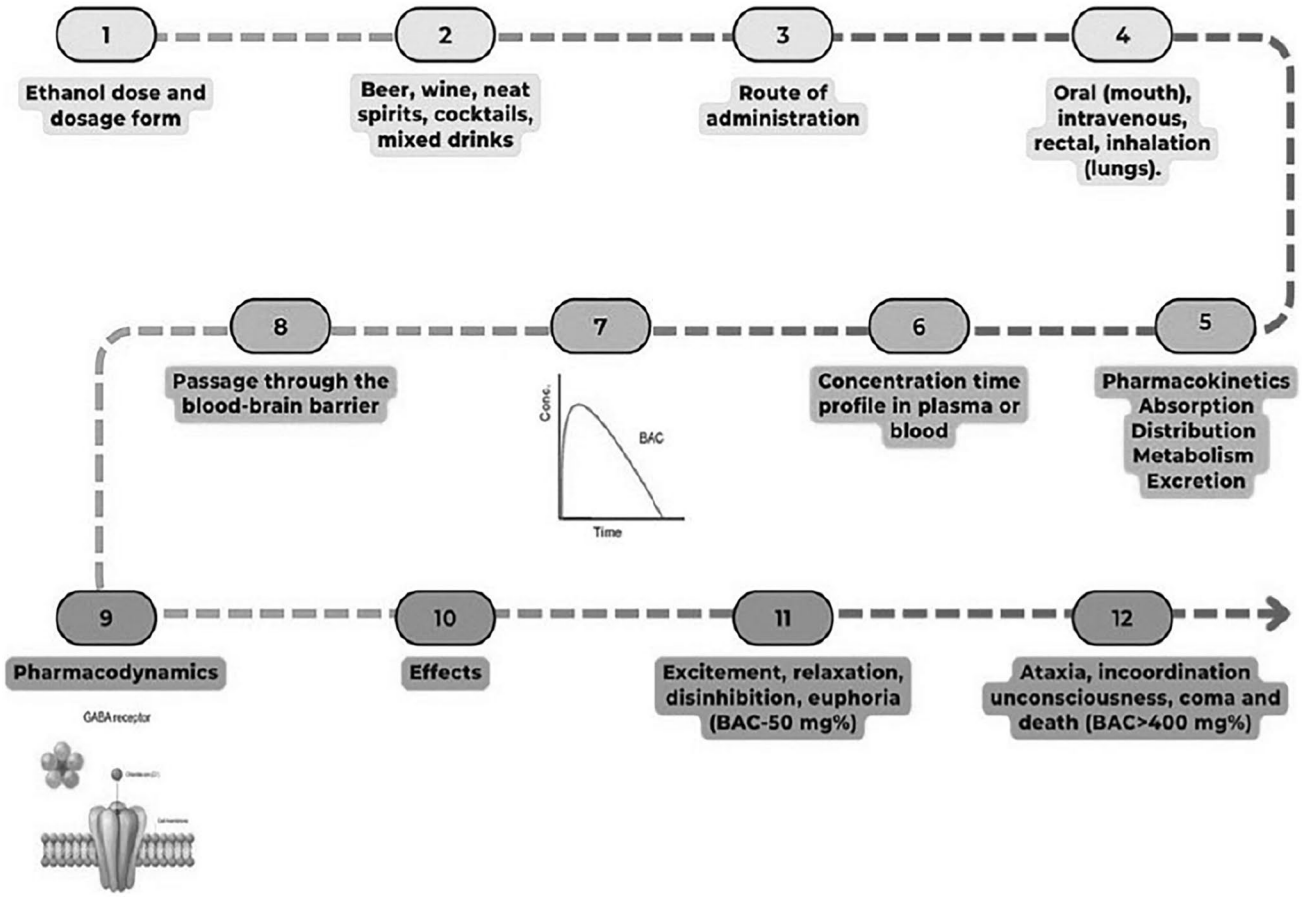

Figure 10.1 Schematic Block Diagram of Alcohol Pharmacokinetics and Pharmacodynamics (Reproduced from Jones A. Alcohol, its absorption, distribution, metabolism, and excretion in the body and pharmacokinetic calculations. Wiley Interdiscip Rev Forensic Sci. 2019 May 20;1:e1340.)

10.2 How do Blood Glucose (BG) Levels Get Impacted by Alcohol Intake (Table 10.1)

Table 10.1. Impact of Alcohol on Glycemic Regulation in People with T2D and Prediabetes

Hypoglycemia	• Acute (short-term, moderate) alcohol consumption can lead to transient hypoglycemia, in particular when taken with carbohydrate-rich meals. This effect is pronounced in individuals with diabetes or those taking medications that lower BG levels. • Excessive alcohol consumption or consumption on an empty stomach can lead to hypoglycemia, especially in individuals with impaired glycogen stores or irregular eating patterns. • Alcohol impairs hepatic gluconeogenesis, the liver's process of producing glucose from non-carbohydrate sources. This reduces glucose production and potentially causes hypoglycemia. • Delayed hypoglycemia or reactive hypoglycemia is caused by the rise in BG followed by a steady drop later, especially during sleep hours.
Hyperglycemia	• Conversely, chronic alcohol consumption without adequate nutrition may lead to disruptions in glucose metabolism and insulin sensitivity, contributing to hyperglycemia and insulin resistance. • Alcohol metabolism generates acetaldehyde and other reactive metabolites, impairing insulin signaling pathways and promoting insulin resistance. • Excessive alcohol intake can lead to weight gain and abdominal obesity, further exacerbating insulin resistance and predisposing individuals to hyperglycemia.
	• Moderate alcohol intake and certain alcoholic beverages, such as red wine (that contains polyphenols and other bioactive compounds), may improve insulin sensitivity and glucose metabolism in studies.[7] • Though, as mentioned above, light to moderate alcohol consumption in some studies has been shown to have a beneficial effect on glycemic control and been shown to decrease cardiovascular risk, these beneficial effects are offset by periods of episodic heavy drinking. This prompted the World Health Organization (WHO) to advise against any degree of alcohol consumption.
Note	• Individuals with underlying health conditions or those taking medications that affect glucose metabolism may experience more significant fluctuations in BG levels in response to alcohol consumption. Beer with higher carbohydrate content may have a more pronounced effect than spirits or dry wines.
Impact of Alcohol on Glycemic Regulation	
Fed-state	• In well-nourished people with diabetes, chronic alcohol consumption is associated with elevated BG levels. • Excessive alcohol consumption or consumption on an empty stomach can lead to hypoglycemia, especially in individuals with impaired glycogen stores or irregular eating patterns.
Fasting state[8,9]	• Research has shown that habitual drinkers with T2D exhibit higher fasting BG levels and HbA1c levels compared to non-drinking people. • Drinking alcohol without eating for extended periods can result in severe hypoglycemia.

10.3 TYPES OF ALCOHOL, SERVING SIZE, AND CALORIE CONTENTS

Understanding the types of alcoholic beverages, their serving sizes, and their nutrient contents is essential for individuals with diabetes to make informed choices regarding alcohol consumption. Different types of alcohol vary in their carbohydrate content, serving sizes, and associated nutrients, which can impact BG levels and overall glycemic control. Alcohol By Volume (ABV) and alcohol proof measure the alcohol concentrations in a drink. ABV is the number of milliliters (or 2.4 fl.oz.) in a solution, while alcohol proof (usually termed as *proof* in relation to a beverage) is a measure of the content of ethanol (alcohol) in an alcoholic beverage. Proof can also be defined as twice the alcohol percentage by volume. (Table 10.2) For example, a drink with 50% ABV will be 100% proof[10,11]

Table 10.2. Types of Alcohol, Serving Size, and Nutrient Contents [12,13,14,15]

Alcoholic beverages	Sub-types	Serving size	Calories per serving	ABV (%)
Undistilled				
Beer, Fermented cereals	Light	355 mL (12 oz)	103	2 to 4
	Regular	355 mL (12 oz)	153	4 to 6
	Higher alcohol, Craft Beers	355 mL (12 oz)	170 to 350	6 to 8
Wine, Fermented grapes	White	145 mL (5 oz)	128	10 to 12
	Red	145 mL (5 oz)	125	10 to 12
Distilled				
Gin, Fermented grains, grapes, potatoes, or other fermentable sugars	-	30 mL (1 oz)	64	35 to 55
Brandy, Fermented fruit-based wine	-	30 mL (1 oz)	65	40
Tequila, Fermented agave plant	-	30 mL (1 oz)	64	40
Whiskey, Fermented grain mash	80 proof*	45 mL (1.5 oz)	97	40 to 50
	94 proof*	45 mL (1.5 oz)	116	40 to 50
Rum, Distilled fermented sugarcane	overproof*	235 mL	185	57.5
	151 proof*	235 mL	100	75.5
Rum	with soda beverage	42 mL	97	40
Vodka, Distilled fermented tubers	80 proof*	45 mL	97	40
	94 proof*	45 mL	116	40

Mixed Drinks				
Bloody Mary	-	136 mL (4.6 oz)	120	12
Chocolate martini	-	74 mL (2.5 oz)	418	13.9
Cosmopolitan	-	81 mL (2.75 oz)	146	16.5
Mai Tai	-	145 mL (4.9 oz)	306	26.2
Margarita	-	120 mL (4.0 oz)	168	27.7
Daiquiri	-	80 mL (2.7 oz)	137	15
Mojito	-	177 mL (6 oz)	143	13
Pina Colada	-	200 mL (6.8 oz)	526	13
Rum and Coke	-	235 mL (8.0 oz)	185	12
Rum and Diet Coke	-	235 mL (8.0 oz)	100	9.5
Tequila Sunrise	-	200 mL (6.8 oz)	232	13.3
Vodka and Tonic	-	207 mL (7.0 oz)	189	37.5

It is best to recommend Alcohol abstinence in people with T2D. When alcohol is consumed with lifestyle intervention, the choice should be those with a low sugar or carbohydrate content—for example, light beers, red and white wines, distilled spirits, and low-carbohydrate cocktails. Avoid sugary beverages. Traditional cocktails, dessert wines, and cream liqueurs have high sugar content.

10.4 ALCOHOL MECHANISM IN DIABETES MANAGEMENT

Impact of alcohol consumption on BG levels

Alcohol consumption can impact BG levels even in normoglycemic individuals. However, the effects may vary depending on several factors, including the amount of alcohol consumed, the presence or absence of food intake, individual metabolism, and other lifestyle factors.

Impact of acute alcohol consumption: In the short term, moderate alcohol consumption may lead to a transient decrease in BG levels. This effect is primarily observed when alcohol is consumed with meals, especially carbohydrate-rich meals. Alcohol can stimulate insulin secretion, which helps lower BG levels by facilitating glucose uptake into cells. However, further long-term studies are required to confirm these effects. Moreover, excessive alcohol consumption or consumption on an empty stomach can lead to hypoglycemia (low BG) in some individuals, mainly if they are not eating regular meals or have impaired glycogen stores due to fasting. The glycemic control may also be worsened in such situations.

Impact of chronic alcohol consumption: Long-term alcohol consumption can have varying effects on BG levels. Chronic heavy alcohol consumption, especially without adequate nutrition, may lead to disruptions in glucose metabolism and insulin sensitivity. This can result in fluctuations in BG levels, including hyperglycemia (high BG) and hypoglycemia, depending on factors such as alcohol intake patterns and individual metabolic factors. Additionally, chronic alcohol consumption may contribute to the development of insulin resistance. In this condition, cells become less responsive to insulin, leading to impaired glucose uptake and elevated BG levels.[8,16]

Other factors: The impact of alcohol on BG levels can also be influenced by other lifestyle factors, such as diet, physical activity, and overall health status. For example, individuals with underlying health conditions or those taking medications that affect glucose metabolism may experience more significant fluctuations in BG levels in response to alcohol consumption. The type of alcoholic beverage consumed may also play a role, as beverages with higher carbohydrate content, such as sweetened cocktails or certain types of liqueurs and wines, may have a more pronounced effect on BG levels compared to spirits or dry wines. Research has shown that habitual drinkers with T2D exhibit higher Fasting Blood Glucose (FBG) levels and HbA1c levels compared to those who do not consume alcohol.[8,17] Conversely, alcohol consumption in the fasting state can induce significant reductions in BG levels, leading to hypoglycemia. During fasting, the body's mechanisms for maintaining BG levels, such

as glycogenolysis and gluconeogenesis, are impaired by alcohol metabolism in the liver. This can result in severe hypoglycemia, especially in individuals who have been drinking alcohol without eating for extended periods. Alcohol-related hypoglycemia can be exacerbated by factors such as hypoglycemia unawareness and delayed glucose recovery, particularly in T2D. Hypoglycemia unawareness, combined with impaired counter-regulatory responses, increases the risk of severe hypoglycemia and its associated neurological complications. (Table 10.3)

Table 10.3. Alcohol Mechanism in T2D Management When Other Comorbidities Also Exist

Prediabetes	• Research suggests a complex relationship between alcohol consumption and the risk of prediabetes and T2D. Moderate alcohol intake is associated with a reduced risk of prediabetes in some populations, particularly women and non-Asian groups. However, heavy alcohol consumption may increase the risk of diabetes. Guidelines recommend tailoring physical activity and exercise recommendations for individuals with prediabetes, considering their specific needs and health status. Primary care interventions focusing on behavioral counseling may help reduce risky alcohol consumption. However, more research is needed to fully understand the mechanisms behind these associations. • Consider individual factors such as overall health status, medication use, and alcohol tolerance when advising individuals with prediabetes on alcohol consumption. • For some individuals, particularly those with comorbid conditions or contraindications to alcohol use, abstinence or limited alcohol intake may be recommended.
Type 2 Diabetes (T2D)	• Alcohol consumption can have both acute and chronic effects on BG levels in individuals with diabetes. • However, excessive alcohol consumption or consumption on an empty stomach can lead to hypoglycemia, especially in individuals with impaired glycogen stores or irregular eating patterns. • Chronic alcohol consumption can also disrupt glucose metabolism and insulin sensitivity, leading to fluctuations in BG levels over time. • Heavy alcohol intake may contribute to insulin resistance, exacerbating hyperglycemia and increasing the risk of diabetes complications. Evidence suggests that moderate alcohol consumption, defined as up to one drink per day for women and up to two drinks per day for men, may have beneficial effects on diabetes management.[18] • Alcohol, if at all taken, should be taken in moderation and, along with the advised lifestyle modifications being followed religiously and with regular monitoring of glycemic status and other alcohol related health parameters.
Hypertension (HTN)	• Alcohol consumption has a complex relationship with blood pressure regulation. • While moderate alcohol intake may acutely increase blood pressure, chronic alcohol consumption is associated with both acute and chronic effects on blood pressure levels.
Hyperuricemia	• Southeast Asians, particularly those with diabetes, may have underlying insulin resistance, where their cells are less responsive to insulin. • Insulin resistance can disrupt the average regulation of glucose and lipid metabolism, leading to dyslipidemia and hyperglycemia.[19,20] • These metabolic disturbances can further exacerbate the effects of alcohol consumption on uric acid metabolism. • Southeast Asians may also have genetic predispositions that influence their susceptibility to hyperuricemia and gout, a condition characterized by elevated uric acid levels and deposition of urate crystals in the joints. • Genetic variations in enzymes involved in purine metabolism, such as xanthine oxidase, can affect uric acid production and contribute to differences in individual responses to alcohol consumption.
High triglycerides levels	• Moderate alcohol consumption is associated with adverse lipid profiles, including higher triglyceride levels, particularly in women with T2D. • Alcohol consumption, particularly chronic and excessive intake, can exacerbate insulin resistance in individuals with diabetes. Alcohol metabolism generates excess Nicotinamide-Adenine Dinucleotide (NADH), which inhibits gluconeogenesis and promotes lipid synthesis in the liver, contributing to hepatic insulin resistance.[21,22,23,24]

Obesity	• Chronic heavy alcohol consumption increases the risk of overweight/obesity, reflected in higher Body Mass Index (BMI) and waist circumference. • Frequent binge drinking exacerbates obesity by inducing systemic insulin resistance and promoting high-fat food intake. • Increased energy intake from alcohol metabolism and pancreatic β-cell dysfunction contribute to obesity in heavy drinkers with decreased insulin-secretory ability and disrupted glucose homeostasis.[25,26]
Alcoholic Liver Disease[26]	• Heavy and binge drinking exacerbate liver injury in individuals with T2D and alcoholic liver disease. • Overweight/obesity increases the risk of fatty liver disease synergistically with high alcohol intake. • Moderate alcohol consumption may reduce the risk of fatty liver disease but may increase the risk of advanced liver fibrosis in overweight/obese individuals.[27] • Importantly, a synergistic effect between moderate alcohol consumption and T2D was observed, significantly increasing the risk of advanced fibrosis. • Also, some research indicates that moderate alcohol consumption may increase the risk of hepatocellular carcinoma in Nonalcoholic Fatty Liver Disease (NAFLD) patients with advanced fibrosis. • Patients with poor metabolic health and Metabolic Dysfunction-Associated Steatotic Liver Disease (MASLD) have no safe alcohol consumption limit.[28] • Adipose tissue inflammation and CYP2E1-mediated oxidative stress contribute to liver inflammation and fibrosis progression. • Chronic heavy drinking and obesity promote the secretion of inflammatory factors, worsening liver health in T2D patients with alcoholic liver disease. (Figure 10.2)

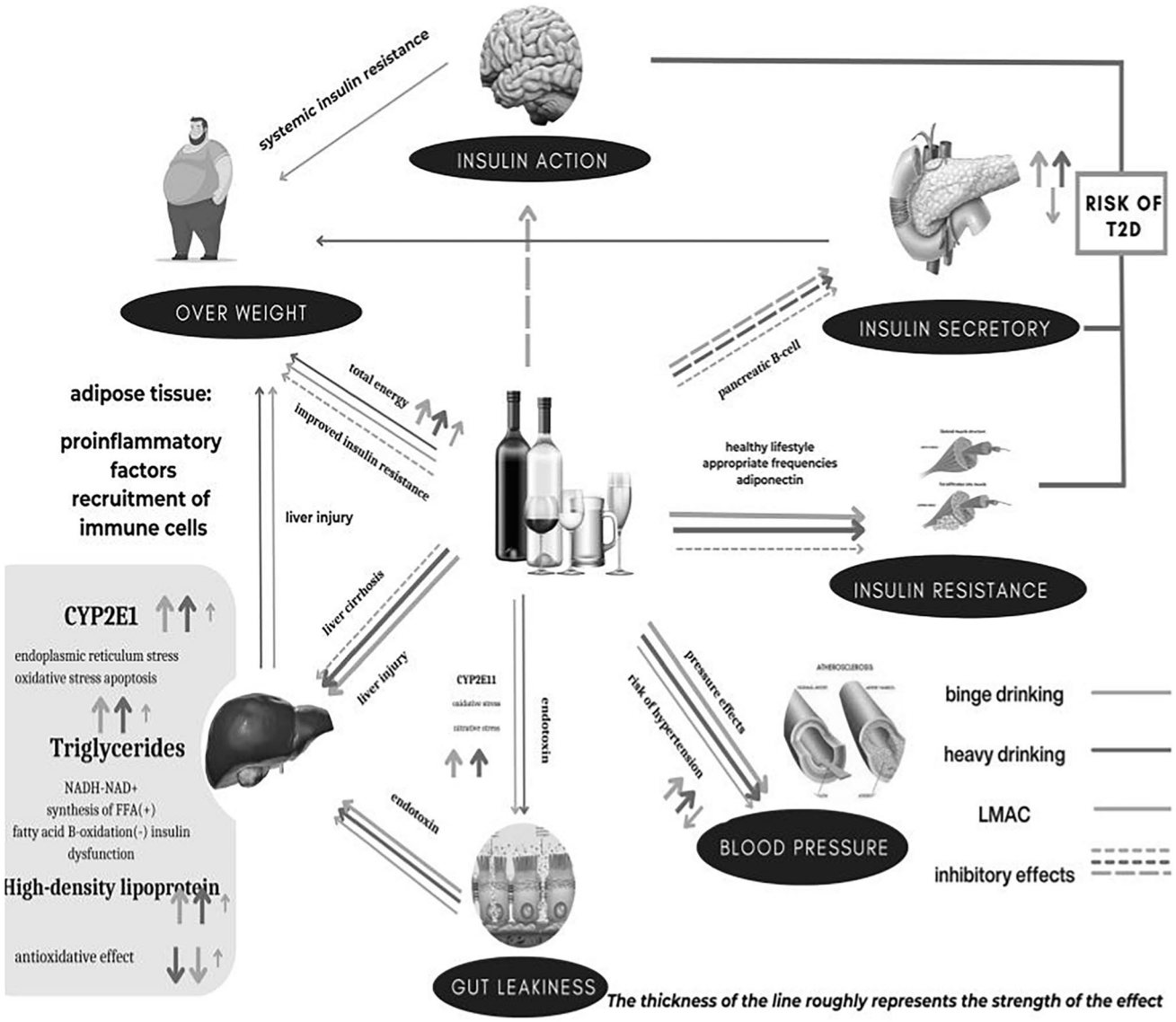

Figure 10.2 Relationship between alcohol consumption and metabolic dysfunctions Sun FR, Wang BY. Alcohol and Metabolic-associated Fatty Liver Disease. J Clin Transl Hepatol. 2021 Oct 28;9(5):719–30. (Free permission is available to use the figure)

In summary, evidence-based research suggests that moderate alcohol consumption may have both positive[29] and negative effects on individuals with diabetes, HTN, and prediabetes. Moderate alcohol intake has been associated with improved insulin sensitivity, metabolic health markers, and reductions in cardiovascular risk, especially if lifestyle modifications are regularly followed. However, excessive or chronic alcohol consumption can exacerbate hyperglycemia, hypertension, and other diabetes-related complications. Considering the risk of progression from moderate alcohol intake to episodic or regular higher intake of alcohol in many individuals with T2D, we endorse the stand of the WHO and do not advocate initiation or continuation of alcohol intake.

10.5 ALCOHOL-ASSOCIATED HYPOGLYCEMIA RISK AND ITS MANAGEMENT

Alcohol takes time to impact the body and liver. The quantity of alcohol ingested along with the quality of food taken may impact the risk of hypoglycemia. Concurrent diabetic medications compound the risk and may exacerbate the occurrence of nocturnal hypoglycemia. When people with T2D consume alcohol, the liver may then neglect BG level maintenance in favor of metabolizing alcohol. The person may then experience hypoglycemia. People with diabetes need to pay particular attention to their alcohol consumption because of its effects on BG levels. Additionally, if an individual drinks on an empty stomach or when their BG levels are already low, it increases the likelihood of hypoglycemia. The symptoms of hypoglycemia include drowsiness, slurred speech, confusion, trembling, fast heartbeat, light-headedness or dizziness, headaches, and seizures. Many of these symptoms are also signs of being drunk, making it a challenging task to discriminate between hypoglycemic or intoxicated. Severe hypoglycemia occurs when someone has very low BG levels. Without treatment, it can lead to loss of consciousness and coma. Therefore, it is important to seek immediate medical attention to confirm this diagnosis and receive appropriate treatment.
In addition to an increased likelihood of hypoglycemia, alcohol also raises the risk of diabetes complications such as ocular pathologies, including vision loss, heart disease, and strokes. Alcoholic beverages provide the body with empty calories, which means no nutrition. Therefore, if a person consumes more calories than they require, T2D contributes to weight gain. Optimum weight with lifestyle modifications, including recommended exercise, helps lower the risk of T2D and other health complications.

10.6 EATING SENSIBLY WITH THE DRINK: FOODS THAT CAN ACCOMPANY ALCOHOL

In the context of alcohol consumption, it is well-established that eating alongside drinking is imperative. Alcohol has been shown to stimulate appetite, leading to cravings for salty and high-fiber foods. Ignoring hunger while consuming alcohol can predispose individuals to conditions such as pancreatitis and liver-related diseases.[30,31,32,33] While the inclination during alcohol consumption may be towards salty snacks like pizza, french fries, fried and spicy nuts, and cheese, opting for healthier food choices is prudent. Salty foods can exacerbate dehydration, a common effect of alcohol consumption.[32] Therefore, it is advisable to avoid such foods to mitigate dehydration. Fiber-rich food can prolong digestion, so it should be consumed judiciously. Large portions of food before bedtime, with or after alcohol consumption, disturb sleep and contribute to GI discomfort. (Table 10.4)

Table 10.4. Nutrient-Rich Foods Preferred[33,34,35,36,37]

Food items	Preferred	Should be avoided
Beans, legumes	Chana, sprouts as chaat hummus	Deep-fried dhal.
Caffeine	-	Avoid caffeine before or after drinking alcohol.
Chocolates	-	Avoid chocolates.
Oats	Cooked oats	Salty and fried oat nuggets.
Rice	Plain rice can be paired with a light vegetable dish	Salty, spicy, oily rice.
Milk	Low-fat paneer as a starter Cheese cube (in limited quantity 1-2) Hung curd.	Fried and Spicy paneer.
Nuts	Unsalted nuts, makhana	Salted and fried nuts.
Egg	Boiled, poached, scrambled	Fried,
Chicken	Low-fat dressing, boiled, shredded chicken. Chicken as a starter with less spices and oil	Fried chicken, marinated chicken with spices.
Salad	Sliced cucumber, carrot, capsicum, or any other salad vegetables	Mayo/cream-based dressings in salad.
Soup	Clear soup with a broth-like texture- Chicken or Vegetable	Creamy soup- chicken or mushroom.
Other Habits to Follow Before Alcohol Consumption		
• Eat a balanced meal with protein and avoid venturing out on an empty stomach.		

10.7 DRINKING PATTERN OF ALCOHOL AND ITS EFFECTS

The number of drinks a person consumes and the rate at which he or she consumes them influences how much alcohol enters the brain and how impaired that person becomes.[38] (Table 10.5, 10.6, 10.7, 10.8)

Table 10.5. Standard Drink Equivalents

	Millilitres	Ounce	Grams
Standard drink	18	0.6 (Pure Alcohol)	14
Equivalent to a regular beer	355	12 (5% of alcohol)	NA
Equivalent to Wine	148	5 (12% of alcohol)	NA

Table 10.6. Understanding Alcohol Drinking Pattern

Definition		
Low risk drinking	No more than 3 drinks per day and no more than 7 drinks per week.[39]	Men- No more than 4 drinks on any single day and no more than 14 drinks per week.
Binge drinking	The pattern of drinking that brings blood alcohol concentration to 0.08 gm per decilitre (0.08%) or higher.[39]	In a two-hour time frame: • Men-5 drinks. • Women-4 drinks.
Extreme binge drinking	Two or more times the gender-specific drinking thresholds.[40]	In a two-hour time frame: • Men- 10 drinks. • Women- 8 drinks.
Heavy drinking	Binge drinking on 5 or more days in the past 30 days.[41]	

Table 10.7. Relative Risk for T2D

Among	Most Protective	Deleterious
Men	• 2 drinks /day[42]	• >3 drinks/day
Women	• 1 drink /day	• ~2 drinks/day

Note: No level of alcohol is safe for health.[43]

Table 10.8. Who Should Avoid Alcohol Altogether?

- Individuals under the minimum legal drinking age
  - 21 in Delhi.
  - 18 years in the states such as Andaman and Nicobar Islands, Goa, Himachal Pradesh, Karnataka, Puducherry, Rajasthan, and Sikkim.
- Women who are pregnant or trying to become pregnant.
- People who have a medical condition that alcohol can aggravate.
- Individuals taking medications that interact with alcohol.
- People driving vehicles or operating machinery (or who plan to do so shortly after drinking).

10.8 NUTRIENT DEPLETION WITH ALCOHOL INTAKE

Chronic alcohol consumption leads to malnutrition by damaging vital organs and impairing their function, resulting in nutrient depletion. Chronic alcoholism causes toxic effects on the gastrointestinal system, impairing nutrient digestion and absorption. Chronic alcoholism leads to severe depletion of essential micronutrients, including vitamins A, B-complex (such as thiamine, niacin, and folate), C, D, and E, as well as minerals like zinc, magnesium, selenium, and chromium, exacerbating liver injuries. Alcohol interferes with the hepatic storage of vitamin A, causing hepatocyte depletion and accumulation in vital organs. Deficiencies in B-complex vitamins contribute to alcohol-related liver damage and cognitive decline. Vitamin C and E deficiencies increase oxidative stress and worsen liver injuries, while vitamin D deficiency exacerbates alcoholic liver injury and steatosis. Zinc deficiency enhances oxidative stress and liver toxicity, with supplementation showing potential benefits in reducing dysfunction. Magnesium deficiency exacerbates liver fibrosis and oxidative stress, with supplementation suggested for alcoholic liver injuries. Selenium deficiency reduces antioxidant activity, contributing to increased lipid and protein oxidation, and chromium deficiency is linked to insulin resistance and pancreatic dysfunction in chronic alcoholism. (Table 10.9)

Table 10.9. Nutrient Depletion by Alcohol Intake

Nutrient	Proposed Mechanism	Deficiency Symptoms
Calcium[44,45,46]	• Disrupted mitochondrial Ca^{2+} and Energy metabolism. • Altered bone mineralization. • Impaired Ca^{2+} signalling leads to altered neuronal homeostasis and gene transcription. • Neural circuit dysfunction due to defective Ca^{2+} signalling.	• Osteoporosis, muscle cramps, dental problems.
Chromium[47]	• Oxidative stress. • Insulin resistance. • Pancreatic dysfunction.	• Impaired BG levels, confusion, weight loss.
Iron[48,49]	• Iron overload causes damage to hematopoietic stem cells. • Induces Liver Fibrosis. • Mitochondrial dysfunction. • Oxidative stress.	• Anemia, fatigue, pale skin.
Magnesium[50]	• Oxidative stress. • Increased serum transaminase levels. • Causes fibrosis of hepatocytes.	• Muscle weakness, tremors, irregular heartbeat.
Potassium[51,52]	• Hypokalemia. • Disrupted acid-base balance. • Ventricular Fibrillation. • Cardiac Arrhythmia.	• Muscle weakness, muscle spasms and cramps, irregular heartbeat, fatigue.
Selenium[53,54,55]	• Oxidative stress. • Steatohepatitis. • Inflammation. • Increased lipid and protein peroxidation.	• Fatigue, Myalgia, muscle weakness, Impaired immunity.
Zinc[56,57]	• Hepatic steatosis. • Hepatic fibrosis. • Oxidative stress. • Inflammation. • Higher serum transaminase levels.	• Impaired immune function, hair loss, delayed wound healing.

Vitamin A	• Oxidative stress. • Depletion in hepatocytes of vitamin. • Increased accumulation in vital organs.	• Vitamin A depletion in hepatocytes and accumulation in vital organs.
B_1, Thiamine[58,59]	• Accumulation of neurotoxic oxygen-reactive species. • Impaired functioning of the blood-brain barrier. • Altered energy metabolism.	• Beriberi, Wernicke encephalopathy; Wernicke-Korsakoff syndrome, alcohol-induced dementia.
B_9, Folate[60,61]	• Hypomethylation (impaired DNA methylation). • Altered gene expression. • Activation of CYP 2E1. • Increased endoplasmic reticulum stress.	• Megaloblastic anemia, neural tube defects (in pregnant women).
B_{12}, Cobalamin[62]	• Acts as a cofactor along with folate. • Causes impaired DNA methylation. • Altered gene expression.	• Anemia, fatigue, and neurological symptoms.
Vitamin C[62]	• Oxidative stress. • Inflammation.	• Weakness, fatigue, slow wound healing, frequent infections.
Vitamin D[63,64,65]	• Oxidative stress. • Dysfunction of the gut barrier. • Causes toxicity to hepatocytes. • Aggravates the severity of liver diseases. • Increased serum transaminase levels.	• Weakness, bone pain, and increased risk of fractures.
Vitamin E[62]	• Oxidative stress. • Injury to hepatocytes.	• Muscle weakness, impaired immune function, vision problems.

10.9 EXCESSIVE (CHRONIC) ALCOHOL CONSUMPTION AND HEALTH RISK

Chronic alcohol consumption harms multiple organ systems through cell injury and toxicity, driven by mechanisms like oxidative stress and impaired gene expression. This leads to nutrient depletion, malnutrition, and increased vulnerability to infections, exacerbating tissue damage in vital organs and resulting in health risks. (Table 10.10)

Table 10.10. Excessive (Chronic) Alcohol consumption and health risk in T2D patients

Glycemic Control Impairment	Alcohol can disrupt BG levels, leading to hyperglycemia or hypoglycemia.
Liver Dysfunction	Chronic alcohol abuse can lead to fatty liver, alcoholic hepatitis, and cirrhosis, which can worsen metabolic issues in people with diabetes and lead to liver failure.
Cardiovascular Complications	Excessive alcohol intake is associated with an increased risk of hypertension, heart disease, and stroke, which can compound the existing risks for people with diabetes.
Neuropathy	Chronic alcohol consumption can exacerbate diabetic neuropathy, causing nerve damage and sensory impairment, leading to pain, tingling, and numbness in the extremities.
Nutrient Depletion	Alcohol interferes with the absorption and utilization of essential nutrients, including B vitamins, magnesium, and zinc, exacerbating existing deficiencies common in people with diabetes.
Acute pancreatitis	Alcoholic acute pancreatitis results in inflammation, impaired pancreatic enzymes, and hormonal secretion. Further, AP leads to frequent hospitalization, chronic pancreatitis, dyslipidemia, necrotizing pancreas, and high mortality, and may also result in T3cDM or secondary pancreatic diabetes.
Chronic pancreatitis	Chronic pancreatitis (CP) is a consequence of recurrent pancreatitis attacks. Importantly, impaired exocrine and endocrine functioning of the pancreas increases the risk of cardiovascular disease. Additionally, reduced pancreatic enzyme secretion leads to malabsorption and, finally, malnutrition.
Cognitive Impairment	Excessive alcohol consumption can impair cognitive function and lead to conditions such as dementia, which can worsen cognitive decline in people with diabetes.[66,67]
Increased Risk of Infections	Chronic alcohol abuse weakens the immune system, making individuals more susceptible to infections, which can be particularly concerning for people with diabetes who are already at higher risk for infections and complications.[68,69,70]

10.10 CONCLUSION AND RECOMMENDATIONS

Alcohol consumption significantly impacts global health, contributing to a substantial burden of disease and mortality. The Global Burden of Disease study estimates that alcohol use accounted for 85.0 million disability-adjusted life years (DALYs) in 2015. Alcohol's metabolic effects are complex, influencing obesity, lipid and glucose metabolism, and blood pressure.[71]

Alcohol absorption occurs rapidly in the gastrointestinal tract, influencing glycemic regulation through various mechanisms. While acute alcohol consumption may lead to hypoglycemia, chronic intake can contribute to hyperglycemia and insulin resistance. Understanding the interplay between alcohol absorption and glycemic regulation is essential for optimizing health outcomes in individuals who consume alcohol, particularly those with diabetes or at risk of metabolic disorders.[72,73]

Clinical Pearls of Practice

- As per a January 2023 announcement from the WHO, there is no safe threshold for alcohol consumption concerning human health.
- As per the global burden of disease study, the advantages of *modest alcohol intake, particularly of red wine, may lower the risk of cardiovascular disease, diabetes, and mortality, but this* may be confined to individuals aged 40 and above, as no such protective effect was observed in younger age groups. However, data from the US shows an increase in heavy drinking episodes from 2000 to 2010, particularly among men, which suggests that many individuals with T2D taking alcohol in moderation are likely to progress to episodic or regular heavy alcohol intake, which is deleterious to their health.
- ADA guidelines also suggest alcohol abstainers not to begin use of alcohol to improve health outcomes.
- Episodic / Regular alcohol consumption exceeding recommended limits, and without observing lifestyle modifications, increases the risk of various health problems, including liver diseases, cardiovascular issues, mental health issues, and accidents.
- To mitigate alcohol-related hypoglycemia, people with diabetes are advised to consume alcohol with or shortly after meals.
- For individuals with comorbid conditions or contraindications to alcohol use, abstinence is recommended.
- In circumstances where you choose to consume alcohol in moderation, choose alcohol types with low sugar or carb content, such as light beers, red and white wines, distilled spirits, and low-carb cocktails, while avoiding high-sugar options like traditional cocktails and dessert wines.
- In circumstances where you choose to consume alcohol in moderation, pre-alcohol consumption habits include eating a balanced meal with protein and avoiding alcohol intake on an empty stomach.
- If BG levels fall below 70 mg/dL, adhere to the "15–15 rule."
  - Consume 15 g of carbohydrates and recheck BG levels after 15 minutes.
  - Repeat these steps until BG levels rise above 70 mg/dL.
- Once BG levels are stabilized, consume a snack or meal to prevent further drops.
- Patients with diabetes who cannot safely manage low BG levels with the 15–15 rule may require glucagon injections.
- Excessive alcohol consumption in people with diabetes significantly increases the risk of complications and worsens overall health outcomes. Therefore, individuals must limit alcohol intake and seek support for alcohol cessation if needed to optimize their health and well-being.

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Section 11: Nutritive and Non-Nutritive Sweeteners

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11.1 INTRODUCTION

Sweeteners or sugar substitutes are defined as food additives that give a sweet taste to foods and beverages, such as soft drinks, desserts, dairy products, sweets, chewing gum, and low-calorie and weight-control products.[1] (Table 11.1.)

Table 11.1. Nutritive Sweeteners

Name or Scientific Name	Source or Raw Ingredient	Composition	Calories per gram (kcal)	Glycaemic Index (GI)	Sweetness Index (sucrose = 1)	Side effects
I. Regular Sweeteners						
Sucrose or table sugar	Sugarcane	Disaccharide—glucose and fructose	4	80[2]	1[2]	Positive energy balance or weight gain, dental caries.[3]
Coconut sugar	Phloem sap from coconut palm tree[4]	Glucose, fructose, Sucrose[5]	4	35[2]	0.9[2]	Positive energy balance or weight gain, dental caries.[3]
Palm jaggery	Sap from coconut palm tree	Sucrose and reducing sugars	4	35[2]	0.9[2]	Positive energy balance or weight gain, dental caries.[3]
Jaggery	Sugarcane	Sucrose, reducing sugars (glucose and fructose)[6]	4	84[2]	0.9[2]	Positive energy balance or weight gain, dental caries.[3]
Honey	Floral nectar	Fructose, glucose[7]	4	50[8]	1[2]	Positive energy balance or weight gain, dental caries.[3]
II. Commercial Sweeteners						
Fructose	Fruit	Fructose	4	25[9]	1.2–1.8[2]	Positive energy balance or weight gain. Excess consumption is a risk factor for elevated Triglycerides and Uric acid levels[10] dental caries.[3]
Glucose	Root starch	Glucose	4	100[11]	0.7[2]	Positive energy balance or weight gain, dental caries.[3]
High fructose corn syrup	Starch of corn	Glucose and fructose	2.8	87[12]	0.9–1.1[12]	Positive energy balance or weight gain. Excess consumption is a risk factor for elevated triglycerides and uric acid levels, MASLD[10] dental caries.[3]

Corn syrup	Starch of corn	Glucose, maltose, and higher oligosaccharides	2.8	75[13]	0.3[2]	Positive energy balance/weigh t gain, dental caries.[3]
Maple syrup	The sap of maple tree	Sucrose, along with lesser amounts of glucose and fructose and complex carbohydrates[14]	2.6	54[2]	0.6[2]	Positive energy balance/weigh t gain, dental caries.[3]
III. Sugar Alcohols						
Sorbitol	Potato starch	Hydrogenation of glucose	2.6	4[15,16]	0.6[15]	Osmotic diarrhea & bloating.[17]
Mannitol	Flowering ash	Hydrogenation of fructose	1.6	2[15]	0.6[15,16]	Osmotic diarrhea & bloating.[17]
Xylitol	Birch bark	Pentitol	2.4	12[15]	1[18]	Osmotic diarrhea & bloating.[17]
Isomalt	The enzyme-catalyzed reaction of sucrose[19]	Mixture of the two disaccharide alcohols	2	2[19]	0.5[20,21]	Osmotic diarrhea and flatulence.[17]
Maltitol	Starch of cereals-corn/wheat/potato[19]	Disaccharide polyol[19]	2	0[22]	0.9[23]	Osmotic diarrhea and flatulence.[17]
Polyglycitol syrup	Catalytic hydrogenation of a mixture consisting of glucose, maltose, and higher glucose polymers	Maltitol, sorbitol, and higher molecular weight polyols[24,25]	3	39[26]	0.4–0.9[27,28,29,30,31]	Gastric symptoms such as diarrhea, bloating, and flatulence.[17]
Lactitol	Catalytic hydrogenation of lactose	Disaccharide sugar alcohol produced from lactose	2[19]	6[19]	0.3–0.4[19]	Laxative effects (if > 20–50 g/day)[19]
IV. Rare Ones						
Agave syrup (nectar)	Agave plant[32]	Xylose, fructose, glucose, sucrose, maltose[32]	3	10–27[32,33]	1.4[33]	Dysbiosis, MASLD, hypertriglycer idemia[33]

11.2 NON-NUTRITIVE SWEETENERS

Table 11.2 mentions the sweeteners available in the retail market for direct consumer use. Notably, there are products available as a combination of more than one nutritive and/or Non-Nutritive Sweetener (NNS). This is mainly done to reduce the calories that otherwise come from using sugar and to imitate the sensory profile of sugar, such as acceptable mouthfeel and reduced aftertaste. (Table 11.2, 11.3, 11.4)

Table 11.2. Non-Nutritive Sweeteners

Names	Source	Heat and cold stability/ cooking suitability	After taste	Relative sweetness compared to sucrose*	kcal/g	Metabolism and Excretion	Acceptable Daily Intake (ADI) (mg/kg/day)*	Contraindications	Side Effects
Aspartame	Synthetic sweetener composed of aspartic acid and phenylalanine[34]	Loses sweetness and denatures with high heat.[18]	Prolonged sweetness[35]	160–220	4[35]	Broken down into aspartic acid, phenylalanine, and methanol upon digestion. All compounds are metabolized normally, except in individuals with PKU.[34,35]	50	Phenylketonuria (PKU)[34,35,36] Hyperphenylalaninemia	Multiple sclerosis, systemic lupus, brain tumors, and methanol toxicity can also be related to cancer, lymphomas, and leukemia.
Acesulfame-K	A combination of an organic acid and potassium[34,35]	Highly heat stable for cooking and baking. [18]	Very slightly bitter. Metallic aftertaste[34]	150–200	0[35]	Not metabolized and excreted unchanged by kidneys.[34,35]	15	People with renal disease should use it with caution due to the potassium part of it.	Not reported
Saccharin	Synthetic sweetener in forms of sodium or calcium saccharin[34]	Highly heat stable for cooking and baking.[34,35]	Bitter metallic	300–600	0[35]	Not metabolized and excreted unchanged by kidneys.[34,35]	5	Pregnant individuals are advised against saccharin consumption due to its ability to traverse the placental barrier.	Not reported
Sucralose	A sugar derivative by replacing 3 hydroxyl groups with 3 chlorine atoms on the sugar molecule[34]	Highly heat stable for cooking and baking.[34,35]	Not unpleasant	400–800	0[29]	It is not metabolized and excreted by the kidneys or in feces.	5	Not reported	Not reported

Neotame	Dipeptide methyl ester derived from aspartic acids and phenylalanine.[34]	Highly heat stable for cooking and baking.[34]	Clean sweet, sucrose-like taste, not unpleasent[34]	7000–13000	0	Partially absorbed and excreted in feces and urine.[34]	18 mg/NA	Exhibits structural resemblance to aspartame. Nevertheless, the likelihood of phenylalanine release is restricted; hence, no cautionary notification is warranted.[35]	Not reported
Advantame	Synthetic sweetener produced in a 3-step process that ultimately combines aspartame and HMPA[34]	Heat Stable for cooking and baking. Ultra-high potency.[34]	Clean sweet sucrose like taste[34]	20000[34]	0[34]		1970 mg/day	Not reported	Not reported
Stevioside	Derived from the leaves of Stevia rebaudiana plant	Heat stable. Licorice aftertaste. Enhances sweet and savory flavors. Lacks bulking property.[34]	Bitter and unpleasant[34]	200–300	0	Not absorbed in small intestine. Degraded into steviol by bacteria in the colon, where it is absorbed. Excreted in the feces and urine.[34]	0–4 (as steviol)	Not reported	Not reported
Cyclamate	Artificial [D]	Sodium cyclamate is very stable in solid form and in beverages at a pH in the range of 2–10.	Prolonged sweetness. At high concentration, a distinct sweetsour lingering.	30–40			1970 mg/day	Not reported	No sufficient data reported for the carcinogenicity in humans.
Erythritol	A tetrose alcohol derived from the cultivation of yeast-like fungi on glucose[32,37]	Very water-soluble. Non-hygroscopic.[37]		0.6–0.8[37]	0.2[37]	90% is absorbed. Rapidly excreted in the urine and feces within 24 hours.[38]	Not specified[37]	Not reported	Not reported[39]
Monk fruit	Siraitia grosvenorii plant[40]	Heat Stable[40]	Off taste[40]	300[40]		Mogroside V is mainly excreted in the urine, whereas its metabolites are mainly excreted in feces.[41]		Not reported	Not reported

Table 11.3. Lifecycle and Sweeteners

Children and adolescents	• Obesity: The World Health Organization (WHO) advises against using NNSs for weight control in children or for reducing the risk of noncommunicable diseases in children.[3] • Diabetes: The International Society for Pediatric and Adolescent Diabetes (ISPAD) suggests adhering to country-specific NNS recommendations for NNSs in children and adolescents with Diabetes. Polyols are used as sweetening and bulking agents in food and beverages. It can cause laxative effects in children if consumed ≥ 20 g.[42] • FDA-approved Non-Sugar Sweetner (NSS) could be considered safe to consume within the FDA-Acceptable Daily intake (ADI).
Adults	• Obesity: WHO advises against using NSS for weight control as a lifetime strategy.[3] There is no clear evidence on the long-term weight control effects of NSS when taken in the ADI range. • Type 2 Diabetes: RSSDI-ESI guidelines suggest that NSS can be part of Medical Nutrition Therapy within ADI.[43] • NNSs: Aspartame, Acesulfame K, stevia, sucralose, and saccharin are currently approved for use.[44] However, they should be used in moderation and are best avoided during pregnancy.[45]
Pregnancy and GDM	• The guidance on using NNS in pregnancy is inconclusive, with limited evidence suggesting potential risks.[3] Traces of NNS could be present in amniotic fluid, breast milk, and placenta.[46] Hence, consultation with a Healthcare Professional (HCP) for its usage is advised/mandatory.[47] • Saccharine is contraindicated in pregnancy as it crosses the placental barrier. • The use of aspartame should be avoided in women with hyperphenylalaninemia. The safety of acesulfame-k and polyols use in pregnancy is questionable.[48]

Table 11.4. How to Identify a Sweetener in a Food Product

Location	Type	Identification Guidelines
Ingredient list	Nutritive Sweeteners	Search for sugar derivatives ending in '-ose' such as maltose and '-ol' such as Sorbitol, etc.
	Non-Nutritive Sweeteners	Identify artificial sweeteners by the names given in the Tables above, such as Aspartame, Saccharin, Stevia, etc.
Nutrition table	Nutritive Sweeteners	Check the 'Total Sugars' content, including naturally occurring and added sugars. The presence of added sugars indicates that adding a sugar substitute contributes to calories.
	Non-Nutritive Sweeteners	Typically, they contribute minimal to zero calories. Look for low or zero-calorie mentions in the Calories section. Some products may list NNSs separately in the ingredient list.

11.3 CONCLUSION AND RECOMMENDATIONS

Sweet taste is desirable to humans as it activates the pleasure centers of the brain, commonly known as the *sweet spot* in the insula. Hence, sweeteners hold an important place in the industry. Nutritive Sweeteners have calories and hence can impact weight and metabolic parameters, especially BG levels. It is important to be aware of and be able to identify these sweeteners, especially in ready-to-eat foods. NNSs have recently become a popular ingredient in commercially available foods, households, restaurants, and hotels. Though leading scientific bodies have set the ADI for NNS, it may be challenging for individual to assess their daily intake all by themselves. The easy access to sweeteners, both nutritive and non-nutritive, can leave people with diabetes confused. It is advised that adequate intake, usage, and ADI for safety limits be discussed with the healthcare providers to be clear and confident while using them.

Reading food labels involves identifying sweeteners' calories in the nutrition table and spotting sources of hidden sugars in the ingredient list. It is also important to know the content of foods being chosen and their overall calorie and carbohydrate intake. Also, many food products may use more than one sweetener in preparation for better sensory acceptability. The experts highly advocate an emphasis on educating people with diabetes to be able to read food labels.

The gut microbiome plays a very important role in the metabolism of sweeteners, and recent findings show a close relationship between the two.[49] The NS, such as isomalt, maltitol, and lactitol, do not affect the gut[50] microbiota substantially. However, high intake of glucose and fructose may lead to metabolic syndrome.[50] There is a minimal effect of NNS, such as stevia, sucralose, aspartame, and acesulfame-K, on gut microbiota composition, making it safe within ADI limits. The Firmicutes to Bacteroidetes ratio determines obesity. A higher ratio is a hallmark of obesity.[51] Further long-term studies are required to explore the specific effect of sweeteners on the human population.[52]

Clinical Pearls of Practice

- **Educate People With Diabetes about reading the labels carefully:** To identify nutritive and NNS in products, always check the ingredients list and nutrition table for specific names and content.
- **Educate People with Diabetes about considering the context of their diet:** Sweeteners can be a tool for managing calorie intake and BG levels as part of a balanced diet, especially for people with diabetes or those aiming to control weight.
- **Educate People with Diabetes about moderation:** Even for approved sweeteners, it is wise to consume them in moderation within the ADI limits to avoid potential adverse health impacts.
- **Educate People with Diabetes about consulting healthcare providers:** People with health conditions, including diabetes and kidney disease, should consult healthcare providers for personalized advice on sweetener use.
- **Educate People with Diabetes about opting for whole foods:** Whenever possible, prioritize whole foods and naturally available sweet options like fruits over processed foods with added sweeteners to support overall health.
- **Educate People with Diabetes about new research:** Dietary guidelines and recommendations may evolve as new research emerges, so stay informed about the latest findings on sweeteners and their health effects.

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Section 12A: Medical Nutrition Therapy (MNT) in Different Types of Diabetes

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12.1 MNT IN SPECIAL GROUPS WITH TYPE 2 DIABETES MELLITUS (T2D)

12.1.1 Introduction

This chapter focuses on the application of Medical Nutrition Therapy (MNT) in special groups of individuals with diabetes, emphasizing the importance of individualized care. In children, early dietary interventions are critical to support growth, development, and glycemic control, while adolescents face unique challenges related to hormonal changes, increased independence, and social pressures. Young adults, often in the transition from pediatric to adult care, require guidance to balance lifestyle demands with diabetes management. Lean individuals with diabetes, particularly those with type 1 (T1D) or atypical forms of T2D, need targeted strategies that differ from those used in individuals with obesity-related diabetes.[1] The elderly population presents with its own complexities, including comorbidities, functional limitations, and the need for careful nutrient management to prevent complications. Additionally, the chapter delves into the intricacies of MNT in women, addressing specific life stages and conditions, such as Polycystic Ovary Syndrome (PCOS), pre-conception care, hyperglycemia in pregnancy, and nutritional management in lactating and post-menopausal women.[1,2]

12.1.2 Different Conditions and Special Groups

12.1.2.1 MNT in Children

The incidence of T2D has increased among children, along with obesity. Management includes lifestyle modification along with proper treatment.

• Genetic factors like close relatives of individuals with T2D show a significantly increased risk.[3]

• Monozygotic twins: If one twin has T2D, the other has a 90% chance of developing it. Offspring risk is 3.5 times higher if one parent has T2D; this risk increases sixfold if both parents are affected.[4,5]
• Environmental Factors: Environmental influences include obesogenic factors (calorie-dense food, large portion sizes, sedentary lifestyle) prevalent in modern societies.[6]
• Maternal Health and Offspring T2D Risk: Maternal obesity and Gestational Diabetes Mellitus (GDM) elevate the risk of obesity and T2D in offspring. Increased visceral fat in children caused by obesity leads to increased Insulin Resistance (IR). (Table 12.1)

Table 12.1 ADA Guidelines for T2D Management in Children[Z]

- Should prioritize nutrient-dense, high-quality foods while reducing the intake of calorie-dense, nutrient-poor foods, especially those containing added sugars, such as sugary beverages. To prevent macro- or micronutrient deficiencies, experienced nutritionists must implement specific dietary interventions.
- Families should be encouraged to adopt gradual changes that align with healthy eating guidelines, and positive parenting practices related to diet and physical activity should be recognized and encouraged.
- Elimination of sugar-sweetened soft drinks and fruit juices, refined, simple sugars, and corn syrup.
- Reduce consumption of processed and prepackaged foods.
- Reduced intake of saturated and total fat.
- Increased consumption of fiber-rich foods, such as whole grain products and legumes, green leafy vegetables, and foods with a low Glycemic Index (GI).
- Minimize the frequency of eating out or while screen-watching.
- Limited use of fruit as a substitute for high-calorie and low-nutrient foods.
- Children and adolescents with T2D should aim for at least 60 minutes of moderate to vigorous daily physical activity, including muscle and bone strength training, at least three times per week.
- Children aged 5–13 years should sleep 9–11 hours daily for overall well-being.[8]

Recommendations
• Management of T2D in the pediatric population is best approached through non-pharmacologic and pharmacologic strategies, emphasizing diligent monitoring and regular follow-up.[9]
• For children with obesity without T2D, a decrease in Body Mass Index (BMI) of ≥ 0.5 kg/m^2 has enhanced insulin sensitivity. Children diagnosed with T2D should aim for a 7−10% reduction in BMI once linear growth is complete or strive to maintain a BMI below the 85th percentile for their age and sex if they are still growing. In the latter case, maintaining current weight can lead to a relative reduction in BMI as the child grows taller.[10]

12.1.2.2 MNT in Adolescents

According to the SEARCH database from the Centre for Disease Control and Prevention (CDC), the prevalence of obesity among adolescents has increased by 2.3% annually. To address this, the treatment options for T2D in Adolescents and Youth (TODAY) study was initiated in 2004.[11]
Contributing factors in developing diabetes in adolescents

- Level of central and visceral obesity correlates with increased IR.[12]
- Sedentary lifestyle, eating habits, positive family history, children born to mothers who had GDM or who were born with Low Birth Weight (LBW) or prematurely before 39 to 42 weeks of gestation.[13,14]
- Excess maternal adiposity (e.g., high pre-pregnancy BMI and excessive gestational weight gain, hyperglycemia, and poor prenatal diet quality).

Management
Appropriate lifestyle and dietary changes, MNT (achieve a 1–2% decrease in HbA1c), and pharmacological therapy are necessary for effective management. According to the guidelines, the daily energy intake should consist of 50–55 % carbohydrates, 15–20% protein, and 20–25% fat (Saturated fat <10%).[8,15,16]
Dietary recommendations
Dietary education includes educating families about the importance of reading nutrition fact labels and maintaining food and activity logs, focusing on healthy practices, and promoting meals eaten on schedule with family, along with minimizing snacking and screen time.[17]
• Eliminate sugar-sweetened beverages.
• Reduce intake of foods made from refined, simple sugars and high fructose corn syrup (HFCS).
• Limit intake of high-fat and/or calorie-dense foods.
• Reduce the intake of processed, pre-packaged, and convenience foods.
• Limit portion sizes.
• Reduce eating out or ordering in
• Increase fiber and vegetable intake
1. Add- Chew food properly
2. Avoid- Energy Drinks
3. Do not follow FAD diets blindly, consult a qualified dietitian.
• Include low GI foods.
• Include children in grocery shopping and cooking and impart nutrition awareness.
Exercise and sleep education:
• Encourage at least 60 minutes of moderate to vigorous daily physical activity.
• Reduce sedentary time, including watching television, computer-related activities, texting, and video games, to less than 2 hours a day.
• Promote physical activity such as using stairs instead of elevators, walking or bicycling to school and shop.
• Promote adequate quality sleep of 8–11 hours.[13,18]

12.1.2.3 MNT in Young Adults

Young adults or early adulthood range from the age of 19 to 25 years, and behavioral, psychological, and physiological changes occur at this stage; they also get easily influenced by unhealthy practices like drinking, smoking, which can lead to more stress and other medical complications like obesity, T2D, Cardiovascular Diseases (CVD), etc. According to the National Family Health Survey-5 (NFHS-5), obesity now affects one in four Indians.[19] Women often have a higher percentage of body fat than men.[20] From the start of puberty until menopause, women have a higher percentage of Body Fat Mass (BFM) than men. Ovarian hormone levels are also higher during the reproductive years and during pregnancy. Fertility is affected by obesity because of hormonal and metabolic changes. (Table 12.2)
Nutritional concerns:
• Adults fail to maintain the balance between work and personal life, affecting mental and physical health.
• Work pressure leads to skipping meals, less physical activity, and increased reliance on ready-to-eat and outside foods.
• More screen time aids in less physical activity.

Table 12.2 ADA Guidelines for T2D Management in Young Adults[Z]

- All youth with T2D and their families should receive comprehensive diabetes self-management education and culturally appropriate support.
- Lifestyle programs that are integrated with diabetes management to achieve at least a 7–10% decrease in excess weight.
- Lifestyle intervention should be based on a chronic care model and offered in the context of diabetes care.
- At least 60 minutes of moderate to vigorous daily physical activity (with muscle and bone strength training at least three days/week) to decrease sedentary behavior.
- They should focus on healthy eating patterns emphasizing the consumption of nutrient-dense, high-quality foods and decreased consumption of calorie-dense, nutrient-poor foods, particularly sugar-added beverages.
- Moderation is the key to a healthy diet.

Dietary recommendations:
For young adults to lead a healthy life, it is important to make conscious and healthy food choices, read food labels (to check for hidden sugars) and ingredient lists on food products, or try to educate themselves in the art of cooking healthy foods to achieve the selection of healthy food choices.[2]
• Always include seasonal fresh fruits and vegetables in meals.
• Reduce the amount of total fat intake to less than 30% of total energy to lower the risk of Non-communicable Diseases (NCDs).
• Replacing both saturated fats and trans-fats with unsaturated fats. Replace frying with steaming or boiling.
• Limit the consumption of baked and fried foods and prepackaged snacks. Limit salt intake to the recommended level of less than 5 g per day. Avoid table salt.
• Limit high-sodium food products (e.g., soy sauce, monosodium glutamate) while cooking.
• Add lemon, vinegar, and raw mango powder for flavor.
• Avoid sugar-sweetened beverages and simple sugars.
12.1.2.4. MNT in Lean People
MNT plays a crucial role in managing diabetes, whether the person has lean diabetes or is undergoing malnutrition along with diabetes. The goal of MNT is to maintain a healthy weight, which can be achieved by adding nutrient-dense and low to medium-GI foods to the diet.
Lean people - dietary recommendations:
• Complex carbohydrates like whole grains, pulses, vegetables, low glycemic fruits, nuts, and oil seeds are to be included in the diet.
• Foods rich in high biological protein are needed to help build muscle mass and tissue repair. Lean meats, poultry, fish, eggs, milk and milk products, pulses, whole legumes, and dairy products are to be included in the diet for good glycemic control.
• Nuts, seeds, avocados, and Omega-3 Polyunsaturated Fatty Acids (PUFA) oils are to be added.
General recommendations:
• Maintain meal timings and follow the proportions of My Plate to ensure fiber and protein in the diet.
• It is very important to maintain the fat mass within the target range in lean diabetes as increased fat mass is linked to progression to Diabetic Nephropathy (DN).[21]
• A negative energy balance can lead to upregulation of ghrelin secretion, which has salient effects on the person's nutritional state.

Diabetes with malnutrition: Dietary and exercise recommendations
• Design well-planned meals that are nutrient-dense to correct the deficiencies caused by malnutrition.
• Low GI, complex carbohydrates must be added to manage Blood Glucose (BG) levels.
• Step-by-step weight gain to achieve the ideal body weight to regain health.
• Enough calories must be provided to achieve healthy weight gain.
• Use the healthy fats as listed above in the section under MNT for Lean Diabetes.
• Regular monitoring and meal plans should be advocated under the guidance of a qualified Dietitian.
• Regular exercise is important to build muscle mass.

12.1.2.5. MNT in Elderly Population

In older persons, malnutrition is a condition that is commonly reported. It is strongly associated with poor physical outcomes, such as reduced muscle strength, impaired function, and increased dependency. Nonetheless, observational studies have also discovered connections between insufficient nutrition and assessments of mental health and cognitive performance, which are crucial components of healthy aging. Poor eating habits, weight loss, and an increased risk of malnutrition are all linked to depression in older adults. Inadequate diet has also been linked to cognitive decline. Changes in health and physiology accompanying old age impact the dietary requirements of the elderly. The elderly's diet fails to supply them with the nutrients required, resulting in deficits in nutrients and the development of degenerative diseases. Meeting guidelines might be difficult for older adults who have a lower appetite, early satiety, and limited access to food. Examining these and other aspects that may limit one's ability to meet predicted demands, such as socioeconomic status, illness state, overall health, ability to chew and swallow, and ability to taste, is critical.[22–24] (Table 12.3)

Table 12.3 ADA Guidelines for Geriatrics

- Optimal nutrition and protein intake are recommended for older adults with diabetes; regular exercise, including aerobic activity, weight-bearing exercise, and/or resistance training, should be encouraged in all older adults with diabetes who can safely engage in such activities.
- For elderly with T2D and overweight and obesity with a capacity to safely exercise, an intensive lifestyle intervention focused on dietary changes, physical activity, and modest weight loss (e.g., 5–7%) should be considered for its benefits on quality of life, mobility and physical functioning, and cardiometabolic risk factor control.

• **Nutritional Requirements:**
The Academy of Nutrition and Dietetics believes that estimated needs for older adults should be met through individualized nutrition care plans based on nutritional status, medical condition, and personal preference and that disease-specific diets should be thoroughly evaluated for risk and benefit to each individual.[25–29]
• The European Society for Clinical Nutrition and Metabolism advises protein intake equaling 1.0–1.2 g/kg of body weight/day for healthy older adults and 1.2–1.5 g/kg/day for older people who are malnourished or suffer from chronic disease.[30]
• As energy requirements diminish with age, the dietary Protein-to-Energy (PE) ratio rises among the elderly. Thus, the PE ratio is more essential than protein consumption alone. Furthermore, due to a decreased desire or inability to masticate protein-containing foods such as meat, a higher quantity of necessary amino acids, particularly branched-chain amino acids such as leucine, isoleucine, and valine, is required.[31–33]
• As per the recommendations, 50–55% of energy should be provided by carbohydrates.[33,34]
• Dietary fat provides vital fatty acids and is necessary for absorbing fat-soluble vitamins. Monounsaturated and polyunsaturated fats,

particularly omega-3-rich fats, should replace Saturated Fatty Acids (SFAs) since they protect the heart and brain. .[35,36]
• Because older adults have a higher percentage of fat mass to lean muscle mass, and fat mass has a lower water content than muscle mass, they are more likely to become dehydrated. Impaired thirst and physical restrictions tend to reduce water consumption. Therefore, the elderly should be encouraged to drink water often. The daily fluid requirements for healthy older persons are typically 30 ml/kg of body weight, with a minimum of 1.5 l/day or 1 to 1.5 ml/kcal ingested.[37]
• Adequate fiber, combined with adequate hydration, not only helps to maintain regular bowel function but also lowers the risk of intestinal inflammation.[38]
• Vitamin A enhances vision, aids in the proper functioning of the digestive, urinary, and immunological systems, and protects the skin in the elderly.[39]
• Vitamin D and Calcium should be inculcated, as low Vitamin D levels are associated with the risks of fractures, falls, diminished muscle strength, poor physical performance, impaired cognitive function, and depression in older persons.[40]
• The link between low thiamine (vitamin B_1) levels and neurodegenerative disorders, cognitive impairment, and depression is well documented. In the aged, riboflavin (vitamin B_2) supplementation is useful in decreasing excessive levels of homocysteine in the blood.[41]
• Zinc is also important in the elderly's immune response and neurological function.[42]

12.1.2.6. MNT in Women

12.1.2.6.1 MNT IN POLYCYSTIC OVARIAN SYNDROME (PCOS)

Treatment is broadly aimed at tackling IR, effects of hyperandrogenism, irregular menstruation, and infertility. The current Good Clinical Practice Recommendations (GCPR) provide evidence-based scientific & well-balanced information on multi-disciplinary approaches for managing PCOS. Obesity commonly occurs with PCOS and can worsen the complications of the disorder.[43]

Dietary and Exercise Recommendations:

MNT has been shown to improve pregnancy rates and normalize hyperandrogenemia, insulin sensitivity, menstrual functions, and hirsutism. A 5–10% reduction in total body weight can decrease central adiposity by up to 30%, increase the insulin sensitivity of peripheral tissues, reinstate ovulation, and be beneficial in metabolic disturbances. Research has shown that healthy eating habits and regular physical activity help to manage PCOS.
• Balanced meals with adequate protein and fats and low GI carbohydrates to reduce postprandial BG excursions. Include Proteins (such as whole grains, pulses, low-fat dairy products, egg whites, lean chicken and fish), healthy fats (olive oil, edible nuts and seeds, rapeseed oil, and avocados), and low-GI fruits or vegetables, as well as high-fiber, low-carbohydrate foods.
• Include omega-3 fats such as oily fish, seaweed, algae, chia seeds, flaxseeds, and walnuts.
• Vitamin D supplementation improves insulin sensitivity and lowers inflammation. Consider enough sunlight exposure and vitamin D supplementation daily.
• Quercetin, a natural flavonoid found in apples and onions, possesses anti-inflammatory properties and may help lower inflammation and improve metabolic markers.
• Coenzyme Q10 (CoQ10) is essential for cellular energy production, and it's a potent antioxidant.
• N-acetylcysteine (NAC) is an antioxidant that helps manage PCOS-related inflammation IR and improve ovulation.
Curcumin (the active compound in turmeric) may help reduce inflammation and improve IR.Cinnamon, ginger, and green teas are herbs and spices with potential benefits for lowering inflammation in people with PCOS. Cinnamon may improve insulin sensitivity, and ginger has anti-inflammatory properties.
• Green tea, rich in antioxidants, can help reduce inflammation and has been shown to reduce testosterone levels in women with PCOS.
• Avoid skipping meals. Junk and fried items, ready-to-eat meals, and bakery items.
• Drink 10–12 glasses of water daily.
• Regular exercise helps increase IR and weight loss.

12.1.2.6.2 MNT in Pre-Conception

The focus on pre-conceptual nutrition and health is important for both women and men. Women with a BMI less than 20 have an increased risk of anovulation. Obesity appears to negatively affect the sperm (both concentration and motility), oocyte (development, quality, and ovulation), embryo, and endometrium, including uterine receptivity.[44] Keen attention is to be given to diet, exercise, glucose monitoring, and adherence to prescribed medication regimens.

Treatment strategies:
• A woman of childbearing age should be informed about the importance of preconception care and the precautions required to maintain appropriate BG control.
• Weight loss, eliminating tobacco and alcohol, increasing physical activity, and stress management may be more productive for improved conception.[45]
• Dietary changes have been shown to decrease ovulatory disorders and improve fertility and embryonic growth trajectory.[46]
• Iodine deficiency has been associated with decreased fertility in women.[47]
• Preconceptual guidance is based on findings that many women enter pregnancy with suboptimal nutritional status, including obesity, and with low intakes of fiber, Long-Chain Polyunsaturated Fatty Acids (LCPUFAs), protein, zinc, iron, phosphorus, potassium, calcium, magnesium, vitamins A and D, folate, riboflavin, and choline.[48,49]
• Even women with a BMI in the obese category can have low-nutrient intakes and, in some studies, have been seen to be more nutritionally vulnerable than other pregnant women.[50]
• Micronutrient supplementation can improve maternal status but may not improve child health outcomes if started after conception.
• Counselling includes knowledge of achieving appropriate HbA1c and BG values before conception, appropriate screening of diabetes-related complications, and knowing the risk of T2D in their child's lifetime to improve outcomes for both mothers and babies and optimize neurological development (e.g., from hypothyroidism).[51,52]
• Exercises have a positive effect on mental health and well-being. 150 minutes per week of moderate to vigorous physical activity is recommended.[53]

Dietary recommendations
• The benefits of a healthy diet include adequate calcium, vitamin D, folic acid, and iron in the preconception period.
• Encouraging consumption of fresh vegetables, fruit, whole grains, meat or meat alternatives, low-fat milk, fish, and unsaturated oils, and limiting salt, sugar, and ultra-processed foods.
• Over the long term, inadequate calcium intake can lead to osteoporosis. Calcium supplementation during pregnancy reduces the risk of preeclampsia and osteoporosis in the long term,
Sources: Milk, milk alternatives (e.g., yogurt, cheese, and fortified plant-based beverages, such as soy), fish with edible soft bones (e.g., canned salmon and sardines), and dark green vegetables (e.g., broccoli, kale, and spinach).
• Vitamin D is essential for the proper absorption of calcium. It can also help the body use calcium and phosphorus to build and maintain strong bones and teeth.

Sources: Natural food sources of vitamin D are fatty fish and egg yolks, cow's milk, margarine, and fortified plant-based beverages (e.g., soy). Infant formula and foods for special uses (such as nutritional supplements and meal replacements) must be fortified with vitamin D. Other vitamin D-fortified foods, such as some goat's milk, some cheeses, and yogurts, are made with vitamin D-fortified milk. The Recommended Dietary Allowance (RDA) for vitamin D for women of reproductive age is 600 IU (15 mcg).[34]

• The preconception period is an ideal time to optimize iron stores, as the requirements will change during pregnancy.

Sources: Incorporate iron-rich foods, such as red meat, poultry, and fish, in their diets. Vegetarians can get iron from dark green leafy vegetables, iron-enriched cereals and grains, beans, lentils, and chickpeas.

• Certain nutrients, such as calcium, can inhibit iron absorption. Soy and tannin-containing teas may also inhibit absorption. Incorporate vitamin C to enhance iron absorption.

• Having folic acid at least one month before and during pregnancy can help prevent major birth defects of the developing baby's brain and spine (anencephaly and spina bifida). CDC recommends a daily intake of 400 micrograms (μg) of folic acid each day.[49,52]

12.1.2.6.3 MNT in Hyperglycemia in Pregnancy (HIP)

Globally, one in 10 pregnancies is associated with diabetes. In India, every 5th woman during pregnancy may have some form of HIP. Of them, 80% have GDM, and those are detected to have hyperglycemia during pregnancy in the 2nd & 3rd trimesters. 11% of these women have pre-existing T2D or T1D, while 9% are detected to have diabetes during pregnancy, which is suggestive of pre-existing diabetes mellitus. Indian women are at an 11 times higher risk of developing GDM during pregnancy. A GDM woman should be initially managed for two weeks by MNT and physical exercise (walk/exercise 30 mins/day). Pharmacotherapy should be instituted if not controlled by lifestyle management. The glycemic targets are Fasting Blood Glucose (FBG) < 90 mg/dL & 2-hour Post-prandial Blood Glucose (PPBG) ≤ 120 mg/dL. ~70–80% of women diagnosed with GDM can be managed with MNT and lifestyle modification alone.[54–56]

Goals of MNT *in* GDM

• To promote adequate nutrition for maternal and fetal health.

• To promote appropriate gestational weight gain and fetal growth.

• To achieve and maintain normoglycemia and prevent ketosis.

Calorie intake during pregnancy is based on the pre-pregnancy BMI. Table 12.5 mentions the rate of weight gain in the second and third trimesters. (Table 12.4)

Table 12.4 Recommendations for calorie intake and weight gain during pregnancy according to Pre-Pregnancy BMI

BMI (kg/m^2)	Total weight gain (kg)	Rate of weight gain in second and third trimester (kg/week)	Approximate caloric intake
Underweight <18.5	12.5–18	0.51 (0.44–0.58)	35–40 kcal/kg/day
Normal 18.5–22.9	11.5–16	0.42 (0.35–0.50)	30 kcal/kg/day
Overweight 23–24.9	7–11.5	0.28 (0.23–0.33)	22–25 kcal/kg/day
Obese >25	5–9	0.22 (0.17–0.27)	22–25 kcal/kg/day

No increase in caloric intake is recommended during the first trimester. The energy requirement should only be increased in the first trimester if the woman is underweight. As per ICMR-NIN, the RDA of a pregnant woman, apart from the daily requirement of energy/kg of body weight, an additional energy allowance of 350 kcals/day is required during the second and third trimesters.

Dietary recommendations

Carbohydrate:

• Estimated Average Requirements (EARs) for pregnant women should be 135 g/day + 35 g/day for the fetus during the last trimester.[57,58]

• The RDA for carbohydrates in pregnant women is a minimum of 175 g/day, which is necessary for appropriate fetal growth and cerebral development and function.

• The quantity and distribution of carbohydrates will vary depending on the caloric requirement, glycemic targets, and pre-meal BG levels.

• Simple carbohydrates (sugar, jaggery, and honey) must be completely avoided. Spreading complex carbohydrates with Low GI foods throughout the day will help achieve euglycemia.

• In most GDM mothers, there is a deficiency in first-phase insulin secretion. Due to the dawn phenomenon, more IR is seen at the start of the day; therefore, breakfast sugars are the most difficult to control.

• Split the breakfast into two: Eat half the portion, wait for an hour, test glucose levels, and then eat the remaining half.

• It is thus advisable that the first meal is low in carbohydrates and high in protein to avoid undue spikes in post-breakfast plasma glucose levels.

• Reducing the breakfast's Glycemic Load (GL) reduces the post-prandial peak.

Protein:

• Protein requirement increases during pregnancy, as per ICMR-NIN 2024[57]. An additional amount of 9.50 g/day in the second trimester and 22 g/day in the third trimester of protein should be added. Protein is necessary for synthesizing maternal (blood, uterus, and breasts), fetal, and placental tissues.

• At least three servings of protein foods are required daily to meet the increased demand.

• Protein intake should be distributed throughout the day and included in all meals and snacks to promote satiety and provide adequate calories.

• The baby is continuously fed while the mother is fed intermittently; thus, irrespective of the therapy, women during pregnancy are likely to develop early-morning hypoglycemia. The risk of this can be reduced by adding late-night protein-rich snacks. A bedtime snack may be needed to prevent accelerated (starvation) ketosis overnight.

FAT:

• In pregnancy, maternal lipids [triglycerides and free Fatty Acids (FA)] are associated with excessive fetal growth because triglycerides, which are sensitive to dietary fat intake, are hydrolyzed, and free FA transported across the placenta are important substrates for fetal fat accretion.[10,59,60]

• Pregnant women should consume 200 mg/day of DHA for optimal health and fetal development.

• Dietary cholesterol should be less than 300 mg/dL.

• The diet should emphasize monounsaturated and polyunsaturated fats while limiting saturated fats (less than 10 % of total calories), and *trans* fats should be avoided.

Micronutrients:

Micronutrient deficiencies can lead to complications such as anemia and hypertension and impair fetal function, development, and growth. Iron (27 mg/day), Calcium (1000 mg/day), folate (570 mg/day), and vitamin D (600 IU/day) are recommended during pregnancy. (Table 12.5)

Table 12.5 Summary of RDA of Micronutrients During Pregnancy and Lactation

	Calcium (mg/day)	Iron (mg/day)	Zinc (mg/day)	Iodine (ug/d)	Thiamine (mg/day)	Riboflavin (mg/day)	Niacin (mg/day)	Vit B_6 (mg/day)	Folate (ug/day)	Vit B_{12} (ug/day)	Vit C (ug/day)	Vit A (ug/day)	Vit D (ug/day)
Pregnant Woman	1000	27	14.5	220	2.0	2.7	13	2.3	570	2.45	80	900	600
Lactation													
0–6 months	1200	23	14.1	280	2.1	3.0	16	2.16	330	3.2	115	950	600
7–12 months	1200	23	14.1	280	2.1	2.9	16	2.07	330	3.2	115	950	600

12.1.2.6.4. MNT in Lactation

The fourth trimester is a critical transition period after childbirth when infants are adjusting to life outside the womb and mothers to parenthood. It is marked by significant biological, psychological, and social changes. As per the WHO expert committee, the optimal daily milk output of the mother's milk is estimated to be 850 mL, and during lactation, about 80% of energy, 50% of proteins, and 30% of the calcium is converted into the milk to the newborn. Exclusive breastfeeding is advised for the baby during the first six months. Breastfeeding is associated with reduced BG levels & reduced incidence of future development of T2D amongst women with a history of GDM.[61]
In light of the immediate nutritional and immunological benefits of breastfeeding for the baby, all women, including those with T2D, should be supported in attempts to breastfeed. Breastfeeding may confer long-term metabolic benefits to both the mother and the offspring. The ICMR-NIN 2024, RDA recommends an additional 17 g/day and 13 g/day dietary protein in 0–6 months and 7–12 months, respectively, over and above her normal requirements during the lactation period.

Role of specific vitamins and minerals:
• Additional vitamin A requirement during lactation is calculated based on the amount secreted in milk, which is 350 mcg of retinol per day.[62]
• Vitamin D requirements may be higher during lactation, and an additional need of 40 mg of vitamin C has been calculated based on the vitamin C secreted in milk in an average yield of 850 mL/day in a well-nourished mother.[63]
• Intake of vitamin B_6, folic acid, and vitamin B_{12} are recommended to the tune of 2.16 mg, 330 µg/day, and 3.2 µg/day, respectively.
• The ICMR Nutrition Expert Committee has estimated that the average amount of milk secreted by lactating mothers in India is 600 mL.
• During lactation, an intake of 1200 mg/day of calcium is recommended to be continued as a lactating woman produces about 850 mL of milk daily, which represents about 280 mg of calcium.[64]
MNT in Post-Menopausal Women
Menopause is observed after 12 months of amenorrhea[65] with no evidence of pathological and physiological causes due to the exhaustion of ovarian follicles. It is a complete natural attenuation of ovarian hormone secretion.

12.1.2.6.5 Individualized Plan for Menopause[66,67]

• Because muscle mass decreases and fat mass increases during menopause, one requires nutrient-dense foods that increase good-quality protein, fat, and fiber.
• Weight gain can be prevented by increasing physical activity levels and reducing portion sizes.
• Additionally, a balanced diet is vital because bones are made up of many different components. Include iron, calcium, foods rich in Vitamin D, phytoestrogens and isoflavones like soybeans, tofu, temph, chickpeas, peanuts, flaxseed, barley, grapes, berries, green and black tea.
• Caffeine-rich beverages like coffee, tea, and colas can exacerbate hot flashes; hence, opt for decaffeinated beverages.
• Limit daily alcohol intake or abstain completely. It exacerbates the symptoms.
• Consume a heart-healthy diet that consists of a wide range of fresh fruits and vegetables, whole grains, peas, beans, sprouts, legumes, fiber-rich foods, nuts and oil seeds, eggs, lean meat, chicken, and fish.
• Limit the intake of refined flour and sugar, and avoid cakes, candies, and sugar-sweetened beverages.
• Limit your intake of salted snacks, processed bakery foods, packaged foods, cooking sauces, and ready-to-eat meals.
• Indulge in regular, moderate exercise, particularly weight-bearing activities, and dedicate two or more days each week to muscle-strengthening exercises.
• Consult a doctor, dietitian, or health care professional for guidance.

12.2 CONCLUSIONS AND RECOMMENDATIONS

Clinical Pearls of Practice

- Clinical evidence suggests that people with diabetes receiving MNT can reduce their HbA1c by 1–2%.
- By focusing on whole, natural, nutrient-dense food, portion control, monitoring carbohydrate intake, and mindful eating, individuals can achieve and maintain better BG control while enjoying a varied and satisfying diet.
- As per guidelines for adolescents with diabetes, the daily energy intake should consist of 50-55% carbohydrates, 15-20% protein & 20-25% fat, along with diet, exercise education & good sleep quality.
- Reading food labels helps to unmask the hidden sources of sugars in the food item.
- **Young adults with T2D** require behavioral and psychological counseling along with MNT for the management of diabetes.
- For **lean diabetes**, correct nutrient deficiencies by providing nutrient-dense foods, good-quality protein, and adequate carbohydrates and fat to achieve ideal body weight. Regular exercise is important to build muscle mass.
- **MNT in elderly population-** Optimal nutrition and protein intake are recommended for older adults with diabetes; regular exercise, including aerobic activity, weight-bearing exercise, and/or resistance training, should be encouraged in all elderly adults with diabetes who can safely engage in such activities. Avoid, treat, and prevent malnourishment and dehydration in the elderly, especially if they lack the required support system.

MNT in WOMEN with T2D

- In PCOS, lifestyle modification is the key. A 5–10% reduction in total body weight helps to reduce central obesity, increase insulin sensitivity, reinstate ovulation, and improve overall metabolic health. Research has shown that healthy dietary habits and regular physical activity improve pregnancy rates and normalize hyperandrogenisms, insulin sensitivity, menstrual functions, and hirsutism.
- **Preconception nutrition** should focus on maintaining ideal body weight by consumption of adequate macro and micronutrient intake. Self-monitoring of BG and moderate to vigorous physical activity helps achieve preconception glycemic targets, i.e., HbA1c <6–6.5%, FBG <90–95 mg/dL, and 2-hour PPBG <120 mg/dL.
- **MNT in Pregnancy -** During pregnancy, nutritional requirements increase to promote maternal metabolism and tissue growth while supporting fetal growth and cerebral development/function. Protein requirement increases in the second and third trimesters, which should be well distributed in every meal. An increased energy, essential fatty acids, and micronutrients (iron, folic acid, calcium, zinc, selenium, iodine, Vitamin B, C, D, etc.) demands should also be matched with advancing pregnancy. Principally, one should not try to treat obesity during pregnancy.
- **MNT in lactation—**Exclusive breastfeeding is recommended for the baby during the first six months. It may confer long-term metabolic benefits to both the mother and the offspring. Nutrient-dense foods must meet the additional nutritional demands of the mother.
- **MNT in post-menopausal women -**Lifestyle modification may help maintain bone density and reduce the risk of heart disease and menopausal symptoms. Consumption of a heart-healthy diet consisting of a wide range of fresh fruits and vegetables and whole grains is advised.
- The dietary pattern should be developed by considering individual geographic, cultural, and financial factors to ensure compliance, and the Macronutrient distribution should be individualized based on preferences and metabolic goals.

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Section 12B: Medical Nutrition Therapy (MNT) in Different Types of Diabetes (Special Situations/Conditions)

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12.2 INTRODUCTION

This chapter explores how Medical Nutrition Therapy (MNT) can be applied in the context of unique challenges faced by individuals with diabetes in specific medical conditions. These situations often add complexity to diabetes management, necessitating tailored interventions to maintain optimal glycemic control and prevent complications.

12.2.1 Celiac Disease

Celiac disease is a condition characterized by an inappropriate immune response to gluten, leading to inflammation and damage in the small intestine. This can increase the risk of hypoglycemia and glycemic variability in individuals with diabetes. As nutrient absorption in the small intestine becomes compromised, accurate diagnosis and strict adherence to dietary modifications are crucial for effective management and overall health.[1–7]

• There is no established link between Type 2 Diabetes Mellitus (T2D) and celiac disease. T2D does have genetic components, but they are not associated with celiac disease genes such as Type 1 Diabetes Mellitus (T1D).

• If people with diabetes do not have celiac disease and do not experience any problems with gluten consumption, there is no reason to avoid gluten.

A meta-analysis examined the impact of a gluten-free diet on glycemic control and weight in individuals with T2D and obesity. Findings suggested that a gluten-free diet might have some beneficial effects on glycemic control. More research is needed to fully understand the implications and benefits of such dietary interventions. Additionally, individualized approaches to diabetes management should consider various factors, including overall dietary patterns, lifestyle factors, and personal preferences, in collaboration with healthcare professionals.[8,9]

12.2.1.1 Gluten-Free Diet

This diet is primarily followed by individuals with celiac disease, and those with non-celiac gluten sensitivity or wheat allergy. According to the World Health Organization/Food and Agriculture Organization (WHO/FAO), Food Safety and Standards Authority of India (FSSAI), European Commission, and Food and Drug Administration (FDA) - Gluten-free foods are: Gluten level not exceeding 20 ppm (<20 mg/kg food), consisting of, or made only from ingredients which do not contain any prolamins from wheat or any Triticum species, such as spelt, Kamut or durum wheat, rye, barley, oats, or their crossbred varieties. (Table 12.8)

Table 12.8. Gluten-containing and Gluten-free foods

Category	Foods to Avoid	Alternatives
Wheat and wheat-based products	Breads, wheat roti, pasta, couscous, flour, cakes, cookies, pastries, and certain sauces.	Rice, corn, quinoa, millet, sorghum, buckwheat, and gluten-free oats (certified gluten-free to avoid cross-contamination).
Barley and barley-based products	Malt, malt extract, malt vinegar, and some types of beer.	Gluten-free flour and starches: Such as almond flour, coconut flour, tapioca flour, potato starch, and cornstarch.
Rye and rye-based products	Rye bread, rye crackers, and rye-based cereals.	Products specifically labeled as gluten-free.
Derivatives of these grains	Bulgur, farro, semolina, spelt, and triticale.	Lentils, millets, Amaranth.
Hidden sources of gluten	Soups, sauces, gravies, salad dressings, premixed spices, and processed meats.	Emphasize naturally gluten-free whole foods such as fruits, vegetables, legumes, nuts, seeds, eggs, dairy products, fish, poultry, and meats. These foods are inherently gluten-free and provide essential nutrients, fiber, and antioxidants.

Label reading: Products labeled as gluten-free or certified gluten-free, which undergo testing to ensure they meet gluten-free standards, are recommended. People with diabetes, celiac disease, or gluten sensitivity must become adept at reading food labels to identify gluten-containing ingredients and assess the nutritional content of gluten-free products.
Cross-contamination awareness: Cross-contamination is a possibility when dining out or preparing food in shared kitchen spaces. To avoid gluten cross-contact, we recommend using separate cooking utensils, cutting boards, and kitchen equipment.
Recommendations:
• Adopting a gluten-free diet for diabetes management in individuals without celiac disease requires careful attention to food choices, portion sizes, and overall dietary balance.
• By focusing on whole, nutrient-dense foods and monitoring carbohydrate intake, individuals can achieve and maintain better BG control while enjoying a varied and satisfying diet.
• Consulting with healthcare professionals can provide additional guidance and support in managing diabetes effectively.

12.2.2 MNT in Post-Bariatric Surgery

Bariatric surgery is a widely recognized intervention for individuals with obesity. It often leads to significant weight loss and improvements in glycemic control, particularly in those with T2D. However, the pre- and post-surgical period introduces unique nutritional challenges, making MNT essential for long-term management. Individuals must be prepared to adopt comprehensive lifestyle changes to ensure long-term post-operative success.[10,11]

Nutritional recommendations are divided into three main sections:[12]

• Pre-surgery nutritional evaluation, pre-surgery diet, and supplementation.
• Post-surgery diet progression, eating-related behaviors, and nutritional therapy for common gastrointestinal symptoms.

• Recommendations for lifelong supplementation and advice for nutritional follow-up.

12.2.2.1 Pre-Surgery Nutritional Care

• Adequate nutritional assessment and behavioral and dietary guidance are essential in preparing for surgery and are key in achieving optimal surgical outcomes, monitoring nutritional status, preventing nutrient deficiencies, and maximizing long-term weight loss.[13] (Table 12.9)

Table 12.9. Pre-Surgery Nutritional Care

Iron	Recommended daily allowance (RDA) for Indian adult males is 17 mg/day, and for Indian adult females, 21 mg/day. If a patient has severe iron deficiency before surgery, IV iron supplementation before surgery and post-operative follow-up until optimum levels are achieved is recommended.[14–16]
Vitamin B_{12}	RDA for adult Indian males and females is 1 µg. Vitamin B12 should be administered through a medium where it can be directly absorbed into the bloodstream due to a reduction in the Intrinsic Factor (IF). In cases of severe deficiency, 500–1000 µg of vitamin B12 should be administered intramuscularly at least every fortnight. Sublingual or nasal administration of 1000–1200 µg vitamin B12 is recommended as a maintenance dose.[17–20]
Vitamin D_3	RDA: 400–800 IU/day.[21]
Calcium	The RDA for calcium for Indian adults is 600 mg/day. A very high intake of calcium (more than 2000 mg/day), especially with high levels of vitamin D, is a potential cause of hypercalcemia. High intake of calcium from supplements, but not foods, has been associated with an increased risk of kidney stones.[22]
Folic acid	RDA for folic acid for Indian adults is 200 µg/day.

Thiamine (B_1)	Thiamine deficiency is of particular concern as it most often goes undetected or is confused with vitamin B12 deficiency and, if untreated, can cause irreparable nerve damage.
Protein	The RDA for Indian males and females is 1 g/kg of body weight. The protein provided should be of high biological value and should be easily digested and absorbed.
Pre-surgery diet Recommendations	**Dietary evaluation:** 24-hour dietary recall/food frequency (qualitative and quantitative)/ alcohol, smoking, and tobacco usage. **Be aware of eating disorders and seek help:** emotional eating, binge eating, night eating syndrome, Prader-Willi syndrome. **Biochemical assessment for Nutritional deficiencies** Pre-operatively, all individuals must follow a high-protein (75–80 g protein/day), low-carbohydrate (1000 kcals or less) diet and low-calorie fluids for at least 7–10 days. This is essential as it decreases the size of the liver and helps the individuals prepare for nutritional restriction post-surgery. • As the pre-operative diet is calorie-restricted, people with diabetes, especially those on insulin, should be counselled to check Blood Glucose (BG) levels frequently to avoid hypoglycemia. A consultation with their endocrinologist/physician is necessary to adjust doses and anti-diabetic drugs. • In individuals with compromised renal function: ○ High biological protein (0.8–1 g/kg of ideal body weight) should be advised. The amount of protein should be based on urinary creatinine clearance, serum creatinine, and serum albumin. Potassium and sodium restriction may be necessary in case of electrolyte imbalance. Fluid intake also may be restricted (Fluid intake = urine output 24 hour + 500 mL). • In individuals with liver disease: Protein and albumin levels are to be monitored. 1.0–1.5 g/kg of body weight protein is advised. Sodium and fluid restrictions are to be evaluated in cases of ascites and hyponatremia.

12.2.2.2 Post-Operative Care

Patients gradually progress from a liquid diet to soft and solid foods in the initial weeks following bariatric surgery. Long-term dietary recommendations encourage adherence to a structured post-surgical eating plan, including consuming small portions and three to five balanced meals.[13] Patients are advised to eat slowly, avoid sugary foods, and separate eating and drinking by at least 30 minutes to optimize digestion. Additionally, carbonated and caffeinated beverages should be avoided due to their potential to increase the risk of ulcer formation, as carbonated drinks contain phosphoric acid, and caffeine can irritate the stomach lining.[23] (Table 12.10, 12.11 & 12.12)

Table 12.10. Post-Operative Nutritional Care

Days 1 and 2 post-operatively	Individuals should be on clear liquids only to assess tolerance of oral intake. Start with 50 cm^3/h and then progress slowly.
Day 3 onwards	• Progress to a full liquid diet. (Protein supplementation should commence; avoid sugary drinks) liquid foods, such as low-fat milk, plain soy drinks, and dals at 3–7 days post-surgery should be encouraged. Slow, small sips, advice against gulping, no straw. • Soups and vegetable juices come next. Sugary drinks, flavored syrups, carbonated beverages, and alcohol should be strictly prohibited. Quantity can be increased as per tolerance.
After 15 days post-surgery	• The patient can introduce soft, moist food (mashed or puréed), overcooked vegetables, well-cooked rice preparations (pureed *khichdi*), mashed soft or blended fruit without seeds, semolina and broken wheat preparations, porridges, cottage cheese, scrambled or boiled egg whites, baked/steamed fish, chicken mince, or chicken shreds. • At this stage, hard fruits, seeds, nuts, breads, tough meats, and stringy vegetables should be avoided. • During this phase, it is recommended to separate liquids from solids by avoiding drinking beverages 15 minutes before or 30 minutes after eating.
Late post-op stage	• A regular low-fat diet that includes all the food groups is encouraged, prioritizing protein-rich foods. Individuals should be encouraged to continue with protein supplements until about three months post-operatively. • *Heber* et al. recommended that 30 g of protein be present in more than one meal each day to maintain healthy bones and muscles, and that individuals should eat protein at breakfast to relieve the catabolic state of overnight fasting.[24] • In clinical practice, a loss of 25% or less of Fat-free Mass (FFM) seems to be a reasonable goal; however, there is no "gold standard," and the range of acceptable FFM loss post-bariatric surgery is unknown.

Table 12.11. Comprehensive Nutritional Follow-Up

One month	• Weight check. • Dietary assessment. • Progression to a full diet.
Three months	• Weight check + full body consumption. • Check on nutritional profile. • Check on compliance with supplements. • Dietary evaluation. • Monitor and check on medication and co-morbid conditions.
Six months	• Same as three months + check for any long-term complications, nutritional deficiencies, hypoglycemia, weight regain, etc.
One year	• Same as six months + check for any long-term complications, nutritional deficiencies, hypoglycemia, weight regain, etc.
Yearly follow up	• Same as one year + check for any long-term complications, nutritional deficiencies, hypoglycemia, weight regain, etc.

Table 12.12. Supplementation Post–Operatively

Multivitamins: Complete adult multivitamin	**Once daily**
Calcium	1000 mg/day, preferably in doses of 500 mg.
Calcium citrate	Apart from iron supplements.
Iron (Ferrous fumarate or glycinate)	28–30 mg/day with added ascorbic acid.
Vitamin D_3 (Cholecalciferol)	For severely deficient (less than 10 ng/mL), 60,000 IU oral granules every week (for 6–8 weeks). In cases of severe deficiency, 300,000 IU of cholecalciferol is administered intramuscularly weekly or fortnightly for 6–8 weeks. Oral administration of cholecalciferol in doses of 30,000–60,000 IU should be administered weekly or fortnightly as a maintenance dose.
Thiamine (B_1)	Bariatric beriberi can develop post-operatively; individuals are given an infusion containing dextrose without vitamins. In the immediate post-operative phase, all individuals are recommended to receive an exclusive B-complex formulation for at least one month post-operatively in addition to a complete multivitamin formula.
Vitamin B_{12} (Methylcobalamin)	Severely deficient—weekly 500 µg intramuscular injection Insufficient—500 µg intramuscular injections fortnightly or sublingual drops/tablets daily.
Protein	Protein intake after bariatric surgery should be at least 60 g/day, including ~10 g of leucine. Protein intake should be calculated as 1–1.5 g/kg ideal body weight (via supplementation and diet). However, in a malabsorptive procedure such as the duodenal switch, biliopancreatic diversion, and long limb gastric bypass, protein intake should be calculated as 1.5–2 g/kg of ideal body weight.

Post-Surgery Sequelae- Dietary Management

• ***Constipation:*** This can result from sudden decreased food and fluid intake or restricted physical activity. Individuals should be encouraged to sip liquids throughout the day. Fiber supplements should be used sparingly in this immediate post-op phase as they may aggravate the condition and cause the smaller stomach pouch to fill up quickly, leaving no space for food intake. Hence, liquid paraffin should be used.[25–27]

• ***Hypoglycemia:*** This is one of the most devastating sequelae of some bariatric surgeries. A complex carbohydrate diet plan is sufficient to prevent hypoglycemia-like symptoms in most individuals. Both soluble and insoluble fiber should be encouraged. The gap between solids and liquids is essential to prevent the flushing down of the food.
• ***Dumping syndrome:*** This condition is caused by the rapid emptying of a high carbohydrate (especially sugary foods and alcohol) load into the small bowel. Early dumping syndrome occurs within the 1st hour after ingestion of a meal. Late dumping occurs 1–3 hours after eating and is most likely caused by the rapid absorption of glucose, with hyperglycemia triggering an exaggerated insulin release. It can be managed by avoiding simple carbohydrates, eating slowly, and consuming small portions of a low-carbohydrate diet.
• ***Hyperuricemia:*** Care should be taken to spot signs and symptoms and modify purine intake accordingly.
• ***Weight Regain***: High-calorie foods, sugary drinks, excessive alcohol intake, and hypoproteinemia are causes of weight regain. Include complex carbohydrates and fiber, eliminate simple and refined sugars, and work in conjunction with a psychologist, especially in cases of excessive alcohol intake and maladaptive eating habits. Physical activity should be promoted in these individuals.

Recommendations

• Pre-operative nutrition counseling and pre-operative nutritional investigations are compulsory for all individuals who are to undergo bariatric/metabolic surgery.
• A high-protein, low-carbohydrate, low-fat diet should be recommended for at least seven days before the surgery.
• Modifications should be made in the pre-operative diet in special cases.
• Compulsory protein, multivitamin, calcium, and iron supplementation post-operatively, irrespective of the type of surgery.
• Life-long nutritional follow-up is required.
• Look out for hypoglycemia, dumping syndrome, and weight regain.
• Recognize signs and symptoms of nutritional deficiencies.

12.2.3 Secondary Diabetes

12.2.3.1 MNT in Fibrocalculus Pancreatic Diabetes (FCPD)

MNT is the cornerstone of FCPD management. A balanced diet with adequate carbohydrates, including whole grains, fat, proteins, and micronutrients, must be ensured. Fat-soluble vitamins must be replaced. Avoid calorie restriction, smoking, and foods with toxic effects on the pancreas, such as cassava.

12.2.3.2 MNT in Post-Pancreatitis

The pancreas regulates digestion and hormone secretion, including insulin and glycemic regulation. Post-Pancreatitis Diabetes Mellitus (PPDM) is one of the complications of pancreatitis. It is characterized by poor glycemic control, lower Body Mass Index (BMI), and a higher risk of cancer compared to T2D. PPDM individuals might have concomitant Exocrine Pancreatic Insufficiency (EPI), leading to fat malabsorption and loss of fat-soluble vitamins. The loss of vitamin D can lead to metabolic bone disease and osteoporosis. From a nutritional point of view, exocrine function is more important.[28,29]

Nutritional screening

• According to The Global Leadership Initiative on Malnutrition, a two-step strategy is recommended for evaluating malnutrition. The first step consists of identifying individuals at risk of malnutrition, subsequently confirming the diagnosis, and assessing the severity in the second step.[30]
• The Malnutrition Screening Tool (MST) is a reliable screening tool. It consists of two questions, one concerning unintentional weight loss and one concerning decreased appetite. According to the total score obtained, individuals can be classified as being at low (0 points), moderate (2 points), or high risk (3–5 points) of malnutrition.[31] Another validated, quick, and easy screening tool is the Malnutrition Universal Screening Tool (MUST). It is a five-step score that evaluates BMI, weight loss, and the effects of acute illness. Finally, individuals could be differentiated into low-risk (MUST 0 points), medium-risk (MUST 1 point), or high-risk (MUST $\geq$ 2 points) malnutrition.[32]
• Assessing sarcopenia is another way of estimating malnutrition by assessing muscle strength, quality/quantity, and physical performance. It is important to assess and manage malnutrition aggressively. A frequent consequence of malnutrition is reduced serum fat-soluble vitamins such as A, D, E, K, and other micro-nutrients.

Table 12.13. Management strategies for PPDM

Behavioral/ Lifestyle interventions	• Alcohol/substance abstinence • Nutrition • Exercise • Pain management
Pharmacological therapies	• Fiber • Pancreatic enzyme supplementation • Insulin and oral hypoglycemic therapies • Osteoporosis treatment

Dietary Recommendations:

• The American Diabetes Association (ADA) does not recommend a specific diet to manage PPDM.
• The strongest evidence exists for Mediterranean, low-fat, or carbohydrate diets, with a recommendation to use whole complex carbohydrates rather than processed foods.
• The dietary pattern should be developed by taking into consideration individual geographic, cultural, and financial factors to ensure compliance,[33] and the macronutrient distribution should be individualized based on preferences and metabolic goals.[34] Glycemic control, dietary tolerance, and overall health are to be considered.
• In chronic pancreatitis, calorie intake ranges from 25–35 kcal/kg, with 30–40% of energy coming from vegetable fat.
• The inclusion of Medium-Chain Triglyceride (MCT) oils, such as coconut oil, can be beneficial. Protein should be 1 to 1.5 g/kg, especially in those with poor nutritional status.
• In cases of acute pancreatitis, oral feeding is recommended within the first 72 hours. If oral intake is not possible, nutrition may be provided throug
• Nasogastric (NG) or Nasojejunal (NJ) tube feeding or Total Parenteral Nutrition (TPN) as needed. Despite specific dietary guidelines for pancreatitis management, maintaining an appropriate nutritional balance to achieve glycemic control and pain management in PPDM can be challenging.

12.3 CONCLUSION AND RECOMMENDATIONS

Clinical Pearls of Practice

- A gluten-free diet requires attention to food choices, portion sizes, and overall dietary balance.
- Post-bariatric surgery—Provide the optimal amount of high-biological-value protein, 1–1.5 g/kg ideal body weight. In the post-operative phase, gradually introduce foods from clear liquids to full liquids to soft, moist food to a normal diet. Add vitamin supplements and check for long-term complications, nutritional deficiencies, hypoglycemia, constipation, and weight regain.
- The dietary pattern should be developed by considering individual geographic, cultural, and financial factors to ensure compliance, and the macronutrient distribution should be individualized based on preferences and metabolic goals.

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Section 13: Medical Nutrition Therapy (MNT) and Anti-Hyperglycemic Agents

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13.1 INTRODUCTION

The effectiveness of MNT is maximized when tailored to the individual's lifestyle, food preferences, and cultural needs, and when aligned with the pharmacological treatment. The choice of medication, or combination of medications, is guided by several factors, including efficacy, patient characteristics, risk of hypoglycemia, weight considerations, and cardiovascular benefits.[1–5]

The interplay between MNT and pharmacological therapy with structured diabetes education is a key consideration in the comprehensive management of Type 2 Diabetes Mellitus (T2D). Tailored nutrition plans that align with anti-hyperglycemic medication regimens ensure synergy between pharmacotherapy and dietary management. An individual's dietary intake and nutritional status can significantly influence the efficacy of anti-hyperglycemic medications. For example, carbohydrate intake directly impacts postprandial Blood Glucose (BG) levels, necessitating medication type and dosage adjustments to prevent hypoglycemia or hyperglycemia. MNT strategies promote a balanced and consistent carbohydrate intake throughout the day, minimizing fluctuations in BG levels and reducing the risk of hypoglycemia. It also involves educating patients on the timing and composition of meals and snacks to coincide with medication administration, optimizing glucose metabolism, and reducing the likelihood of severe hypoglycemic episodes.[6] It helps to identify early warning signs and take appropriate corrective actions to help prevent the progression of mild hypoglycemia to more severe episodes requiring medical intervention. Similarly, weight loss achieved through MNT can enhance insulin sensitivity, potentially requiring a reduction in medication dosage.[7] MNT can also help mitigate potential side effects associated with anti-hyperglycemic medications, such as weight gain or gastrointestinal disturbances, through dietary modifications and counseling.[8]

Additionally, by promoting dietary changes by prioritizing whole foods, fiber-rich sources, and balanced macronutrient distribution, MNT interventions aim to improve insulin sensitivity and reduce insulin resistance.[9] Thus, they enhance the effectiveness of oral anti-hyperglycemic drugs, contributing to long-term glycemic control and reducing the risk of complications associated with diabetes.

By integrating evidence-based MNT interventions with pharmacological treatments, healthcare providers can empower people with diabetes to effectively manage their condition and improve their overall health and well-being. As advocates for patient-centered care, we must prioritize the integration of MNT into diabetes management protocols to optimize treatment outcomes and enhance the lives of those with diabetes.

13.2 INTEGRATION OF ANTI-HYPERGLYCEMIC AGENTS AND MNT

In the comprehensive management of T2D, pharmacological treatment and MNT are deeply intertwined, forming a symbiotic framework for patient care. This integration acknowledges that the efficacy and safety of anti-hyperglycemic medications are profoundly influenced by an individual's diet and nutritional status, and vice versa. For instance, the pharmacodynamics and pharmacokinetics of medications can affect and be affected by nutritional intake, necessitating a nuanced understanding of how these elements interact.[10]

Healthcare providers, including endocrinologists, dietitians, and diabetes educators, must comprehensively understand the mechanistic action of anti-hyperglycemic agents and the principles of nutritional management. This knowledge allows for tailoring treatment plans that harmonize medication regimes with dietary advice, facilitating targeted glycemic control.

13.3 KINETICS AND DIETARY IMPLICATIONS OF ANTI-HYPERGLYCEMIC AGENTS

The pharmacokinetics of anti-hyperglycemic agents—how the body absorbs, distributes, metabolizes, and excretes these drugs—have significant implications for dietary management.

13.3.1 Anti-hyperglycemic Agents Leading to Hypoglycemia

13.3.1.1 Sulphonylureas

Sulphonylureas are potent in increasing insulin levels in the body, significantly enhancing tissue glucose uptake, and lowering BG levels.[11] However, this increased efficacy comes with the heightened risk of hypoglycemia due to the non-glucose-dependent action of these drugs.[12] When used appropriately, sulfonylureas enhance insulin secretion and action, with effects that can be sustained for years. When combined with a hypocaloric diet, rapid- and short-acting sulfonylureas may help patients achieve and maintain euglycemia without causing chronic hyperinsulinemia or weight gain.[13]

Failures in achieving desired outcomes with sulfonylurea treatment are often due to dietary noncompliance or the late introduction of the drug at a stage when β-cell function is already significantly impaired.[13] Sulfonylureas should be used with caution in patients who are undernourished or have a history of alcohol abuse, as well as in those with impaired renal or cardiac function, gastrointestinal disease, or those concurrently treated with medications such as salicylates, sulfonamides, fibric acid derivatives (e.g., gemfibrozil), and warfarin.[14] Sulfonylureas should be avoided in people with diabetes who are at high risk of hypoglycemia, particularly older adults or those with conditions precipitating hypoglycemia.[15]

Hypoglycemia may be severe, especially after a missed meal or exercise or after taking sulfonylureas at a high dose.[14] Glipizide, glimepiride, and gliclazide are associated with a lower incidence of hypoglycemia than glyburide.[16,17] First-generation sulfonylureas are no longer used for T2D management.

Drugs and meal instructions

• Glyburide is a long-acting sulfonylurea that is available as an immediate-release oral tablet. Food does not delay glyburide absorption, so it can be prescribed with a meal.[18]
• Glipizide is available as an immediate-release and an extended-release oral tablet. Glipizide immediate-release has an intermediate duration of action, and glipizide extended-release has a long duration of action. Food delays the absorption of glipizide immediate release by 30 minutes, which leads to a delay in the onset of action and less control of BG. Therefore, administer the scheduled dose of glipizide immediate-release 30 minutes before a meal; this allows enough time for insulin release and glucose control in response to food ingestion. Administer glipizide extended-release with a meal.[19]
• Glimepiride is available as an immediate-release oral tablet. It can be administered within 30 minutes of a meal.[20]
• Gliclazide is an immediate-release oral and modified-release oral tablet. Immediate-release gliclazide should be taken 30 minutes before a meal. Take Gliclazide modified release with a meal.[14]
Special note: When planning a diet for patients on sulfonylureas, it is important to avoid excessive restrictions on carbohydrates and calories. Diets such as fasting, intermittent fasting, the keto diet, and Very Low Calorie Diets (VLCD) should be avoided as they can lead to severe hypoglycemia. Since sulfonylurea can promote weight gain, calorie intake should be regulated to prevent additional weight gain, particularly in overweight or obese individuals. If a patient is fasting, reducing or holding the sulfonylurea dose and ensuring frequent monitoring of BG levels is advisable.

13.3.1.2 Glinides

Glinides, or meglitinides, are insulin secretagogues that depolarize pancreatic β-cells, leading to an increase in insulin release. Glinides are rapid-acting glucose regulators, unlike sulphonylureas, with a short duration of action, making them effective for managing postprandial hyperglycemia when taken with meals.[21]
Hypoglycemia is one of the major concerns associated with the use of glinides. Most of these hypoglycemic episodes are mild to moderate and may not require assistance;[22] however, severe episodes can occur in rare situations. Hypoglycemic events appear to be more common with sulfonylureas than with glinides. Similar to sulfonylureas, glinides can also lead to weight gain.[23]

13.3.1.3 Insulin

If the desired BG control is not achieved using oral anti-hyperglycemic agents, initiating insulin therapy is advised. It is important to adjust other non-insulin therapies when insulin is added, especially agents that increase hypoglycemia risk, such as insulin secretagogues (e.g., sulfonylureas and glinides).[24] Hypoglycemia is the most serious adverse effect of insulin therapy and the major barrier to achieving glycemic targets. Hence, efforts should be made to prevent it.

Implications For Insulin Therapy

Insulin is the cornerstone in managing T2D for people unable to achieve glycemic targets with Oral Antidiabetic Agents (OADAs). Insulin regimens, particularly the basal-bolus approach, necessitate a highly individualized and coordinated effort between healthcare providers and patients to synchronize insulin administration with daily living habits, including meal patterns, carbohydrate intake, and physical activity levels.
Initially, basal insulin therapy is advised to control fasting hyperglycemia. The new peakless ultra-long-acting insulins do not require alterations in nutrition therapy,[25] and very few people need a bedtime snack. Patients on older insulins like Natural Protamine Hagedorn (NPH), Glargine, and Detemir may experience hypoglycemia at midnight.[25,26] Such individuals are usually managed by reducing the dose of insulin. Some patients may need to incorporate slow-release carbohydrates and proteins into dinner to avoid midnight hypoglycemia.[27] However, using NPH insulin as basal insulin carries a higher hypoglycemia risk than other basal insulins, as the former has a 'peak' effect approximately 4 to 6 hours after injection. Regular monitoring of BG levels to check for hypoglycemia is advised. Insulin doses can be titrated to achieve the desired glucose control, and if required, a small carbohydrate snack can be advised to prevent hypoglycemia.
If the desired glucose targets are unmet with basal insulin therapy, rapid-acting or short-acting (bolus or prandial) insulin is advised at mealtime to control the expected postprandial rise in glucose levels.[28] Adequate carbohydrate intake is important while taking bolus insulin to prevent hypoglycemia and ensure adequate energy intake for overall well-being. Other healthy dietary principles of adequate protein, fiber, and healthy fat must be followed.
For adults on fixed daily insulin regimens, especially premixed insulin, maintaining a consistent carbohydrate intake, both in timing and quantity and considering insulin action time, can enhance BG control and decrease the risk of hypoglycemia.[29,30]
Individuals with postprandial spikes after every meal often need a basal-bolus regime. The basal-bolus regimen mimics the body's natural pattern of insulin release. It involves administering long-acting insulin to provide a steady baseline (basal) insulin level and short-acting or rapid-acting insulin(boluses) at mealtimes to manage the rise in BG following food intake.[31]
Additionally, when mixed meals contain significant amounts of fat and protein, insulin dosing should be based beyond simple carbohydrate counting. It is advisable to adopt a careful approach when increasing insulin doses at mealtimes. Continuous Glucose Monitoring (CGM) or Self-Monitoring of Blood Glucose (SMBG) should guide the administration of any additional insulin needed.[32–35]
Weight gain can be another concern for individuals on insulin therapy, as insulin promotes glucose uptake into cells, which can lead to increased energy storage. Caloric intake should be moderated to prevent excess weight gain while ensuring optimal glucose control. In part, weight gain can result from frequent hypoglycemic episodes, in which individuals consume extra calories to treat their low glucose level and often overeat in response to hunger.[31,36]
Timing is the key to meal planning for people on insulin treatment. Meals should match the insulin dose, peak, and duration. While midmeals are important for people on short-acting insulin, they may not be important for people on rapid-acting insulin unless they are physically active.[36] CGM or SMBG[32–35] can help guide these decisions. Midmeals should ideally consist of protein, fiber, and healthy fat snacks, such as nuts and seeds.

13.3.2 Anti-Hyperglycemic Agents Not Leading to Hypoglycemia

The management of T2D includes a spectrum of pharmacological agents, some of which do not typically cause hypoglycemia as a side effect. While these agents reduce the need for stringent hypoglycemia-related dietary adjustments, they still influence nutritional recommendations and considerations due to their unique mechanisms of action and side effects. These drugs do not cause hypoglycemia. However, combination therapy with sulfonylureas or insulin poses the risk of hypoglycemia.

13.3.2.1 GLP-1 Receptor Agonist

Glucagon like Peptide -1 Receptor Agonist (GLP-1 RA) are popular because of their weight management, cardiovascular benefits, and glucose-lowering effect. These drugs do not cause hypoglycemia per se; however, when used in conjunction with sulphonylureas or insulin, the risk of hypoglycemia can increase.[37] Nutritional counseling for patients on GLP-1 analogs focuses on strategies to mitigate this risk. This might include advice on the timing of meals and snacks to coincide with the peak action of these medications and recommendations on adjusting the carbohydrate

content of meals to ensure stable BG levels throughout the day. This drug class's most common side effects are related to the gastrointestinal tract. Individuals often experience anorexia, nausea, and sometimes vomiting. Such individuals may need to be advised to have small, frequent meals and to avoid high-fat food items (Discussed in detail in Chapter 9 - Oral Antidiabetic Agents (OADA) Associated Nutritional Considerations).[38]

13.3.2.2 Metformin

Metformin is the cornerstone medication for the initial management of T2D, primarily due to its efficacy in lowering BG levels without significantly increasing the risk of hypoglycemia. This characteristic obviates the need for dietary adjustments specifically aimed at preventing hypoglycemia. However, metformin has been associated with decreased absorption of vitamin B_{12} and, to a lesser extent, folate, which can lead to deficiencies over time.[39] This has been discussed in detail in section 9.

Precautions with the use of metformin

Prevention of Gastrointestinal (GI) side effects: The drug's tolerability is improved with prebiotics. The diet should be high in fiber. Prevention of Vitamin B_{12} Deficiency and Its Consequences: Supplementation will be necessary when Vitamin B_{12} deficiency is identified. Prophylactic B_{12} prescription for levels between 150 and 300 pmol/L, especially in patients with poor glycemic control in whom metformin's neuroprotective action may be compromised.[40]

13.3.2.3 SGLT2 Inhibitors

Sodium-glucose cotransporter 2 (SGLT2) inhibitors control BG by promoting glucose excretion through the urine. This mechanism not only aids in lowering BG levels but also contributes to weight loss, as calories are lost with the excreted glucose. Besides BG control, gliflozins have been shown to provide significant cardiorenal benefits in people with T2D.[41] Despite not increasing the risk of hypoglycemia, individuals on SGLT2 inhibitors may require dietary counseling focused on maintaining adequate hydration, given the diuretic effect of these medications.[42] Furthermore, considering the weight loss effect, nutritional advice may also involve discussions on a balanced diet that supports weight management goals while ensuring nutritional adequacy. Patients should also be educated about the signs and risk factors for side effects, including recurrent Urinary Tract Infections (UTI) and euglycemic diabetic ketoacidosis (eDKA),[43] to ensure prompt identification and management. DKA with SGLT2 inhibitors can be associated with a low-carbohydrate, ketogenic diet, fasting, dehydration, and excess alcohol consumption.[43,44] SGLT2 inhibitors must be discontinued in patients who have developed fever, diarrhea, or vomiting or who have difficulty taking sufficient meals due to loss of appetite (e.g., during "sick days").[41,45] SGLT2 inhibitors and low-protein diets provide renal-protective benefits by decreasing single nephron hyperfiltration and reducing urinary protein excretion. Beyond their impact on glomerular hemodynamics, protein restriction, and SGLT2 inhibitors can restore autophagy. These mechanisms may offer protective effects against diabetic kidney disease.[46,47]

13.3.2.4 Dipeptidyl peptidase-4 (DPP-4) inhibitors

While these agents do not necessitate specific dietary adjustments to mitigate the risk of hypoglycemia, they may influence overall dietary planning.

13.3.2.5 Alpha Glucosidase Inhibitors

Alpha-glucosidase inhibitors (AGIs) are drugs used to treat T2D alone or combined with other antidiabetic drugs.[48] Acarbose should be taken with meals rich in complex carbohydrates and low in simple sugars.[49] AGIs delay the digestion of complex carbohydrates, helping to manage spikes in BG levels after meals.[50]

13.3.2.6 Thiazolidinediones

Thiazolidinediones, also called glitazones, help with glycemic control and insulin resistance in T2D management. These medications should be used with lifestyle modifications such as diet, exercise, and weight reduction. The most significant advantage of thiazolidinediones is that they do not cause hypoglycemia as monotherapy and are not contraindicated in patients with renal disease.[51] When pioglitazone is combined with other oral anti-hyperglycemic agents, it increases the risk of hypoglycemia, especially with insulin and insulin secretagogues.[52] There are undesirable side effects, particularly with long-term use, such as fluid retention and weight gain. The mechanism behind weight gain is a combination of factors. Glitazones upregulate PPAR-gamma receptors in the central nervous system, leading to increased feeding. Glitazones expand adipose tissue mass via the maturation of preadipocytes into mature adipocytes and increase fat storage by increasing free fatty acid movement into cells. Hence, calorie restriction in individuals on glitazones can help prevent weight gain.[53] Additionally, fluid retention can also increase weight. Monitoring sodium intake from salt and other hidden sources is recommended.

13.3.2.7 Glimin (Imeglimin)

Imeglimin is a first-in-class OADA with both a glucose-dependent insulin production-enhancing effect and an insulin sensitivity-improving effect.[54] Studies have shown better gastrointestinal tolerability in comparison with metformin.
Imeglimin, with its mitochondrial modulation, holds promise in mitigating beta-cell dysfunction and improving insulin sensitivity.[55] As monotherapy, it has not been shown to cause hypoglycemia. Hypoglycemia is slightly increased with imeglimin when added to glinides and sulfonylureas. Hence, monitoring carbohydrate intake and avoiding low-carbohydrate diets when combined with other OADAs is important.

13.3.3 Meal Patterns and Carbohydrate Intake

Carbohydrate intake must be consistent in timing and amount, as bolus insulin doses are calculated based on the carbohydrate content of meals and snacks.[56] This consistency helps avoid unexpected fluctuations in BG levels and reduces the risk of hypoglycemia and hyperglycemia. Mastering carbohydrate counting is essential, as it allows individuals to adjust their insulin doses according to the carbohydrate content of their meals.[56]

Few benefits to carbohydrate counting and insulin dosing

Carbohydrate counting is vital for patients on basal-bolus therapy. It involves estimating the total carbohydrates in a meal or snack and adjusting the short-acting or rapid-acting insulin dose accordingly. It positively affects metabolic control and helps keep the postprandial glucose levels within range, improving HbA1c. Healthcare providers play a critical role in educating patients on how to count carbohydrates accurately and understand the insulin-to-carbohydrate ratio, which is the amount of insulin needed to manage a certain amount of carbohydrates.[57]

13.4 CONCLUSION AND RECOMMENDATIONS

Clinical Pearls of Practice

- Incorporating MNT with anti-hyperglycemic agents offers several benefits in the management of diabetes. It can enhance adherence and help mitigate potential side effects associated with antidiabetic drugs like hypoglycemia, weight gain, and gastrointestinal disturbances.
- Health care professionals should tailor treatment plans that harmonize medication regimes with dietary advice.
- People with diabetes on agents leading to hypoglycemia (Sulphonylureas, Glinides, and Insulin) should not be prescribed VLCD, and diets that encourage long fasting hours should be avoided. Timely medication, portion control, and carb-consistent diets are helpful. Missing meals and the consumption of alcohol must be avoided with these drugs.
- Certain dietary factors may increase the risk of SGLT2 inhibitor-associated ketoacidosis, such as VLCD, ketogenic diets, long hours of fasting, dehydration, and excess alcohol consumption.
- Counseling people for adequate hydration is important while on SGLT2 inhibitors.
- With GLP1RAs, patients can have gastrointestinal side effects, and in combination with insulin and sulfonylureas, it can increase the risk of hypoglycemia.
- For people on insulin, carbohydrate consistency helps avoid fluctuations and reduces hypoglycemia and hyperglycemia risks.
- Carbohydrate counting is a vital tool for patients on basal-bolus therapy.
- Synchronisation of meals with insulin: **m**eals should match the insulin time, dose, peak, and duration.

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Section 14: MNT in Diabetes-Associated Complications

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14.1 INTRODUCTION

14.1.1 Medical Nutrition Therapy (MNT)

MNT is pivotal in managing complications associated with diabetes by optimizing nutrition intake and extending its impact beyond glycemic control.[1]

14.1.2 Diabetes Complications

Among the acute metabolic complications, diabetes may precipitate conditions such as ketoacidosis, hyperglycemic hyperosmolar state, hypoglycemia, and hypoglycemic coma. The most devastating consequence of diabetes lies in long-term vascular complications, categorized as microvascular and macrovascular, with the former having a much higher prevalence, encompassing conditions such as retinopathy, nephropathy, and neuropathy. Macrovascular complications include conditions like Cardiovascular Disease (CVD), stroke, Erectile Dysfunction (ED), and Peripheral Vascular Disease (PVD). PVD may lead to chronic conditions such as skin ulcers, which may be non-healing, gangrene, and, ultimately, amputation. Diabetes is also associated with an array of other chronic complications, including depression, dementia, dental problems, reduced immunity, sexual dysfunction, and pregnancy-related challenges.[2–4]

14.1.3 Incidence and Prevalence of Diabetes Complications

People with diabetes, undiagnosed and untreated, are at a greater risk of complications than those who are receiving treatment. Although it is widely accepted that managing normal Blood Glucose (BG) levels can help reduce the risk of complications associated with diabetes, evidence suggests that glycemic control alone is not sufficient to prevent and manage diabetes complications. However, while there is strong evidence to support this claim regarding microvascular complications, the evidence is not as strong regarding cardiovascular complications. The most effective approach for reducing diabetes-related complications is combining efforts to control BG, Blood Pressure (BP), lipids in blood, and other lifestyle factors, including nutrition.[5]

According to a recent Meta-Analysis, which included 59 population-based studies, among people with diabetes, the global prevalence was 22.27% for diabetic retinopathy.[6] In a recent systematic review of 4,549,481 people with diabetes, the overall prevalence of macrovascular complications (such as CVD and stroke) was 32.2%.[7] The literature reports that 6–51% and 31–73% of patients with diabetes mellitus will eventually develop neuropathy and nephropathy, respectively, during their lifetime.[8–13]

Individuals with diabetes are nearly twice as likely to develop Chronic Kidney Disease (CKD) compared to those without diabetes. The likelihood of CKD, reflected in odds ratios ranging from 1.3 to 4.6, varies depending on geographic location and the presence of risk factors such as hypertension, dyslipidemia, obesity, and a sedentary lifestyle. Among those people with diabetes, CKD prevalence varies widely between countries, with estimates ranging from 27.1% in China to 83.6% in Tanzania.[11] A retrospective cohort study with 1,35,199 individuals in the US showed that among all complications of diabetes, at the time of diagnosis, the prevalence of CKD was the highest (prevalence = 12.3%), while CVD was among the lowest at 3.3%. The median time to incidence of a diabetes complication ranged from 3.0 to 5.2 years. High incidence rates included peripheral neuropathy (26.9 to 27.3/1000 person-years (PY), CKD (21.2 to 21.6/1000 PY), and CVD (11.9 to 12.2 per 1000 PY).[14] Data from the Indian CKD (ICKD) study, a large cohort study of individuals with mild-to-moderate CKD in a lower-middle-income country, shows that CKD in India occurs at a lower mean age than in the rest of the world. Most individuals (2/3rd) in the ICKD study are males, which contradicts the Western literature. While the majority of individuals exhibit a sedentary lifestyle, the Body Mass Index (BMI) within the ICKD cohort is lower.[15]

India is the second country in the world with the highest number of people with diabetes. The reason for this is the genetic predisposition of Indians to Type 2 Diabetes Mellitus (T2D) combined with rapid urbanization and socio-economic development, which has led to significant changes in lifestyle.[16] Asian Indian people with diabetes tend to have a higher risk of Coronary Artery Disease (CAD) and, possibly, a lower risk of microvascular complications compared with white individuals.[17] In studies on the prevalence of diabetic retinopathy (DR) in India, a lower prevalence compared with Western populations has consistently been seen. In the population-based Chennai Urban Rural Epidemiology Study (CURES) cohort,[18] the prevalence of retinopathy in self-reported people with diabetes was 17.6% (vs. 30% in the Western population), and similar figures were reported by two other studies from other regions in India.[19,20] More than 65% of people with diabetes die of CVD; of these, nearly 80% are attributable to CAD. The susceptibility of Asian Indian individuals to CAD is well-known.[21,22] Compared with white individuals, CAD tends to develop a decade or two earlier, and triple-vessel disease is more common. Mortality after an acute coronary event is also 40% higher in Asian Indians.[23] The presence of T2D seems to confer a 3–4 times higher risk of CVD to Asian Indians than to their white counterparts, even after adjusting for sex, age, smoking status, hypertension, and obesity.[17] The prevalence of diabetic neuropathy in India was found to be between 19.1 to 39.3%.[12] (Table 14.1)

14.1.4 Modifiable Risk Factors for Diabetes Complications Helpful in Preventing/Managing the Disease

Table 14.1. Lifestyle Modification Strategies for Managing Complications

Self-management behavior	• Essential for glycemic control and preventing disease progression and associated complications. • Need to empower intervention programs, including self-care routine involving a change in dietary patterns, exercise, regular self-medication, insulin injection, Self-Monitoring of Blood Glucose (SMBG) and insulin dose adjustment.[24]
Hypertension	• Treating hypertension reduces both micro- and macrovascular complications of T2D as per the United Kingdom Prospective Diabetes Study (UKPDS). • Every 10 mm Hg drop in systolic BP (through either Angiotensin Converting Enzyme Inhibitors (ACEIs) or Beta-blockers (BBs) yields a o 15% decrease in DM-related mortality. o 11% decrease in Myocardial Infarction (MI). o 13% decrease in microvascular complications such as retinopathy or Diabetic Kidney Disease (DKD).[25] • Lifestyle interventions for individuals with hypertension should involve o education on adopting the DASH (Dietary Approach to Stop Hypertension) diet. o Appropriate dietary intervention for weight reduction for those with higher BMI.
Body weight management	• T2D is strongly associated with being overweight or obese. • It is a well-known fact that weight loss in people with diabetes and obesity is likely to reverse metabolic abnormalities and improve glucose control. • Losing 15% or more of body weight can have a disease-modifying effect that cannot be achieved through any other glucose-lowering intervention.[26] • People with diabetes should be made aware of their desirable body weight and given a target towards which they need to work. • Antihyperglycemic therapy impacts body weight. • The American Diabetes Association (ADA) recommends weight-neutral and weight-reducing antihyperglycemic medications.[27] • An optimal waist circumference: Men < 80 cm, Women < 84.5 cm.[28] • An optimal waist-to-height ratio (WHtR)≥ 0.52 for both genders.[29]
Exercise	• Regular physical activity and exercise are crucial for managing diabetes and its complications. • Exercise can improve BG control, reduce cardiovascular risk factors, enhance overall well-being, and aid in weight loss. • Even without weight loss, an eight-week exercise program can reduce HbA1c levels by 0.66% in people with diabetes[30] • Encourage people with diabetes to break up prolonged sitting by standing, walking, or doing light physical activities. • Recommend aerobic and resistance training (muscle strengthening) as per the kidney diseases: Improving Global Outcomes (KDIGO) guidelines.[31]
Smoking cessation	• Active smoking significantly increases cardiovascular risks in people with diabetes. • Smokers with diabetes have 1.44 times greater[32] o CVD risk o Premature death o Microvascular complications
Alcohol	• Alcohol use in diabetes has been controversial o Short-term risks: Hypoglycemia, metabolic dysregulation, and acidosis. o Long-term risks: Hypertension, weight gain, and neuropathy. • Alcohol intake impacts glucose metabolism in people with or without diabetes. o Alcohol without food causes hypoglycemia, inhibiting both gluconeogenesis and glycogenolysis. o Mild to moderate alcohol consumption ♣ Has been shown in several studies to lower the risk of atherosclerotic disorders, improve insulin sensitivity, and cause minimal disturbances in glycemic control, weight, and BP. ♣ However, currently, the potential metabolic health benefits of mild to moderate alcohol use remain controversial and unclear at the individual level. ♣ Therefore, counseling should not advocate alcohol use for beneficial purposes. • Heavy consumption negates cardiovascular benefits.[33] • People with diabetes should avoid heavy drinking (more than 10 to 12 drinks/day).[34] o To prevent ketoacidosis and hypertriglyceridemia.

Diet management	• Lifestyle changes can prevent several cases of T2D, and MNT is crucial for managing diabetes-associated complications. o MNT for people with diabetes is the same for those with and without complications. • The goal is to control BG levels, lipid profile, and body weight.
Glycemic control	• Regular monitoring and maintaining near-normoglycemia can delay and reduce the incidence of complications.[35] • Continuous Glucose Monitoring (CGM) can offer added benefits to standard care in diabetes management that may improve glycemic outcomes.
Glycemic variability	• Studies have shown a positive association between glycemic variability and diabetes complications, both macrovascular and microvascular.[36] • Glucose fluctuations (hyperglycemia followed by hypoglycemic episodes) have a significant additional effect to that of mean glucose concentration and are therefore considered a key factor in the development of complications.

14.2 MNT FOR DIABETES-ASSOCIATED COMPLICATIONS

14.2.1 MNT for Complications Associated with Diabetes

India is a country rich in ethnocultural diversity, and different ethnocultural groups have distinct and shared foods, food preparation techniques, dining habits, dietary patterns, and lifestyles that directly impact the delivery of nutrition therapy. Hence, a *one-size-fits-all* eating plan is an unrealistic expectation given the broad spectrum of individuals affected by diabetes and prediabetes. There is a need to develop a *transcultural* approach to nutrition therapy that provides culturally congruent nutrition counseling. Therefore, the MNT in diabetes-associated complications should involve designing individual-centric diet plans that are also medically appropriate and serve as an effective tool for preventing diabetes complications.

14.2.2 Complications Such as Diabetic Nephropathy, Neuropathy, Cardiovascular Diseases, and Stroke

Malnutrition is common in DKD due to anorexia, malabsorption, acidosis, uremic toxins, increased catabolism, urine protein losses, etc. A nutritional assessment should be done at least biannually. A registered dietitian is recommended to guide therapy.
Anthropometry measurement is recommended at least monthly in maintenance hemodialysis (MHD) and Peritoneal dialysis (PD), every 3 months in individuals with CKD stages 4–5, and at least every 6 months in individuals with CKD stages 1–3. Waist circumference, conicity index, and creatinine kinetics are used in individuals undergoing dialysis. Biochemical and body composition measures include serum albumin, lipids, pre-albumin, Bioelectrical Impedance Analysis (BIA), and Dual-Energy X-ray Absorptiometry (DEXA). Subjective Global Assessment (SGA) and malnutrition inflammation score (MIA) are commonly used for nutritional assessment, especially in dialysis individuals.[37] (Table 14.2, 14.3, 14.4, 14.5)

Table 14.2. Medical Nutrition Therapy for Diabetic Nephropathy

Prescribed Intake	Description
Energy	• 25–35 kcal/kg/day is recommended.[37]
Protein	• 14–20% of the total energy intake. • KDIGO (2024) guideline recommends dietary protein intake: 0.8 g/kg body weight/day for adults with CKD, Stages G3-G5[38] • The practice point suggestion is avoiding high protein intake exceeding 1.3 g/kg of body weight/day. • In adults with CKD who are willing and able, and who are at risk of kidney failure, consider prescribing, under close supervision, a very low protein diet (0.3-0.4 g/kg of body weight/day) supplemented with essential amino acids or ketoacid analogs (up to 0.6 g/kg of body weight/day).
Fats	• 20–30% of the total energy intake. o Linoleic acid (Omega-6 Polyunsaturated Fatty Acids or PUFA): 5–10% of energy. Good dietary sources include vegetable oils, nuts, and eggs. o Alpha Linoleic Acid (ALA), an omega-3 PUFA: 0.6–1.2% energy. Good dietary sources include fish oil, flax seeds, walnuts, and chia seeds. • To reduce triglycerides and Low-Density Lipoprotein (LDL) cholesterol and to raise High-Density Lipoprotein (HDL) levels, the updated Kidney Outcome Quality Initiative (KDOQI) 2020 guideline recommends 1.3–4 g/day LC Omega-3 PUFA.[37] • For adults with CKD, Stages G3-G5 with or without dyslipidemia, KDOQI 2020 guidelines suggest Mediterranean Diet (MD) that may improve lipid profiles.
Carbohydrate intake	• 50–60% of the total energy intake • Complex carbohydrates are recommended over simple carbohydrates to reduce triglyceride synthesis and improve glucose tolerance.

Sodium intake	• Most individuals with DKD retain salt. • Salt-sensitive hypertension, often associated with CKD, is a major contributor to the progression of DKD. • For advanced CKD [Glomerular Filtration Rate (GFR) < 10 mL/min/1.73m^2] o Sodium intake should be under 2.0 g/day (salt 5 g or 1 tsp/day) o To prevent fluid and salt overload o Some individuals with CKD have salt-losing nephropathy and may develop sodium depletion. **Note** • Recommended to avoid hidden sources of salt in processed and preserved foods ♣ Sauces, soy sauce, ketchup, salad dressings, ready-to-eat foods, canned food, nankeens, breads, biscuits, bakery items, papads, pickles, and dry fish. • Avoid low-sodium salt substitutes as they contain excess potassium.
Fluids	• Fluid intake in advanced stages of CKD should be adjusted based on fluid status and daily urine output to prevent overload or dehydration[37]
Potassium intake	• Recommended to maintain normal potassium levels Dietary restrictions are to be implemented in case of potassium retention and when potassium-retaining medications are prescribed. • KDIGO clinical practice guidelines on hypertension and antihypertensive agents in CKD recommend o Potassium intake of 4–6 g/day: For CKD stages 1 and 2 o Potassium intake of 2.4 g/day: For CKD stages 3 and 4[31]
	Note • In case of hyperkalemia o Recommended to avoid high-potassium foods o Low-potassium fruits and vegetables are advisable. These include apples, blueberries, raspberries, strawberries, watermelon, pineapple, grapes, oranges, peaches, cucumbers, asparagus, carrots, and cauliflower. o Among millets, kodo millet and samai are low in potassium. o Compared to animal meat, poultry, such as chicken, has less potassium, and prawns and oysters have low potassium.

Calcium intake	• In CKD Stages 3–4, a total elemental calcium intake of 800–1000 mg/day.[37] ♣ Dietary calcium, calcium supplementation, and calcium-based phosphate binders to maintain a neutral calcium balance. ♣ Preferable to use calcium carbonate for high (40%) elemental content; others that can be used include calcium acetate (33%), lactate (13%), or gluconate tablets (9%).[39] ♣ Cholecalciferol should be used to correct vitamin D deficiency, while active vitamin D analogs are used to treat hyperparathyroidism.
	Note • Hypercalcemia may result in vascular calcification and adynamic bone disease. ♣ Recommended to avoid the development of hypercalcemia.
Prescribed Intake	**Description**
Phosphorus intake	• Phosphorus is recognized as a uremic toxin that can lead to vascular calcification if levels are elevated o Recommended controlling serum phosphorus levels through dietary choices and pharmacological interventions o Phosphorus in fast foods, ready-to-eat foods, aerated drinks, and processed foods is absorbed more rapidly. o Plant foods are generally preferred over animal sources due to their lower phosphorus content relative to protein. • It is advisable to choose foods that minimize phosphorus intake while maintaining adequate protein consumption. o A low phosphorus-to-protein ratio foods, such as eggs, will minimize phosphorus intake while maintaining adequate protein consumption o Avoid high-phosphorus foods such as colas, chocolates, and nuts

	• To reduce dietary phosphorus, it is recommended to take a diet with low levels of phosphorus, 8-12 mg/kg/day, and 0.55 g/kg of protein. ♣ To further decrease serum phosphorus to 4–6 mg/kg/day, it is recommended to utilize essential amino acids or keto analogs. ♣ This, however, will not maintain serum phosphorus levels within the normal range in individuals with GFR less than 15 mL/minutes, where phosphate binders must be used to reduce phosphorus absorption. ♣ Older aluminum-based phosphate binders have been replaced for safety reasons with • Calcium-based binders such as calcium carbonate, calcium acetate. • Calcium-free phosphorus binders such as sevelamer hydrochloride/carbonate and Lanthanum carbonate.
Magnesium intake	• Restricted diets for CKD individuals typically contain low levels of magnesium (200 to 300 mg for a 40 g protein intake). • Serum magnesium levels are maintained at normal ♣ Unless individuals take magnesium-containing antacids and laxatives. ♣ This necessitates careful monitoring of CKD individuals.
Vitamin intake	• In adults with CKD 1–5, folate, vitamin B_{12}, and/or B-complex supplements are recommended to correct folate or vitamin B_{12} deficiency based on clinical signs and symptoms. • In adults with CKD 1–5 at risk of vitamin C deficiency, supplementation to meet the recommended intake of at least 90 mg/day for men and 75 mg/day for women is reasonable. • In adults with CKD 1–5, vitamin D supplementation in the form of cholecalciferol to correct 25-hydroxy cholecalciferol vitamin D (25-OH Vitamin D) deficiency/insufficiency is recommended.
Anemia correction	KDIGO guidelines recommend[31] • Maintain hemoglobin at 9.5g/dL to 10.5 g/dL and judiciously use oral/IV iron and recombinant erythropoietin (rEPO) to avoid blood transfusions. • Newer iron therapy targets aim at serum ferritin of 700 ng/mL, compared to previous targets of 500 ng/mL (PIVOTAL trial). • Iron is supplemented as ferrous sulfate 300 mg. Newer oral iron preparations include ferric citrate, ferrous fumarate, sucrosomial, and liposomal iron, which have lesser gastrointestinal side effects. • Erythropoietin is used in iron-replete anemic individuals where anemia is found to be due to CKD. • Short-acting erythropoietin is used in a dose of 4000 units thrice a week Subcutaneously (SC), Darbepoetin can be given weekly while Continuous Erythropoietin Receptor Activator (CERA), can be used either once or twice a month. • Newer drugs called Hypoxia-inducible Factor Prolyl Hydroxylase Inhibitors (HIF-PHIs) are available, which can be used in Epo-naive or Epo-resistant individuals. Desidustat is available nationwide and can be used at 100 mg on alternate days.
Alkaline therapy	• The target should be a serum bicarbonate level of >18 mmol/L[38] • One gram of sodium bicarbonate powder contains 13 mEq of bicarbonate. • Sodium bicarbonate supplementation should be avoided if the individual is fluid-overloaded or hypertensive. • A dietary pattern with increased fruit and vegetable intake in individuals with CKD has potential benefits for lipid profile, BP, and net acid production.
Dietary fiber	• It helps prevent constipation, irritable bowel, diverticulitis, and colon neoplasia. o 15 g/1000 kcal of fiber should be taken/day • Fiber also reduces Blood Urea Nitrogen (BUN) by increasing fecal ammonia excretion.
Dialysis	• It is reasonable to consider supplementation with multivitamins that are lost during dialysis o All water-soluble vitamins (B complex vitamins) should be supplemented. o Fat-soluble vitamins, i.e., Vitamin A and E, are not removed by dialysis.
Critically ill individuals	• For those individuals who are critically ill or unable to eat orally, alternatives include Ryle's tube feeding, jejunostomy, or parenteral nutrition. However, enteral feeding remains the best method.

Table 14.3. Medical Nutrition Therapy for Diabetic Retinopathy

Dietary Approach	Key Points
Diabetic Retinopathy (DR)	• Nutritional counseling aimed at managing diabetes is recommended and may also prove beneficial in preventing the risk of DR. o Increased consumption of fruits, vegetables, dietary fiber, fish, tea, oleic acid, and vitamins A, B_6, and B_{12} have been associated with a protective effect against DR. o Conversely, high intakes of diet soda, sodium, caloric intake, polished rice, and choline have been linked to a higher risk of DR. o Carotenoid intake is associated with a reduced risk of incident DR. o Foods such as green leafy vegetables (spinach, fenugreek, and lettuce) and egg yolks, rich in lutein and zeaxanthin- two carotenoid molecules that have antioxidant properties- have been found to protect the eyes, particularly the macula and retina. o Studies suggest that a higher intake of foods that are rich sources of long-chain omega-3 PUFA, like fish or fish oil, may offer benefits in managing DR. o Research indicates that consuming at least 500 mg/day of dietary omega-3 fatty acids could decrease the risk of DR - fatty fish, is a good source of omega-3 FAs. It can also be found in algae, seeds (flax and chia), and high-fat plant foods (Walnuts).[40,41]

Table 14.4. Medical Nutrition Therapy for Diabetic Neuropathy

Dietary Approach	Key Points
Diabetic neuropathy	• A balanced diet that includes certain supplements, such as alpha-lipoic aid, vitamin B112, and acetyl-L-carnitine, may help alleviate symptoms of diabetic neuropathy. • Vitamin B12 can be obtained from foods like dairy products, nutritional yeast, eggs, fish, and lean red meat. Alpha-lipoic acid is found in foods such as spinach, broccoli, potatoes, yams, carrots, and lean red meat. It is important to consult a healthcare professional before starting any supplements, as they may interact negatively with diabetes medications or could potentially harm kidneys. • In general, regular exercise is beneficial for individuals with diabetes. However, in proliferative neuropathy, it's advisable to avoid exercises that could elevate blood pressure. For those with advanced neuropathy or numb feet, caution is needed with weight-bearing exercises to prevent the risk of diabetic foot ulcers.

Table 14.5. Comprehensive Dietary Strategies for Diabetes Management for All Complications Prevention: A Review of Evidence-Based Approaches

Dietary Approach	Key Points
Medical Nutrition Therapy (MNT)	• It should be tailored to the specific needs of people with diabetes, considering their o Typical dietary patterns o Duration of diabetes o Metabolic status o Treatment objectives o Desired results • Regular monitoring of metabolic indicators, o Glucose levels o HbA1c o Lipid profile o BP o Body weight o Renal function • Continuous access to nutrition education and self-management support is essential • A dietary pattern that may be beneficial for people with diabetes to prevent or treat CVDs.[42]
Low Glycemic Index (GI) diets	• Low-GI foods curb the large and rapid rise of BG, insulin response, and glucagon inhibition that occur with high-GI foods.[36] o Hence, low GI foods may be effective in the management of diabetes and diabetes complications.[35]
Low fat diet	• Limit fat intake to 30% of total calories o A high-fat diet increases insulin resistance. o A high-fat diet enhances hepatic glucose production, contributing to hyperglycemia[43] o A low-fat diet offers minimal glycemic control improvement but has beneficial effects on cardiovascular risks.[44] o Use of different types of oils on rotation provides a balance of all the required FAs. Particularly including foods rich in n3 PUFA, moderate use of n6 PUFA-containing oils, and limiting the use of high saturated-fat (SF) oils is recommended.
High protein diet	• High-protein diets, 15-20% of the total calories (High protein is not recommended for diabetic nephropathy) o It can improve glucose control. [44,45] o Must be individualized for cardiometabolic risk and renal profile. o Quantity of intake depends on age, sarcopenia, and renal dysfunction. o A Plant-dominant low-protein Diet (PDADO) with ≥ 50% plant-based sources to meet the targeted dietary protein improves glycemia, uremia, BP, acid-base balance, and gut microbiota.
Sodium chloride restriction	• Salt (NaCl) intake should be limited to 2.0 g/day.[38] o Low sodium salt substitutes available in the Indian market contain potassium, making them unsuitable for CKD individuals due to hyperkalemia risk. • Fluid intake in advanced stages of CKD should be adjusted based on fluid status and daily urine output to prevent overload or dehydration. • Salt-sensitive hypertension, often associated with CKD, is a major contributor to the progression of DKD.
Vitamins	• Crucial for preventing and managing diabetes and associated complications. It plays a role in glucose metabolism, including insulin release and sensitivity. • Vitamin D deficiency is associated with insulin resistance and macro- and microvascular complications such as CVD, neuropathy, and DKD.[46] o Studies indicate vitamin D is renoprotective, potentially delaying the onset of DKD. o Measures to prevent VDD with diet or sunlight exposure should be considered. o Appropriate doses of supplementation may be recommended for high-risk groups, people with diabetes, and individuals with deficiency.
Dietary Approach	**Key Points**
	• Vitamin B-complex o B_1, B_3, B_6, B_7, B_9, and B_{12} have notable effects on diabetes and nephropathy, neuropathy, retinopathy, and CVD.[47] o B_{12} deficiency is associated with DR and increased

	homocysteine.[48–50] o There is a high prevalence of subclinical deficiencies of B-vitamins and dietary inadequacies in apparently healthy adults, emphasizing the importance of regular monitoring, particularly in long-term diabetes management.[49,50] o For people with diabetes, a recommendation of dietary intake of B-vitamin at a level little above RDA could be made. o To decrease the incidence of Vitamin B_{12} deficiency in people with diabetes, taking metformin, therapeutic supplements, or injections along with a B_{12}-rich diet is encouraged. o Epidemiological studies demonstrate that increased intake of green leafy vegetables and fruits lowers the risk of T2D and its complications through the beneficial effects of phytochemicals, such as carotenoids that improve glucose homeostasis, insulin resistance, and retinal blood flow. o Education on the importance of carotenoids in the prevention and management of diabetes and its complications is crucial for future interventions, as research findings indicate that the dietary intakes and plasma concentrations of carotenoids were low in India and significantly lower in people with diabetes and its complications, such as retinopathy.[51]

14.3 CONCLUSION AND RECOMMENDATIONS

Clinical Pearls of Practice

- The most effective approach for reducing diabetes-related complications.
  - Include combining efforts to control BG, BP, lipids in the blood, and other lifestyle factors such as physical activity, nutrition, and stress management.
- Carbohydrate intake should emphasize nutrient-dense sources high in fiber, such as vegetables, whole fruits, legumes, and whole grains.
- Advise people with diabetes to consume high fiber from vegetables (fenugreek leaves, spinach, beans, peas, bell pepper, cauliflower, broccoli, carrots, sweet potato, etc.).
- Ensure that at least half of all grains are consumed as whole grains.
- Include fiber-rich foods with every meal or snack.
- Advice to consume 15–20% of total calories from protein to improve health in individuals without DKD.
- Protein should not be used to treat acute or prevent nighttime hypoglycemia since ingested protein can increase insulin response without increasing plasma glucose concentrations.
- Those with DKD (albuminuria and/or reduced eGFR) should maintain dietary protein at no more than 0.8 g/kg desirable body weight/day.
- Lowering dietary cholesterol to < 200 mg/day is recommended.
- Advice to limit SF intake by reducing processed and fast foods, red meat, and full-fat dairy products.
- Red meat should be replaced with beans, nuts, skinless poultry, and fish whenever possible.
- Switching from whole milk and other full-fat dairy foods to lower-fat versions is encouraged.
- Instruct using liquid vegetable oils rich in PUFA and MUFA in cooking instead of butter or margarine.
- Check food labels for trans fats; limit fried fast foods.

- Use various oils on rotation to balance all the required FA.
  - o Include foods rich in omega-3 PUFA, like vegetable oils, walnuts, flaxseeds, chia seeds, and fish.
  - o Use of omega-6 PUFA-containing oils should be in moderation.
  - o Limiting the use of highly saturated fat oils is recommended. Examples are canola oil, corn oil, safflower oil, soybean oil, and sunflower oil.
- People with diabetes should fulfill their vitamin and mineral needs through a well-balanced diet of natural food sources rather than synthetic supplements.
- Excessive doses of specific vitamins or mineral supplements, when there is no deficiency, offer no benefit and may even be harmful.
- Evidence suggests that those on metformin therapy have a higher risk of B12 deficiency and may need Vitamin B12 supplementation if tests indicate a deficiency.
- Not adding salt to foods during cooking or at the table and decreasing consumption of most pre-prepared and pre-packaged foods is recommended.
- For patients with diabetes and symptomatic heart failure, dietary sodium intake of < 2,000 mg/day may reduce symptoms.
- Patients with hyperkalemia should still limit the amount of leached high-potassium-containing food.
- Another easy way to lower the amount of extra potassium in food is to avoid drinking or using the liquid from canned fruits or vegetables or the juices from cooked meat.
- Pressure cooking, baking, steaming, microwaving, and stir-frying should be avoided as these cooking methods will not remove enough potassium.
- Avoid eating processed foods as they contain potassium additives.
- Patients with proliferative retinopathy should refrain from engaging in exercises that may lead to high blood pressure.
- Supervised exercise programs in patients with diabetes are well tolerated.
- Alcohol intake is discouraged in patients at high risk for heart failure.

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Section 15: Medical Nutrition Therapy (MNT) in Special Situations

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15.1 SICK DAY GUIDELINES

Acute or chronic illness in diabetes can be potentially debilitating and even life-threatening, disrupting the delicate balance of glucose metabolism and triggering a cascade of metabolic derangements. In this context, optimal nutritional management is crucial in the comprehensive care of individuals with diabetes during acute illness. This section delves into managing acute illness in people with diabetes, emphasizing the critical role of nutritional intervention. (Table 15.1, 15.2, 15.3)

Table 15.1. Metabolic Derangements in Acute Illness in People with Diabetes

Increased catabolism	• Elevates stress hormones, leading to insulin resistance and increased glucagon release. • Subsequently, it contributes to elevated Blood Glucose (BG) levels.
Increased water loss	• Fever and diarrhea result in water loss, potentially leading to dehydration. Dehydration can be exacerbated by polyuria. • Polyuria associated with elevated glucose further depletes electrolytes, vitamins, and minerals.
Electrolyte disturbances	• A significant challenge in managing acute illness among people with diabetes. • Fluctuations in glucose levels, insulin therapy, and comorbidities such as renal impairment causes disruptions in electrolyte balance. • Manifestations include hyperkalemia, hyponatremia, hypernatremia, and hypokalemia.
Diabetic Ketoacidosis (DKA) and Hyperosmolar Hyperglycemic State (HHS)	• Common acute complications associated with profound electrolyte imbalances, especially sodium, potassium, and serum bicarbonate levels, with emphasis on serial improvement in the anion gap, which signals improvement in DKA. • Require prompt recognition and correction to prevent life-threatening complications such as arrhythmias, seizures, and cerebral edema. • Close monitoring of electrolyte levels, hydration status, and renal function is essential in acute management to optimize outcomes and minimize morbidity and mortality.[1] • Manifestations of ketoacidosis include polydipsia, abdominal pain, polyuria, leg cramps, dehydration, nausea/vomiting, shortness of breath, confusion, and drowsiness. • Manifestations of an HHS include polyuria, polydipsia, xerostomia, disorientation or confusion, nausea in the later stages, drowsiness, and gradual loss of consciousness. • The focus of infection, which is more common in HHS and less common in DKA, has to be meticulously ruled out to improve outcomes.

Table 15.2. Management for Aspects of Acute Illness

Fever and infection	• Ensure adequate calorie intake to meet heightened energy requirements. • A soft diet such as curd rice is recommended due to low appetite. • Emphasize intake of liquids for better tolerance. • Incorporate immune-boosting nutrients.[2–5]
Diarrhea and vomiting	• Fluid and electrolyte replacement as primary therapy. • Monitor for dehydration symptoms: low urine output (less than 0.5 mL/kg/h in children and less than 400 mL daily in adults), dry skin, confusion, and sleepiness.[6] • Opt for liquids and a soft diet for better tolerance. • Limit insoluble fiber (<20 g/day) during acute diarrhea. • Consider tender coconut water, fresh juices, and rice porridge if unable to eat. • For BG >180 mg/dL, low-carbohydrate fluids such as plain water, salted buttermilk, vegetable soup, coconut water (around 10 g carb/250 mL cup), World Health Organization Oral Rehydration Solution (WHO ORS) (14 g dextrose/liter), salted lemon water, jaljeera, and such can be given. • For BG <180 mg/day, sweetened liquids such as homemade lemon water or buttermilk with salt can be given.
Hyperemesis Gravidarum[7,8]	• Potentially a life-threatening condition. • Ensure nutritional adequacy to support fetal growth. • Consider oral nutrition supplements supporting euglycemia. • Hospital admission and parenteral nutrition for acutely severe cases. • Enteral feeding options, if unresolved after the first trimester. • Fluid and electrolyte replacement as needed. • Preference for liquid and soft diets. • Consider B6 supplements to reduce vomiting.
Nutritional ketosis	• Monitor for signs of ketosis. • Administer insulin as needed. • Address dehydration promptly.
Electrolyte and hydration guidelines in sick days[2,3]	• Hydrate with 100–250 mL of water (or sugar-free, caffeine-free alternatives) every awake hour. • Consider electrolyte replacement solutions such as WHO ,ORS (Oral Rehydration Solution). • Opt for easily digestible fluids and foods such as lightly sweetened lime juice, buttermilk, rice, dal water, strained vegetable juices and soups, broths, and diluted fruit juices.

Carbohydrate prescription[3]	• Avoid fasting; maintain carbohydrate intake every 4 hours (up to 50 g) with oral feeds or nutrition supplements with balanced macronutrients. • Features of glycemic-friendly oral nutrition supplements[9–12] o High fiber, higher protein (23% energy), higher fat (25% energy), and reduced carbohydrates (40% energy). o Slow-digesting carbohydrates such as isomaltose or sucromalt. o The glycemic index (GI) ~ 46. • Monitor BG levels every 2–4 hours and drink adequate sugar-free fluids if glucose levels are raised.
Monitoring in sick days	• Aim for controlled BG levels (140–180 mg/dL). • Check BG every 4 hours; monitor urinary ketones if necessary. • Seek medical assistance for persistent symptoms or abnormal BG readings. o Persistent vomiting or diarrhoea for more than 6 hours on consumption of liquids. o The individual's temperature has been over 101 degrees F for 24 hours, and breathing difficulty. o Extreme fatigue and confusion, thirst, dry mouth, frequent urination, and fruity odour breath. o BG levels are above 240 even after medications.
Drugs that may need monitoring in acute illness[13]	• Physician's advice on the adjustment in diabetic medications o Consider stopping metformin as it can lead to lactic acidosis. o Consider stopping Sodium-glucose Cotransporter 2 (SGLT2) inhibitors, as they can lead to ketoacidosis. o Consider withholding sulfonylureas if hypoglycemic symptoms arise. o Evaluate Glucagon-like peptide-1 (GLP-1) analogs and other medications in cases of dehydration or abdominal symptoms, nausea, and vomiting so that ketoacidosis can be prevented. o Continue insulin therapy with adjustments as needed. • Consider discontinuing Angiotensin-converting Enzyme (ACE) inhibitors, Angiotensin Receptor Blockers (ARBs), Diuretics, and Nonsteroidal Anti-inflammatory Drugs (NSAIDS) during dehydration.

Table 15.3. Recommendations for Monitoring and Vigilance During Sick Days

Sick day management	• Provide comprehensive sick day education during initial consultations. • Ensure preparedness for acute illness. • Teach and prescribe about hydration and electrolyte status. • Ensure adequate carbohydrate intake using liquids, Oral Nutrition Supplements (ONS), and enteral feeding if necessary. • Educate on vigilance for symptoms of hypoglycemia, ketoacidosis, and hyperosmolar hyperglycemia. • Follow-up to reinforce understanding and address any concerns.

15.2 HYPOGLYCEMIA

15.2.1 Introduction

Hypoglycemia poses a significant challenge to the effective management of diabetes.[14] This condition manifests when blood glucose concentration falls below the physiologically acceptable thresholds due to disequilibrium between insulin or insulinogenic therapy (such as sulfonylureas and exogenous insulin) and a multitude of variables (dietary intake, physical activity, organ functionality, and the presence of hypoglycemia-associated autonomic dysfunction). Notably, the propensity for hypoglycemic episodes escalates in specific demographics and conditions, including older adults, individuals with long-standing diabetes, those suffering from renal insufficiency or kidney failure, pregnancy, fasting states, and in the context of certain metabolic disorders.[14] Moreover, periods marked by heightened stress, acute illnesses, and intense exercises further exacerbate the risk, highlighting the necessity for meticulous monitoring and judicious management of this condition, as highlighted by the American Association of Clinical Endocrinologists (AACE).[15]

15.2.2 Types of Hypoglycemia

Table 15.4. Types of Hypoglycemia

Fasting Hypoglycemia (FH)	• **Definition** o A metabolic condition characterized by low BG levels following a period of fasting. • **Common causes**[16] o Insulinoma: A pancreatic tumor that produces excessive amounts of insulin. o Neoplasia: Various types of cancer that can affect glucose metabolism. o Alcohol consumption: This can interfere with the liver's ability to release glucose. o Drugs: Certain medications may affect BG levels. • **Management approach** o Cause-specific treatment: Management strategies are tailored according to the underlying cause of hypoglycemia.
Nocturnal Hypoglycemia (NH)	• **Definition** o A condition where BG levels drop below 70 mg/dL during sleep. People with diabetes who have dementia, Chronic Kidney Disease (CKD), decompensated chronic liver disease, cardio or cerebrovascular complications should regularly monitor their BG levels around 3 am. • **Management in awake individuals** o Mild-to-moderate cases: These can be corrected by consuming a snack containing about 15 g of fast-acting carbohydrates. Examples: glucose tablets or drinks, biscuits, or a sandwich.[17] o MNT consideration: Avoid high-fat foods during treatment to prevent slowing down glucose absorption.[17]
Drug-Induced hypoglycemia (DIH)	• **Risk of hypoglycemia and antidiabetic agents** o Higher risk classes: Insulins, sulfonylureas, and glinides are associated with a greater risk of moderate to severe hypoglycemia when used as monotherapy. • **Sulfonylureas specifics** o Older and long-acting: Drugs like glibenclamide may cause prolonged and profound hypoglycemia, especially in the elderly. Use it with caution. o Newer generation: Gliclazide modified release and glimepiride are associated with a lower risk of hypoglycemia, making them preferable for South Asian people with diabetes. • **Co-formulation (Aspart and Degludec) insulin benefits**[14,18] o Offers reduced risks of both overall and nocturnal hypoglycemia. • **Management of hypoglycemia in combination therapy** o Alpha-Glucosidase Inhibitor (AGI) Component: If hypoglycemia results from the combination therapy, including an AGI, treat it with oral glucose rather than sucrose(sugar) or lactose-containing foods (like dairy products), since AGIs inhibit the breakdown and absorption of complex carbohydrates and disaccharides (starch-containing foods bread, milk, biscuits, etc.).[15]
Hypoglycemic Unawareness (HU)	• **Symptom recognition failure-** Not identifying hypoglycemia symptoms can result in hypoglycemia-associated autonomic failure. • **Cycle of recurrence-** This failure sets off a cycle of recurrent hypoglycemia and HU. • **Reducing the risk of hypoglycemic unawareness with autonomic failure** o Avoiding hypoglycemia: Several weeks of evading hypoglycemic episodes may partially reverse HU. o Reduced recurrence risk: This strategy can either decrease the risk or prevent the recurrence of severe hypoglycemia.[15]
Pseudo Hypoglycemia (PHG)[19]	• **People with diabetes experience typical symptoms of hypoglycemia** o BG above 70 mg/dL (>3.9 mmol/L).[20] o This phenomenon is known as Pseudo hypoglycemia, where the serum glucose is within normal range despite symptom presentation. • **Symptoms of pseudo hypoglycemia** o Non-specific symptoms - fatigue, headache, visual disturbances, and light-headedness. o They also may have tremors, increased diaphoresis, or increased heart rate. o Few may present with complaints of neuroglycopenia, which includes slurred speech, confusion, and, rarely, seizures. • **Management** o The clinician should remain patient and gradually reduce the BG levels to give the body ample time to acclimatize to normal BG levels. o As the body gets used to lower BG levels, people with diabetes stop experiencing these symptoms at these relatively high BG levels. o Education on recognizing hypoglycemic symptoms, staying calm, choosing appropriate treatment strategies, and providing rapidly absorbable simple carbohydrates/glucose during hypoglycemic episodes.
Reactive Hypoglycemia (RH)	• A condition characterized by postprandial hypoglycemia that occurs 2–5 hours after eating. • **Forms of RH**[21] o Idiopathic RH: Manifests approximately 180 minutes post-meal. o Alimentary RH: Occurs within 120 minutes post-meal. o Late RH: Develops at 240–300 minutes post-meal. **Management strategies** • MNT o Symptoms may be linked to the consumption of high-carbohydrate, high-GI meals.

	o Recommend opting for ♣ Slow digesting (Lente) carbohydrates such as oats, barley, peas, legumes, etc. ♣ Foods with low-GI. ♣ Foods such as vegetables and animal-based lean protein. o Implement small meals and snacks. ♣ Spaced about three hours apart throughout the day. o Recommend restricting the consumption of simple carbohydrates. o Regular exercise. • Engaging in regular physical activity can help alleviate symptoms.
	Metabolic Surgery and RH • 1–3 hours after consuming a high-carbohydrate meal, an overstimulation of insulin release is accompanied by a sharp reduction in plasma glucose. • Post-bariatric hypoglycemia (PBH) can occur with o Roux en Y Gastric Bypass (RYGB) o Vertical Sleeve Gastrectomy (VSG) o Other gastrointestinal procedures present severe RH as one of the symptoms of Dumping syndrome, thereby compromising the quality of life.[22] **For improvement in Post-Gastric Bypass**[22] • Recommend a low-GI and low-glycemic-load meal.
	Recommend the use of an AGI.[16]

Hypoglycemia in Gestational Diabetes Mellitus (GDM) and Complications of Diabetes	
Gestational Diabetes Mellitus (GDM)[23]	• **Prevention of hypoglycemia** o Prevention of hypoglycemia is a key objective in achieving euglycemia during pregnancy. • **Insulin regimen management** o Consistency in carbohydrate intake and adherence to meal timings are crucial to reducing hypoglycemia risk for those on fixed insulin regimens. • **MNT recommendations** o An evening carbohydrate-containing snack can help prevent nocturnal hypoglycemia. o Consuming a protein-rich and low-carbohydrate snack before bedtime can stabilize BG levels in those at risk of hypoglycemia. o To prevent early morning hypoglycemia, a bedtime or late-night protein-rich snack (10–15 g of nuts: almonds, walnuts, pistachios, 20–25 g of roasted bengal gram) can be consumed.[24] • **Morning sickness and Hyperemesis gravidarum** o These conditions increase hypoglycemia risk, necessitating a Sick day diet to manage symptoms along with dehydration and dyselectrolytemia. o Sick day diet components: Porridge, citrus fruit juices without sugar, low-GI oral nutritional supplements, homemade soups, buttermilk, and low to moderate-GI fruits. If unable to tolerate fluids, then tender coconut water may be consumed. o Diet frequency: Consume carbohydrates containing food/snacks fourth hourly with adequate insulin coverage if required. • **Hypoglycemia management** o Tailored to the specific level of hypoglycemia severity, as detailed in Table 15.1.
Liver Disease, Malignancy, and Hypoglycemia	• Depleted hepatic glycogen stores precipitate nocturnal and overnight (early morning) hypoglycemia in Decompensated Liver Disease and hepatocellular carcinoma, requiring a bedtime snack. Providing one carb count is beneficial in preventing nocturnal/early morning hypoglycemia.
CKD (Stages 3–5 & 5D)	• The risk of hypoglycemia is very high due to poor insulin clearance in CKD.[20] • A minimum of 15–20 grams of glucose is lost per hemodialysis session. Therefore, attention should be paid to the symptoms. Hypoglycemia occurs during and after dialysis, indicating a need for a sick day diet in CKD (Stages 3–5) and pre- or during dialysis to prevent hypoglycemia. The management of hypoglycemia is severity specific.
Continuous Glucose Monitoring (CGM) and Hypoglycemia	• **Reduction in severe hypoglycemia** o CGM is effective in lowering the incidence of severe hypoglycemia in T2D individuals on intensive insulin therapy. • **Psychological benefits** o CGM reduces the fear of hypoglycemia and increases confidence in managing and preventing hypoglycemia. Always cross-check with a glucose monitor when BG levels show low on the CGM device and then take corrective action. • **Technology integration** o When paired with insulin pumps and Hybrid Closed Loop (HCL) devices, CGM can further minimize the occurrence of hypoglycemia.[15]
Fear of hypoglycemia[25]	• **Definition** A specific and intense fear that is triggered by an experience of hypoglycemia. • **Triggers** o A single severe hypoglycemic event or recurrent mild episodes can induce fear of hypoglycemia. • **Consequences** o Over-compensatory behaviors such as taking less insulin than required to avoid hypoglycemia. o Frequent Snacking: This may lead to obesity as individuals eat more often to prevent hypoglycemia.

Complications of hypoglycemia	• **Short-term complications**[14] o Neurocognitive dysfunction. o Retinal cell death leads to loss of vision. • **Long-term diabetes-related complications** o Increased risk of cardiovascular events. o Association with higher mortality rates. o Neurological conditions range from temporary cognitive impairment to dementia.[15] o Major vascular events include stroke, heart attack, acute cardiac failure, ventricular arrhythmias, and sudden death.[15] • **Additional risks** o Increased risk of falls, fractures, and accidents due to impaired physical and cognitive function. • **Studies highlighting risks** o ADVANCE and ACCORD studies underscore the association of severe hypoglycemia with heightened cardiovascular risks.

adults may experience altered responses to hypoglycemia compared to younger individuals. Mild-to-moderate and severe episodes of hypoglycemia in people with diabetes m Nutritive Sweeteners
ay go unrecognized due to hypoglycemic unawareness. It is imperative to check that BG levels have returned to normal after an episode of hypoglycemia.[15] (Table 15.6)

Table 15.6 Symptoms and Levels of Hypoglycemia in T2D

15.2.3 Complications of Hypoglycemia

Table 15.5. Complications of Hypoglycemia

Complications of hypoglycemia	• **Short-term complications**[14] o Neurocognitive dysfunction. o Retinal cell death leads to loss of vision. • **Long-term diabetes-related complications** o Increased risk of cardiovascular events. o Association with higher mortality rates. o Neurological conditions range from temporary cognitive impairment to dementia.[15] o Major vascular events include stroke, heart attack, acute cardiac failure, ventricular arrhythmias, and sudden death.[15] • **Additional risks** o Increased risk of falls, fractures, and accidents due to impaired physical and cognitive function. • **Studies highlighting risks** o ADVANCE and ACCORD studies underscore the association of severe hypoglycemia with heightened cardiovascular risks.

15.2.4 Symptoms and Levels of Hypoglycemia in T2D

Hypoglycemia can manifest with symptoms ranging from mild to severe, including anxiety, palpitations, tremors, sweating, hunger, numbness, behavioral changes, cognitive impairment, seizures, and coma. Older

Level of hypoglycemia[14]	**Glucose alert value**	**Clinically significant hypoglycemia**	**Severe hypoglycemia**
	Level 1	**Level 2**	**Level 3**
Measurable blood glucose in people with diabetes[14]	Glucose <70 mg/dL (3.9 mmol/L) and >54 mg/dL (3.0 mmol/L).	Glucose <54 mg/dL <3.0 mmol/L).	Irrespective of the glucose level, a severe event.
Symptoms	May be asymptomatic.	Hypoglycemia presents with varied symptoms or combinations of symptoms, ranging from mild to severe, including dizziness, weakness, anxiety, palpitations, tremors, sweating, hunger, numbness, behavioral changes, and cognitive impairment. Most often characterized by the beginning of neuroglycopenic symptoms requiring immediate attention.	As defined by the American Diabetes Association (ADA), it denotes severe cognitive impairment requiring external assistance for recovery.

The ADA recently recommended using the Ambulatory Glucose Profile (AGP) for Continuous Glucose Monitoring (CGM) tracking.
● Low: percentage of time in low-glucose hypoglycemia (5%: 54 to <70 mg/dL - level 1 hypoglycemia)
● Very low: percentage of time in very low-glucose hypoglycemia (5%; <54 mg/dL-level 2 hypoglycemia).

15.2.5 Those at Risk

Risk assessment of hypoglycemia and empowering people with diabetes with prevention and management strategies can prevent complications and improve quality of life. Nutrition counseling, reviewing dietary habits, and menu planning with a registered dietician are beneficial in reducing hypoglycemic episodes.(Table 15.7)

Table 15.7. Assessment of Hypoglycemia Risk Among Individuals Treated with Insulin, Sulphonylureas, or Meglitinides

Clinical/biological risk factors	Social, cultural, and economic risk factors
Major risk factors • Recent (within the past 3–6 months) intensive insulin therapy • Level 2 or 3 hypoglycemia • Impaired hypoglycemic awareness • End-stage kidney disease • Cognitive impairment or dementia	**Major risk factors** • Food insecurity • Low-income status • Homelessness • Religious fasting
Other risk factors • Multiple recent episodes of level 1 Hypoglycemia • Basal insulin therapy • Age >75years • Female sex • High glycemic variability • Polypharmacy • Cardiovascular disease • Chronic kidney disease (eGFR<60 mL/min/ 1.73 m^2 or albuminuria) • Neuropathy • Retinopathy • Major depressive disorder	**Other risk factors** • Low health literacy • Alcohol or substance use disorder

Table 15.8. Components of Hypoglycemia Prevention for Individuals at Risk for Hypoglycemia at Initial, Follow-up, and Annual Visits

Hypoglycemia Prevention Action
• Hypoglycemia history, awareness, and training. • Cognitive function and other hypoglycemic risk factors. • Continuous glucose monitoring. • Prevention and treatment of hypoglycemia by a structured patient education program. • Appropriate re-evaluation modification or simplification of diabetes treatment plan. • Education on glucagon prescription and training in close contact with insulin-dependent people with diabetes or those at high risk of hypoglycemia. • Training to re-establish awareness of hypoglycemia.
All the above components of hypoglycemia prevention for individuals at risk for hypoglycemia are assessed both at initial and annual visits, whereas most of the components were assessed annually. The frequency of assessment varies based on recurrent hypoglycemic events or at the initiation of medication with a high risk for hypoglycemia, intercurrent illness, and when impaired hypoglycemic awareness is detected.

15.2.6 Alcohol and Hypoglycemia

Table 15.9. Alcohol and Hypoglycemia

Alcohol and hypoglycemia	• **Condition:** Hypoglycemia triggered by heavy alcohol consumption. • **Risk Factors** o Heavy drinking, defined as more than 10 to 12 drinks/day in a fasting state, can lead to hypoglycemia. o Consuming alcohol and skipping a meal or snack can precipitate hypoglycemia. • Drinking alcohol in the evening may elevate the risk of nocturnal hypoglycemia.[18,26-29]

15.2.7 Exercise and Hypoglycemia

Table 15.10. Exercise and Hypoglycemia

- Engaging in physical activity can lower blood glucose during workouts and 6–15 hours after exercise.[30]
  - o If hypoglycemia hinders exercise, people with diabetes should consider.
    - ♣ Consuming a small snack before exercising or
    - ♣ Adjusting medication
  - o To prevent hypoglycemia, adjust the timing of insulin doses in relation to
    - ♣ Exercise
    - ♣ Meals
    - ♣ Snacks
- A combination of these strategies may be required to mitigate hypoglycemia during and after prolonged exercise.[31]

Strategies to Prevent Exercise-Associated Hypoglycemia

Suggested carbohydrate intake or other actions based on BG levels at the start of exercise.[30]

Pre-exercise BG	Carbohydrate intake, or other actions.
Below 90 mg/dL or (5.0 mmol/L)	Before exercise, 15–30 g of fast-acting carbohydrate, adjusting for individual body frame and activity intensity. **Note:** Some brief or high-intensity activities may not require additional carbs.
90–150 mg/dL or (5.0–8.3 mol/L)	Begin carbohydrate intake at the start of most exercises (0.5–1.0 g/kg of body weight/hour), considering exercise type and active insulin levels.
Above 150 mg/dL or (8.3 mmol/L)	Start exercise and delay carbohydrate consumption until BG levels are below 150 mg/dL.

Exercise-induced nocturnal hypoglycemia	This poses a significant concern, with potential risks lasting up to 48 hours. • To mitigate this risk for people with diabetes on Multiple Daily Injections (MDI)[30] o Consider reducing daily basal insulin by about 20% o Additionally, decrease prandial bolus insulin dosage o Recommend consuming low-GI carbohydrates after evening exercise • To reduce the risk of hypoglycemia[24] o Recommend consuming 5–30 g of carbohydrates during and within 30 minutes of high-intensity exercise. When the BG is <100 mg/dL, consume 15–20 g of carbohydrates to raise BG levels. • Treat hypoglycemia During or after exercise, immediately with the 15–15 rule: If the person is conscious, provide 15 grams of fast-acting carbohydrates (1 tablespoon of sugar or honey, 2 tablespoons of raisins, 3 dates, 1/2 cup of fruit juice or non-diet soda), and recheck in 15 minutes. If it's still less than 70 mg/dL, then repeat until the glucose rises to >100 mg/dL or 5.6 mmol/L. After treating low BG, consume a balanced snack or meal with protein and carbs. When the BG is <100 mg/dL Consume 15–20 grams of carbohydrates to raise BG levels. **Note:** • If people with diabetes want to continue working out, ensure that the BG is >100 mg/dl before exercising again.[31] • Alcohol should be avoided before and during exercise to reduce the risk of hypoglycemia, including Nocturnal Hypoglycemia. (NH). • Blood Glucose Monitoring o Check BG levels before and after exercise sessions. o For long or intense exercise, monitor BG during the activity. o After intense exercise, conduct a BG check in the middle of the night to detect Nocturnal Hypoglycemia and provide timely treatment. Those who drive must measure BG before the start of the journey to ensure that the BG is more than 90 mg/dl and preferably monitor it every 2 hours after that during the trip. Periodic healthy carbohydrate snacking is recommended.[14]

15.2.8 Management of Hypoglycemia

Table 15.11. Management of Hypoglycemia

Glucose alert value (Level 1)	Clinically significant hypoglycemia (Level 2)	Severe hypoglycemia (Level 3)	If recurrent hypoglycemia persists[14]
Initial Step If the individual can swallow safely, administer 15 g of rapidly absorbable glucose. This can be in the form of tablets, gels, fruit juice, honey, or sugar candy. Choose sources devoid of protein or fat for quick conversion to glucose in the body. **Post BG normalization** Once BG levels return to the standard range, consume a healthy snack or meal to prevent subsequent drops in BG. The meal or snack should be rich in protein and carbohydrates to replenish glycogen stores.[15] Examples include paneer, curd, nut powder in milk, roti with dal or peas, and whole grams.[15] **Follow-up** Recheck BG after 15 minutes. If levels remain below 70 mg/dL, administer an additional 15 g of carbohydrate. **Preference for oral glucose** Oral glucose in the range of 15–20 g is recommended for conscious individuals experiencing hypoglycemia.[14]	When conscious, they should be treated with oral glucose sublingually or immediate acting sugar/sweets (based on clinical condition).[14]	If a person cannot swallow or is unresponsive, unconscious-subcutaneous, intramuscular, or intranasal glucagon or IV glucose or dextrose should be given by a trained family member or medical personnel.[14,15]	It is crucial to assess renal function and rule out hypothyroidism.[18] Adjusting a person's long-term anti-hyperglycemic regimen may be needed to prevent future hypoglycemic episodes.[15]

15.2.9 Macronutrients and Hypoglycemia

Table 15.12. Mealtime Macronutrients and Hypoglycemia

Mealtime management of hypoglycemia in people with diabetes on Insulin

- Consistent eating schedules are crucial for those on intermediate or long-acting insulin to manage blood glucose levels effectively.
- Delays in mealtimes can lead to hypoglycemia; carrying a carbohydrate-containing snack (low GI fruit or glycemic-friendly oral nutrition supplement providing 15–20 grams of carbohydrate) is recommended to prevent hypoglycemia.

Macronutrients and Hypoglycemia

Carbohydrates

- Inadequate carbohydrate intake or consuming less than usual without adjusting insulin can trigger hypoglycemia.
- The meal's composition (fat, protein, fiber) affects carbohydrate absorption, with liquids being absorbed faster than solids, complicating insulin dosing.
- Extreme carbohydrate restriction, such as very low-carbohydrate or ketogenic diets, without adjusting anti-diabetic agents, has been associated with hypoglycemia.[27]

Protein and hypoglycemia

- Protein intake does not significantly increase peripheral glucose concentrations as it does not contribute to sustained glucose elevations.[26]
- In people with diabetes, protein intake may increase the insulin response to dietary carbohydrates, so carbohydrate sources high in protein (e.g., nuts) should be avoided to treat or prevent hypoglycemia due to the potential simultaneous rise in endogenous insulin.[28]

Fat and hypoglycemia

- No studies have conclusively assessed the role of fat in treating hypoglycemia; avoid high-fat foods to treat hypoglycemia.[26]

15.2.10 Carbohydrate Sources for Treatment of Mild Hypoglycemia

Table 15.13. Carbohydrate Sources for Treatment of Mild Hypoglycemia

Food Item	Amount	Carbohydrate (grams)
Glucose tablets, check the label (each 4 grams) *	4 in number	16
Tablespoon of sugar*	1	15
Tablespoon of honey*	1	15
For small sugar cubes, check the label*	5 in number	15
Tablespoon of raisins*	2	15
Fresh fruit juice without added sugar, Example: orange juice[20]	½ cup (120 mL)	15
Regular soft drink/soda (without sugar, not diet soda)*	120–180 mL	15
Banana[20]	½	15
Bread[20]	One slice	15
Fruit[20]	A small piece	15
Note: 15 grams of carbohydrates provide 60 calories.		

Note:
1. Do not consume sugar-free beverages or high-fat sweets/desserts, chocolates, and ice creams.
2.* The above options are to be used only as management strategies for hypoglycemia and not for people with diabetes on a regular basis.

15.3 FASTING AND DIABETES

15.3.1 Background and Types of Religious Fasting

Religious fasting, a practice deeply embedded within the fabric of Indian culture and observed across its multifaceted communities,[32] necessitates significant metabolic adjustments to maintain normoglycemia. Extended fasting triggers the breakdown of lipids, proteins, and carbohydrates to sustain normal BG levels.[33] For individuals with diabetes, these physiological alterations, coupled with existing medication regimens, introduce potential risks, including hypoglycemic episodes during fasting, postprandial hyperglycemia, and dehydration. The omission of medication dose may precipitate diabetic ketoacidosis, a serious complication necessitating hospitalization.

In the preparatory phase of fasting, a comprehensive evaluation integrating a detailed medical history, physical examination, and diagnostic investigations is imperative to identify any indicators of organ damage.[34] This foundational assessment facilitates the development of personalized health management plans. Critical factors to be considered

encompass the duration and nature of the fast, whether it entails complete abstinence or partial dietary restrictions, alongside the individual's age and level of glycemic control. The abstention from fluid intake, particularly in warmer climates, can lead to dehydration, electrolyte imbalances, and hypotension, further complicated by hyperglycemia, which amplifies the fluid loss via osmotic diuresis. Given these considerations, meticulous planning and medical oversight are essential to safeguard the health and well-being of individuals electing to fast, especially patients with diabetes mellitus.[35] This approach ensures that fasting does not compromise diabetes management but is conducted within a framework that prioritizes individual safety. (Table 15.14)

Table 15.14. Pre-Fasting Counseling and Enhanced Monitoring for High-Risk Individuals- A Recommended Approach for Shared Decision-Making

High-risk: **People with T2D, with an HbA1c > 8.5%, and any of the following**
• Lack of awareness of hypoglycemia. • Severe or Recurrent Hyperglycemia in the preceding three months. • History of diabetic ketoacidosis in the preceding three months. • Acute illness. • Pregnancy. • Hypoglycemia unawareness. • Elderly with comorbidities.
Moderate risk: People with T2D and any of the following
• HbA1c 7.5–8.5%. • Taking basal insulin-along with a sulfonylurea/DPP4 inhibitor/SGLT2 inhibitor, or GLP-1 receptor analog.
Low risk: People with T2D, All of the following
• HbA1c < 7.5%. • Not taking medication to lower blood glucose or taking only metformin.

15.3.2 Glycemic Control

A prudent clinical guideline advocates that fasting be discontinued if BG is <70 mg/dL or >300 mg/dL or in the presence of any symptoms of hypoglycemia or acute illness, irrespective of the individual's medication regimen (insulin or oral agents).[35–37] Notably, in elderly individuals or those with established hypoglycemia unawareness, careful consideration should be given to maintaining glucose levels above 90 mg/dL. The use of self-monitoring of BG should be advocated.

15.3.3 Importance of SMBG During Fasting

Self-monitoring of Blood Glucose (SMBG) during fasting cannot be overstated within clinical practice. SMBG empowers individuals by providing real-time tracking of BG levels throughout the day, facilitating physicians in tailoring medication dosages and MNT regimens accordingly. This practice also empowers individuals to adjust their physical activity and dietary habits regularly to optimize glycemic control. If BG levels deviate significantly, falling below 70 mg/dL or exceeding 300 mg/dL, or if complications of diabetes emerge, fasting should be promptly interrupted.[38] Following episodes of hypoglycemia, individuals should promptly consume fast-acting carbohydrates to restore normoglycemia. Enhanced monitoring may be warranted for those at higher risk of hypoglycemia, particularly in regions with longer fasting periods or warmer climates.[39] Thus, SMBG is a pivotal strategy for mitigating the occurrence of hypoglycemic and hyperglycemic episodes during fasting periods.[39] The integration of telemedicine and CGM devices could hold promise as a forward-thinking approach to optimize individual care in this context.[40] (Table 15.15)

Table 15.15. Key Recommendations

Implementation	**Key Recommendations**
Fluids and MNT advice	• Individuals using SGLT-2 inhibitors, which are known for their diuretic properties, should be cautious. o Must prioritize sufficient hydration. o Particularly in instances of uncontrolled HbA1c levels.[41] • Individuals at risk of dehydration, including those o with poorly managed diabetes mellitus o Or recent febrile illnesses should contemplate abstaining from fasting. • To mitigate the risk of dehydration, choose sugar-free, decaffeinated beverages, such as water, buttermilk, or soups.
T2D and fasting	• To promote stable blood glucose levels.[14] o Incorporate slowly absorbed, low-GI foods into meals. o Maintain consistency in carbohydrate intake. o Practice meal spacing. • To optimize meal composition. o Prefer healthier cooking methods with minimal oil, such as grilling or roasting, steaming, sauteing, etc. • Customize snack inclusion based on o Individualised meal plans o Meal spacing o Metabolic control o Risk of hypoglycemia Note: While also balancing against the risk of weight gain.

GDM and fasting	• Due to the potential maternal and fetal risks, pregnant women with diabetes mellitus are advised to refrain from fasting.[42] • To optimize glycemic control, develop individualized meal plans tailored to the gestational stage and any existing comorbidities. Note: Prioritize three main meals and two snacks • To mitigate associated risks[43] o Aim to maintain key blood glucose parameters within recommended ranges. ♣ Pre-prandial or Fasting BG <90 mg/dL, ♣ Post-prandial BG values • 140 mg/dL at 1 hour • 120 mg/dL at 2 hours Note: Prioritize consumption of whole grains and fresh vegetables to promote satiety and increase dietary fiber intake.
Comorbidities-renal impairment	• Fasting only in low-risk patients, after due advice and supervision of healthcare professionals. • To optimize MNT management[44] o Select fresh, homemade food options; a few are mentioned in Table 15.8. o Tailor meal plans during fasting based on the stage of kidney disease and related complications. o Deliberate on potentially reducing potassium, phosphorous, and protein intake wherever required. Note: Limit carbohydrate consumption from simple sugars to less than 10% of total energy intake.
Elderly and fasting	• To enhance dietary quality and promote favorable blood glucose and cholesterol profiles. o Prioritize the consumption of vegetable proteins. o Promote the intake of low-GI foods and foods low in GL- legumes, whole grains, and vegetables. The elderly with dental issues can opt for porridge, soups, buttermilk, and well-cooked, easily available millets like barnyard millet. o Opt for unsaturated oils and nuts as preferred dietary fats. o Less fluid intake for a prolonged time may result in dehydration, so drink enough fluids throughout the day.

Table 15.16 Key Recommendations During Festivals

	Carbohydrates	Proteins	Fats
Ramadan	• During Ramadan, portion control is crucial when carbohydrate-rich foods are commonly consumed.[37] • Rehydrate with water and replenish energy stores with dates, being mindful of restricting the number of dates to 2–3 in no, prefer low-GI and low GL dates (Ajwah preferably) or low-fat milk options.[45] • Consider fresh homemade vegetable/ mushroom/chicken/dal soups. They provide fluid and energy while ensuring moderate carbohydrate intake. Maintain carbohydrate intake within prescribed goals during suhoor or sehri and iftar to manage BG levels effectively.[46] • Ensure adequate protein intake - opt for lean meats, eggs, low-fat dairy, pulses, and healthy fats that are incorporated into meals in the form of low-fat dairy, walnuts, almonds,	• Select lean meats, eggs, egg white/whole, based on existing co-morbidity, low-fat dairy products, and pulses as primary protein sources in the diet.[45]	• Incorporate healthy fats in moderation from peanuts, almonds, walnuts, pistachios, and flax seeds into the diet. • Refrain from consuming fried foods to promote overall dietary health and minimize intake of unhealthy fats.

	pistachios, or flax seeds. Avoid deep-fried foods. • Diversify food choices by including various vegetables, pulses, grains, and fermented foods to regulate appetite and sustain energy levels throughout the day.[45] • Incorporate whole foods rich in complex or slow-digesting carbohydrates/lente carbohydrates, such as steel-cut oats or whole wheat roti with whole grams or eggs, at the predawn meal to mitigate the risk of hypoglycemic episodes.[47]		
Navratri	• When consuming high-GI cereal/rice during Navratri, emphasize portion control. Low-GI cereal options like buckwheat and barnyard millet could be incorporated, and sweet potato (squeeze fresh lime) should be preferred over potatoes. • Incorporate low to moderate-GI and low glycemic load (GL) fruits and vegetables into the diet to benefit from their antioxidant properties.[48] • Select low-calorie beverage options such as buttermilk, lemon water, green tea, or fresh vegetable soups to maintain energy balance during this festival season.	• Low-fat dairy products, including cottage cheese, are recommended.	• Avoid deep frying and instead choose cooking methods-boiling, grilling, baking, or steaming.
Paryushana	• When vegetable consumption is limited, incorporate whole-grain cereals such as pearl millet, finger millet, sorghum, or oats to maintain fiber intake. • Ensure adequate hydration by consuming fluids regularly.	• Add low-fat dairy products, pulses, and legumes to the diet to meet the protein requirements.[49]	• Integrate flax seeds into the diet as a source of omega-3 fatty acids, particularly when almonds and walnuts are excluded during fasting rituals.[50]
Lenten festival fasting.[51–55]	To optimize dietary quality Prioritize consumption of whole and unprocessed foods. To support nutritional adequacy and overall health Include protein sources, such as lean meats, fatty fish, tofu, tempeh, and low-fat dairy.		

Table 15.17. Common Foods Consumed During Fasting and Associated Glycemic Values

Food	GI	GL per serving
Buckwheat	Medium (50–65)	Low to moderate
Water chestnut	Low (25–25)	Low to moderate
Barnyard millet	Medium (65–75)	Low to moderate
Amaranth	High (65–70)	Moderate
Legumes and pulses	Varies depending on the type	Low to moderate
Nuts and seeds	Low to medium	Low to moderate
Fox nuts	Low (40–50)	Low to moderate
Indian cottage cheese	Low (0)	Low

15.4 TRAVELING WITH DIABETES

This segment equips healthcare professionals with extensive directives for managing diabetes during travel. It emphasizes that individuals with diabetes should not consider any destination inaccessible or off-limits due to their condition. Avoiding hypoglycemia is paramount, as it poses a greater risk than hyperglycemia. Collaborative pre-planning involving consultation with a diabetes educator and healthcare provider instills individuals with the requisite self-assurance to embark on their travel endeavors. (Table 15.18, 15.19)

Table 15.18. Factors Affecting Glycemic Control

- Disruption to routine and circadian rhythms impacting meal and medication timings.
- Challenges in carbohydrate counting due to exploring new cuisines and portion sizes.
- Insulin absorption is affected by changes in temperature and humidity.
- BG fluctuations due to altered activity levels and stress.

Table 15.19. Guidelines for Diabetes Management During Travel

Preparation Before Travel

- With the rising number of Indian travellers, sharing comprehensive pre-travel diabetes management advice is crucial due to the lack of evidence-based guidelines.
- Thorough recommendations should be provided 4–6 weeks before departure.

Documentation	• Provide detailed information on condition, medications (generic names for international use), and equipment (insulin pumps, extra battery, and insulin).[56] • Include emergency prescriptions stating the medical necessity to carry sharps, such as needles and lancets. • If using an insulin pump, notify airlines in advance to prevent complications during security. Also, check beforehand to see if the pump can pass through body scanners that use X-ray technology.[56] • Those on the pump should discuss alternate basal-bolus regimens in case of pump malfunction. • Stress the importance of up-to-date immunizations.
Travel health insurance	• Essential, along with a first-aid kit containing a topical antibiotic.
Travel companions	• Educate on hypoglycemia symptoms. Locate the closest medical facility/pharmacy available at the destination.
Packing	• Recommend doubling diabetes supplies distributed between different bags, especially for air travel. Store in carry-on bags to avoid extreme temperature and pressure conditions in checked baggage.[14,56,57,58] • All supplies should be in their original containers with manufacturer's labels, packed in resealable plastic bags, and stored near the opening of the carry-on bag for quick retrieval during security checks. • Consider carrying glucagon if traveling with insulin. • For insulin pump users, suggest extra batteries, insulin, and glucometer in case of pump malfunction.
Attire	• Suggest breaking into new slip-on shoes 2–3 weeks beforehand to reduce foot injury risk and to rotate footwear to reduce callus and blister risks.[56,57]

Behavior	• Stress the importance of frequent BG monitoring, particularly for recently diagnosed or poorly controlled diabetes.[58] • Plan for meal and medication timing during unexpected delays.
Language	• Advise on wearing medical identification, particularly for solo travellers. • Suggest familiarizing the individual with local phrases like "*I have diabetes*" for effective communication.[56]
MNT	• Discuss local cuisine and carry extra supplies for hypoglycemia to prevent and manage. • For air travel, order diabetes-friendly meals in advance.
During travel	
Take help	• Inform cabin crew of the condition and carry healthy snacks in carry-on luggage for hydration and energy.[58,59] • Walk every 1–2 hours and perform dorsiflexion/plantar flexion exercises.
Insulin pump and CGM management	• Caution against unintentional insulin delivery due to bubble expansion in the pump cartridge during ascent. Limit the amount of insulin in the cartridge to 1.5 mL. Disconnect the pump during take-off and landing. Once at cruising altitude, remove the cartridge and reconnect after visually inspecting and removing bubbles. Ensure that the alarm silence feature is turned off during the flight. Frequent monitoring of the device on board is recommended. After landing, disconnect the pump and reconnect. • Be aware of Wi-Fi interference with aircraft systems. Prepare to manage your diabetes on board with a pen and glucometer.
Insulin injection device and timing	• Pre-meal insulin should be taken after serving food to prevent potential low BG from service delays. • Before using the syringe, remove and replace the plunger to equalize the pressure. Due to pressure changes, insulin pens may leak when the needle tip is applied. • Adjust insulin and meal timings based on travel direction and time zones. When traveling east, decrease insulin and meals; when traveling west, increase both.[56] • Traveling across less than five time zones does not require insulin dose adjustment; the dose and frequency of insulin and medication need to be adjusted for more than five time zones.[14] • Specific advice varies, highlighting the need for individualized plans based on medication type.
After arrival	• Ensure hydration. • Regularly check BG and feet. • Be prepared for emergencies with handy snacks, ketone strips, and local contacts.
Exercise and climate considerations	
In general	• Maintain regular activity but avoid overexertion and stay prepared for weather-related impacts on diabetes management.
Hot weather tips	• Adjust to the climate gradually, use sunscreen, change socks, air out shoes, and dusting powder to reduce the risk of fungal infection due to sweating. • Protect diabetes equipment (BG monitor, insulin pump, test strips) from direct sunlight and a car glove compartment to prevent damage. Heat can affect the accuracy of the meter, leading to misleading results. A waist pouch is recommended for pump security.[59] • Emphasize more frequent BG monitoring to adjust the diet or insulin dose accordingly.[58] • Pump users may consider switching to multiple injections before traveling for a beach holiday involving water activities.
Cold weather advice	• Increased energy use for warmth also poses a hypoglycemia risk.[58] • Educate people on how to store and insulate insulin properly to prevent freezing. • Warn against how insulin absorption slows initially but may spike when the body warms, leading to hypoglycemia.[58] • People with diabetes must wear insulated socks and thick shoes because they are prone to frostbite and infections. • Educate people with diabetes to change damp socks to prevent fungal infections and ensure warm, dry feet at all times.

Clinical Pearls of Practice

Sick day guidelines

- Monitor BG every 4 hours and check urinary ketones if BG > 240 mg/dL.
- Stay hydrated with 100–250 mL of water or sugar-free fluids every hour.
- Use electrolyte solutions (WHO ORS, buttermilk, vegetable soup, diluted fruit juice) if needed.
- Avoid fasting; consume carbohydrates every 4 hours (up to 50 g).
- For fever/infection: Eat a soft diet (curd rice), increase calorie intake.
- For diarrhea/vomiting: Prioritize fluid and electrolyte replacement, avoid high-fiber foods.
- Consult a doctor before adjusting medications.
- Stop metformin (risk of lactic acidosis) and SGLT2 inhibitors (risk of ketoacidosis) if dehydrated.
- Continue insulin therapy with necessary dose adjustments.
- Seek medical help:
    - Vomiting/diarrhea lasts more than 6 hours despite hydration.
    - Fever >101°F for 24 hours or difficulty breathing.
    - BG remains above 240 mg/dL despite medication.
    - Extreme fatigue, confusion, or severe dehydration (dry mouth, excessive thirst).

Hypoglycemia

- To effectively manage hypoglycemia, it is critical to identify the symptoms, level, and type of hypoglycemia.
- Essential approaches include routine BG testing, understanding the influence of different types of carbohydrates on BG, and making sure to always have a handy supply of glucose.
- It is important to note that when people with diabetes are unable to swallow due to a low/poor level of consciousness, administering glucose mixed with water/any liquid orally increases the risk of pulmonary aspiration.
- In the conscious state, recovery from hypoglycemia is much faster when glucose is consumed sublingually rather than orally. In people with diabetes, the quantity, quality, and timing of the meal, anti-diabetic medication, and physical activity play an important role in preventing hypoglycemia.

Fasting

- Given the prevalence of carbohydrate-rich foods in traditional fasting diets, portion control is crucial to prevent BG spikes.
- Maintain a balanced diet with controlled carbohydrate intake as per the healthcare provider's goals and prioritize hydration.
- Encourage the consumption of slowly absorbed low-GI foods to help stabilize BG levels.
- Adapt traditional cooking methods to use minimal oil and avoid fried foods.
- Regular monitoring of BG levels is essential during fasting for timely adjustments in medication or dietary habits.
- Educating individuals about the potential risks of fasting and empowering them to make informed nutritional choices is vital for effective diabetes management during religious fasting.
- Tailor the nutrition management plan to suit the specific needs of each individual for optimal outcomes and satisfaction.
- Consider the GI and GL of commonly consumed foods during fasting.

Traveling with Diabetes

- Carry a doctor’s letter listing your diabetes condition, medications, and equipment.
- Keep an emergency prescription for additional medications.
- Pack twice the needed diabetes supplies and store in carry-on luggage.
- Carry glucose tablets, snacks, and oral rehydration solutions.
- Order diabetes-friendly meals in advance for flights.
- Adjust insulin dosing based on time zone changes:
    - Traveling east → Reduce insulin doses.
    - Traveling west → Increase insulin doses and meals.
- Monitor BG frequently, especially during unexpected delays.
- Inform cabin crew about your diabetes.
- Carry healthy snacks and sugar-free fluids for hydration and energy.
- Move every 1–2 hours and do leg exercises to maintain circulation.
- For insulin pump users:
    - Disconnect the pump during take-off/landing to prevent pressure changes.
    - Monitor insulin delivery to avoid unintentional dosing.
- After arrival, stay hydrated and maintain a regular eating schedule.
- In hot weather, protect insulin from heat, wear breathable shoes, and monitor feet.
- In cold weather, prevent insulin from freezing, wear insulated socks, and avoid frostbite.
- Locate nearby medical facilities and pharmacies at your destination.

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Section 16: Integrating Medical Nutrition Therapy (MNT) and Technology in the Management of Diabetes

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16.1 INTRODUCTION

The integration of Medical Nutrition Therapy (MNT) and technology in Type 2 Diabetes (T2D) management aims to enhance the precision, accessibility, and effectiveness of dietary interventions, ultimately improving health outcomes for individuals living with diabetes. Integrating technology with the expertise of nutritionists delivering Medical Nutrition Therapy (MNT) can significantly enhance its effectiveness by providing real-time data and personalized insights. This integration enables patients to monitor their diet, physical activity, sleep patterns, and glucose levels, allowing for more customized and optimized treatment plans.

The significance of a nutritionist in carb counting lies in their expertise in aiding individuals make informed decisions about their carbohydrate intake-quality (nutrient-dense foods and foods with lower Glycemic Index (GI)) and quantity (portion control when to eat which macronutrient). Nutritionists can provide personalized guidance on meal planning and replacement, portion control, and food choices to ensure a balanced diet while effectively managing Blood Glucose (BG) levels according to the different levels of physical activity of a T2D individual. With their knowledge and support,

combined with advanced diabetes technologies, nutritionists empower people with diabetes to successfully maintain optimal glycemic control.

Diabetes technology encompasses hardware, devices, and software used for diabetes self-management, including lifestyle modifications, glucose monitoring, and therapy adjustments. Historically, it includes insulin delivery by syringes, pens, or pumps [also called continuous subcutaneous insulin infusion (CSII)] and glucose monitoring using glucose meter or Continuous Glucose Monitoring (CGM). These include connected insulin pens and diabetes self-management support software, offering more precise and user-friendly care. These technologies, coupled with education and support, can enhance the quality of life of people with diabetes; however, the complexity and rapid evolution can pose implementation challenges for people with diabetes, their caregivers, and healthcare providers. Healthcare professionals should consider the treatment burden, T2D individuals' confidence, self-efficacy, and social support when providing Diabetes Self-Management Education and Support (DSMES). Routine clinical care should monitor an individual's self-management behaviors, clinical outcomes, health status, quality of life, and psychosocial factors. A Randomized Controlled Trial (RCT) demonstrated that a decision-making education and skill-building program,[1] targeting these factors improved health outcomes in resource-limited populations. Adhering to a DSMES curriculum enhances the quality of care.[2]

16.2 TECHNOLOGY USED IN THE CLINICAL PRACTICE FOR DIABETES MELLITUS

Digital transformation is enhancing diabetes management in India, where a rising number of people with diabetes strains the healthcare system. Advanced technologies like glucose monitors, insulin devices, and health applications are increasingly used for prevention and care. Digitalizing health data is crucial for improving patient outcomes.[3] Digital health encompasses technologies for wellness, chronic disease management, and clinical support, including mobile applications, wearables, and cloud platforms. These innovations improve healthcare interactions, care quality, and therapeutic decisions, particularly in diabetes management.[3,4]

Samanna *et al.* (2021) explored diabetes reversal stages and key health metrics before and after precision nutrition therapy. The Twin Precision Nutrition (TPN) program utilizes digital twin technology, Artificial Intelligence (AI), and the Internet of Things (IoT) to provide personalized care. By integrating data from health devices and a mobile app, it generates customized plans for nutrition, exercise, and sleep, supported by continuous guidance from health coaches and physicians.[5]

CGMs, are crucial for diabetes management in India, offering real-time glucose data and patterns. Their widespread acceptance enhances patient engagement and care by integrating medical devices with data analytics and feedback to improve diabetes management.[6,7]

Insulin pumps, particularly CSII, have proven effective in lowering HbA1c levels and enhancing patient quality of life. While advanced closed-loop systems remain expensive and less available, some patients are adopting innovative approaches, such as Open source AID (Automated Insulin Delivery), to achieve better glucose control and improved well-being.[8,9]

Telemedicine uses technology to deliver remote healthcare, particularly aiding rural patients with limited access to urban facilities. During the COVID-19 pandemic, India promoted telemedicine, enhancing diabetes care in underserved regions.[10]

Apps use mobile phones for convenient healthcare interventions and follow-ups via text, video, voice, and the internet.

Electronic Medical Records (EMR) are the repository of patient records that allows doctors to track and monitor health, help scheduling, e-prescriptions, conduct patient engagement, and improve practice management. Now, with AI-powered workflows, EMRs will become more relevant for practice and clinical decisions.

16.2.1 Evidence for the Benefits

DSMES is associated with improved diabetes knowledge and self-care behaviors,[11] lower HbA1c,[11–16] lower self-reported weight,[17] improved quality of life,[13,18,19] reduced all-cause mortality risk,[20] positive coping behaviors,[21,22] and lower health care costs.[23–25] DSMES participants, especially those with Medicare, are more likely to follow best practices and incur lower Medicare and insurance claim costs.[24,26] Effective DSMES interventions that were >10 h over the course of 6–12 months,[14] included ongoing support,[27,28] were cultural,[29–31] and age-appropriate,[32,33] were tailored to individual needs, addressed psychosocial issues, and incorporated behavioral strategies.[22,34–36] Both individual and group approaches are effective,[37–39] with combined methods offering slightly additional benefits.[14]

Virtual, telehealth, telephone-based, or internet-based DSMES have shown substantial benefits for diabetes prevention and management across populations and age groups. Digital tools such as mobile applications, simulation tools, digital coaching, and self-management interventions are used to deliver DSMES. They provide outcomes comparable to or better than traditional in-person care, with greater HbA1c reductions linked to higher engagement. However, data from trials are heterogeneous.

16.3 PURPOSE, APPLICATIONS, AND EVIDENCE

16.3.1 Self-Monitoring and Feedback

16.3.1.1 Glucometer

People with T2D use self-monitoring of Blood Glucose (SMBG) to measure and track their BG levels as needed. Meta-analysis shows that SMBG reduced HbA1c (MD −0.30%, 95% CI −0.42 to −0.17) compared with no SMBG in non-insulin-treated T2D patients. Better outcomes were seen with SMBG at 8–11 times weekly and lifestyle adjustment based on SMBG results.

What is needed?

- Blood glucose meter, test strips, lancet device, and lancets.
- Washing hands with soap and water will ensure accurate readings.

People with diabetes should be taught how to use BGM data to adjust food intake, physical activity, or pharmacologic therapy to achieve specific goals. The ongoing need for and frequency of BGM should be reevaluated at each routine visit to ensure its effective use.

While there are many positives to using a Glucometer for self-monitoring, some of the challenges are

- Cost: The cost of test strips, lancets, and meters can be a barrier for some individuals.
- Discomfort: Regular finger pricking can be uncomfortable and may lead to a reluctance to perform SMBG.
- Adherence: Consistent monitoring requires discipline and can be challenging to maintain.

16.3.1.2 Carbohydrate Counting

Carbohydrate Counting (CC) is an effective strategy for managing insulin doses in people with insulin-requiring diabetes, particularly Type 1 Diabetes Mellitus (T1D). By calculating meal carbohydrate content and using an insulin-to-carbohydrate ratio, CC can improve glycemic control and reduce HbA1c levels, potentially delaying microvascular complications. A low-GI and Glycemic Load (GL) diet further supports this by enhancing insulin sensitivity and stabilizing BG. Technology-driven educational programs and telephone-based support from a multidisciplinary team can aid in maintaining glycemic control.[40–43] (Table 16.1)

Table 16.1. Carbohydrate counting applications in India

Application Name	Description	Features Specific to Indian Users	Accuracy
MyFitnessPal	Large database with a variety of Indian dishes; users can add custom foods.	Extensive Indian food database; customizable food entries.	Generally accurate for common foods, but user-added entries may vary in accuracy.
Lose It!	Similar to MyFitnessPal, allows users to track food intake with many entries for Indian cuisine.	Includes a wide range of Indian food entries.	Fairly accurate, but relies on user-generated content, which can lead to discrepancies.
HealthifyMe	Specifically designed for Indian users, includes a comprehensive database of Indian foods, tracks workouts, and connects with nutritionists.	Comprehensive Indian food database; workout tracking; access to nutritionists.	Highly accurate for Indian cuisine due to focus on the Indian market and expert-verified data.
YAZIO	Offers a wide range of foods, including Indian dishes, and provides personalized meal plans.	Personalized meal plans with Indian dishes.	Generally accurate but may lack specificity for less common Indian dishes.
Cronometer	Focuses more on nutrition tracking but includes a good database of foods, including some Indian recipes.	Includes some Indian recipes in its nutrition tracking.	Highly accurate for nutritional information due to reliance on verified food databases.
MyPlate by Livestrong	Provides a comprehensive food tracking system, including nutritional information and exercise tracking.	Limited Indian food database; more general focus on common foods.	Moderately accurate but less precise for Indian dishes due to a more general food database.

Carbohydrate counting tools benefitting nutritionists with accurate diet data

- Patient Empowerment: Real-time tools for monitoring carb intake, crucial for diabetes management.
- Enhanced Self-Management: Helps patients make informed dietary choices and adjust insulin dosages.
- Improved Health Outcomes: Accurate carb tracking leads to better health and fewer complications.
- Benefits for Nutritionists: Provides detailed dietary data to personalize nutrition plans.
- Data-Driven Insights: Identifies dietary patterns, aiding in tailored nutritional adjustments.
- Enhanced Collaboration: Facilitates personalized feedback and better patient engagement.
- Support for Research: Data aids research on diet patterns and intervention outcomes.
- Overall Impact: Enhances self-management and care quality, improving patient outcomes.

CC aids in determining insulin doses for meals, enhancing dietary flexibility, and simplifying diabetes management, particularly in T1D. A review of randomized controlled trials involving 1,034 patients found that CC generally improves BG control, especially in adults and when using mobile applications. In T2D, a study on 21 individuals showed improved BG control, lower HbA1c levels, and healthier dietary habits after a CC guidance program.[44–46]

16.3.1.3 Continuous Glucose Monitoring (CGM)

CGMs track interstitial fluid glucose levels in real time, providing immediate feedback on how different foods affect sugar. The monitor is worn on the upper arm or stomach, and it stays on at all times, including during a shower or while one sleeps. This helps patients and nutritionists make informed dietary choices and adjust their intake to maintain stable glucose levels.

CGM is increasingly valued for their role in guiding precise insulin dose adjustments and enhancing treatment outcomes compared to traditional methods. Its automated data collection enhances glucose management by continuously tracking glucose levels.[47,48] Enhanced connectivity between glucose monitors and mobile phones has improved self-care and data sharing. CGM is recommended for patients with T1D and insulin-treated T2D who do not meet glycemic targets, with training and follow-up for data interpretation.[49] CGM offers the potential for enhancing the evaluation and tracking of Ingestive Activity (IA), such as the intake of foods and beverages containing calories.[50]

Advancements in digital technology have made mHealth tools vital for nutritional therapy, using the Ambulatory Glucose Profile (AGP) to customize dietary plans based on glycemic control. (Table 16.2)

Table 16.2. CGM available in India

CGM Device	Features	Accuracy [Mean Absolute Relative Difference (MARD)]
FreeStyle Libre by Abbott	Flash glucose monitoring, real-time readings, and no routine finger pricks.	9.4%
Medtronic Guardian Connect	Standalone system, real-time readings, predictive alerts via mobile application.	10.6%

The accuracy of CGM devices helps nutritionists by providing precise glucose data, allowing them to tailor dietary recommendations based on real-time glucose fluctuations. This ensures better glycemic control and more effective nutrition management for patients with diabetes.

Evidence to Support Value

Compared to SMBG, both CGM and isCGM (intermittently scanned CGM) demonstrated a reduction in HbA1c levels in individuals with T2D, and unlike CGM, isCGM use was associated with improved user satisfaction. CGM reduced HbA1c (mean difference −0.19% [95% CI −0.34, −0.04]) and glycemic medication effect score (−0.67 [−1.20 to −0.13]), reduced user satisfaction (−0.54 [−0.98, −0.11]). isCGM reduced HbA1c by −0.31% (−0.46, −0.17), increased user satisfaction (0.44 [0.29, 0.59]).

A systematic review and meta-analysis of 14 RCTs found that CGMs modestly reduce HbA1c levels in adults with T2D and improve glycemic control in T1D, reducing severe hypoglycemia compared to self-monitoring. Flash Glucose Monitoring (FGM) increased satisfaction and reduced mild hypoglycemia but did not lower HbA1c. CGM with CSII significantly lowered HbA1c compared to SMBG with multiple daily injections, while CGM-regulated insulin systems showed no HbA1c difference compared to SMBG with CSII.[51]

A clinical trial showed that CGM in adults with T2D on basal insulin significantly improved HbA1c levels and glucose control compared to traditional blood glucose meter (BGM) monitoring, with CGM users spending more time in the target glucose range and less time with high glucose levels.15

An online tool has been created to help people with diabetes compare glucose levels after meals, using CGM data. This tool visualizes how different foods affect glucose levels by normalizing preprandial values and highlighting the range of glucose fluctuations. Conducting three repetitions of a meal test to account for individual variability is recommended. The tool provides a clear graphical representation of glucose curves and allows for the direct comparison of different meals. This enables users and diabetes care teams to analyze glucose variability and develop personalized dietary strategies for better diabetes management.[52,53]

CGM in India

CGMs have become more accurate but are still costly, limiting their widespread use.

Smartphone application to detect lifestyle changes and glucose levels

A study involving 2,217 participants evaluated a remote program using CGM and wearable devices to promote lifestyle changes for T2D prevention. Over 28 days, the program tracked glucose, diet, exercise, and weight via a smartphone app, offering personalized recommendations. The results showed significant improvements in blood glucose control, weight loss, and diet, especially in participants without diabetes, suggesting that CGM and digital tools can effectively enhance metabolic health and prevent T2D.[55]

Real-Time Nutrition Assessment via CGM

A scoping review analyzed 19 studies on using CGM to detect IA in real-time for Just-In-Time Adaptive Interventions (JITAIs) in dietary management. The review found varying accuracy and response times (9 to 45 minutes) across studies, with no single CGM method universally suitable due to differences in methodologies and study variability. The optimal method depends on specific use cases.[50]

While patients' self-use and adjustment of their daily routine, including diet, is well known, effective interventions using CGM data to guide food choices that align with nutrition recommendations are sparse. (Figure 16.1)

What is needed?

- Continuous glucose monitoring device
- Smart Phone with Bluetooth connectivity

Figure 16.1 Real-Time Nutrition Assessment via CGM

Type of data received and its use by patients and Doctors

- TIR–Time in range. The total % of time when the glucose levels are in normal range
- TAR–Time above range
- TBR–Time below range
- Hypoglycaemia
- GV–Glycemic variability

Almost all CGM devices allow users to download the 14-day report and share it with their doctors. Newer applications also allow for live report sharing. (Figure 16.2)

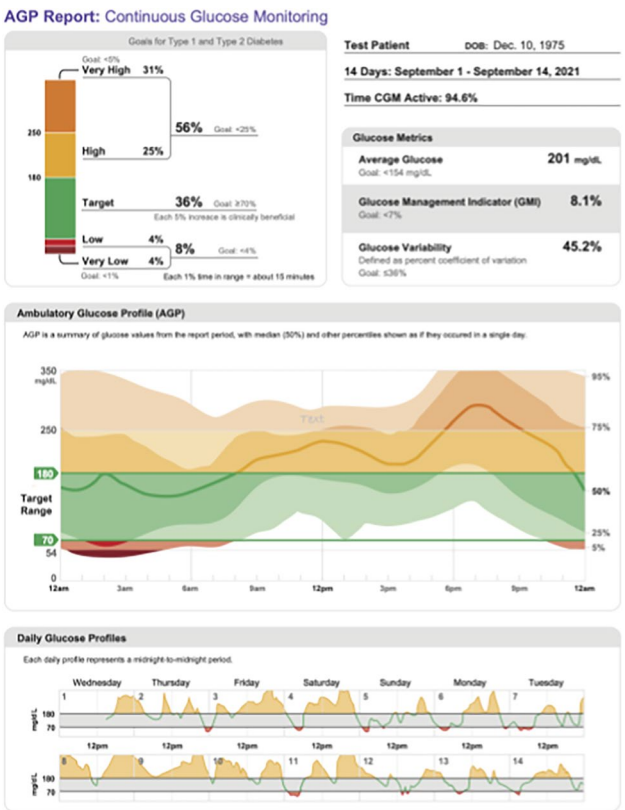

Figure 16.2 AGP Report

http://www.agpreport.org/agp/about
New-generation continuous glucose monitoring (CGM) devices are stable and do not require calibration or routine monitoring. After Bluetooth synchronization with a smartphone, data is automatically transmitted.
A 14-day CGM device would cost the patient about 5000/- INR or USD 60.
CGM devices are easy to attach and remove. The first time a person uses CGM, it is recommended that he/she be appropriately trained, advised on do's and don'ts, and the device attached in an office setting.
CGM at the recommended frequency should help optimize glucose control and facilitate behavioral modifications that translate into improved outcomes. Use in recommended frequency. (Figure 16.3)

AGP Report		Recommendations for CGM Use
TIR	TBR	
>90	<1	Once in 6 months
>70	>4	Once in 3 months
>50	>5	Once in 2 months

CGM: Continuous Glucose Monitoring, **TIR**: Time-in-range, **TBR**: Time-below-range, **AGP**: Ambulatory glucose profile

Figure 16.3 Recommendations for CGM use

While patients may feel that the cost is high, the long-term benefits of CGM make it a cost-effective solution for managing diabetes, aiding physicians in prescribing appropriate medications, maintaining a proper diet and exercise regimen, and serving as a motivational device.

16.3.2 Mobile Health Applications

Applications allow patients to log their meals, carb counting, physical activity, sleep, and glucose readings. These apps often provide immediate feedback and educational content, helping patients understand the impact of their lifestyle choices on diabetes management.
This technology serves as a tool for real-time monitoring of caloric intake for people with diabetes, enabling them to track their dietary choices throughout the day. It allows users to assess their energy intake and expenditure, incorporating features for analyzing various nutrients tailored to specific health conditions such as diabetes and cardiovascular disease. Upon inputting personal information, the application calculates the Recommended Daily Allowance (RDA) of calories. Users can log their food consumption to view the caloric content of meals and monitor their daily caloric balance. Furthermore, physical activity can be recorded to track calorie expenditure, providing users with a comprehensive overview of their net caloric intake. This tool is beneficial for individuals managing their weight, as well as those with diabetes or cardiovascular conditions.
Key characteristics
- A large food database that matches and allows the user to assess their food intake for carb intake
- Take photographs of meals and upload
- Apart from carbohydrates, these applications can also provide a breakdown of a wide range of nutrients, including protein, fat, fiber, sugar, vitamins, and minerals.
- Applications can integrate with various fitness trackers and apps, such as Fitbit, Garmin, and Apple Health, to sync activity and sleep data
- Ease of use and Cost to patient

Usually, the core functionalities of these applications are available for free. Depending on the application, the user may need to pay for premium services. (Figure 16.4)
Caution: Before recommending any application, the quality of the database and its ability to accurately provide data must be verified.

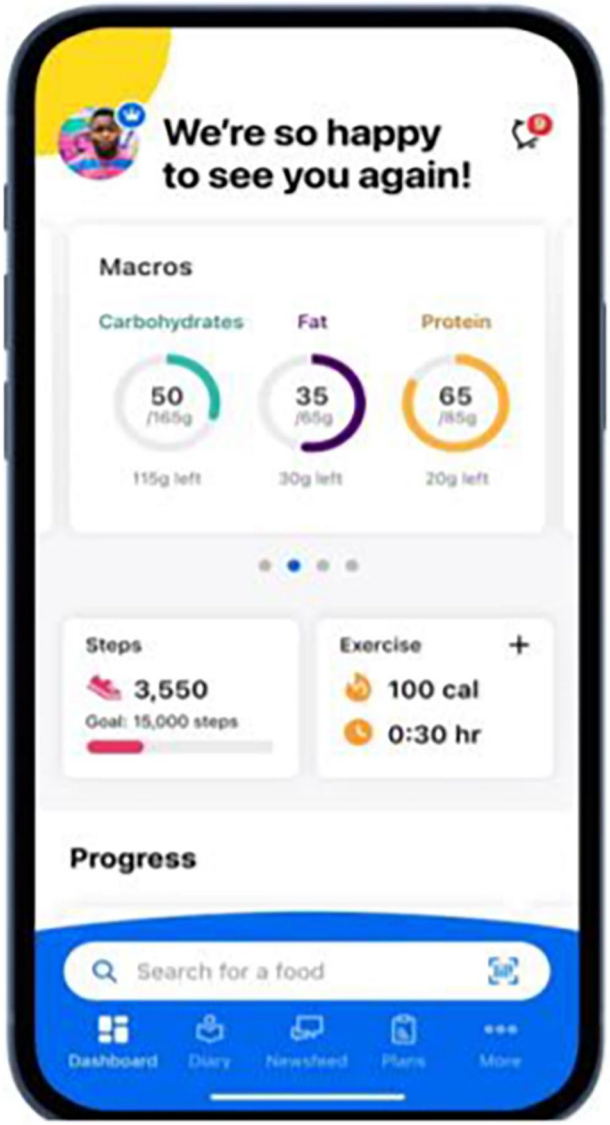

Figure 16.4 MyFitnessPal-Tracking your food made easy

16.3.3 Personalized Nutrition Plans

AI and Technology enable the creation of highly personalized nutrition plans based on individual patient data such as
- BG levels,
- dietary habits, dietary likes and dislikes, and
- Metabolic responses (from CGM or Glucometer)

This ensures that dietary recommendations are tailored to meet the specific needs of each patient, optimizing their BG control and overall health.
In the near future, applications may be available that create personalized plans for individuals, customized to their preferences, socioeconomic status, panty inventory, and other factors, whether for 1-day, 7-day, or 30-day intervals as needed. By integrating data from CGMs, the application could also fine-tune and update these meal plans in real time based on new information.

Figure 16.6 : Personalised Nutrition Plan – A Sample

Caution: This is an upcoming field where technology promises to personalise with minimal time and effort. Please check the outputs provided by AI carefully before sharing them with the patient.

Precision nutrition aims to prevent and manage chronic diseases by creating personalized dietary plans based on genetic, metabolic, and environmental factors. Advances in genomics, metabolomics, and gut microbiome research have enhanced its effectiveness, particularly for diabetes. Nutrigenomics identifies genetic variants affecting nutrient metabolism, while metabolomics and microbiome studies reveal unique metabolic patterns and pathways, allowing for targeted dietary strategies to improve BG control.

The study evaluated the Twin Precision Nutrition (TPN) Program, using Digital Twin Technology and CGM, for personalized dietary management of T2D over 90 days. Significant improvements included a 1.9% reduction in HbA1c, 6.1% weight loss, lower fasting glucose, and a 56.9% decrease in HOMA-IR. Many participants reduced or stopped diabetes medications, showing that combining precision nutrition with CGM and machine learning effectively improves diabetes management.

Application of MNT

A study aimed to assess the impact of a mHealth and community health education intervention on diabetes awareness and promoting healthy dietary and lifestyle habits within a rural population in Andhra Pradesh, India, concluded that the combined mHealth and community health education intervention improved diabetes awareness and healthy habits in rural areas, showing potential for lasting outcomes and guiding future public health efforts in similar settings. In 3 month follow up the Belief in diabetes preventability increased from 25.5% to 69.5%. Improved dietary habits were evident, with fruit consumption and high-fat food avoidance at 78.5% and 67.7% in follow-up. Physical activity levels improved in both endline and follow-up groups compared to baseline.[56]

16.3.4 Enhanced Patient Engagement and Education

Interactive Tools: Mobile applications and online platforms provide interactive tools and educational resources that help patients learn about diabetes management, the importance of nutrition, and how to make healthier food choices. These tools increase patient engagement and empower them to take an active role in managing their condition.

Gamification: Some applications use gamification techniques to encourage patients to adhere to their nutrition plans and engage in regular physical activity by making the process more enjoyable and rewarding.

16.3.5 Telehealth

Patients can consult with nutritionists and diabetes educators remotely through telehealth platforms. This is already a reality, and most EMR platforms are now equipped with Video consultation capability. This makes it easier for patients to receive professional guidance and support without the need for frequent in-person visits.

16.3.6 Insulin Pumps

An Automated Insulin Delivery (AID) system — often referred to as a closed-loop insulin delivery system or artificial pancreas — is a technology that automatically adjusts insulin delivery based on continuous glucose monitoring (CGM) data.[57]

It typically consists of three main components:

• Continuous Glucose Monitor (CGM) – measures glucose levels in real time.

• Insulin Pump – delivers rapid-acting insulin under the skin.

• Control Algorithm – a software program (in the pump or a connected device) that uses CGM readings to determine when and how much insulin to deliver.

Boughton *et al.* (2019) conducted an RCT comparing fully closed-loop insulin delivery to standard insulin therapy in hospitalized patients on enteral or parenteral nutrition. Among 43 inpatients, the closed-loop system kept glucose levels in the target range 68.4% of the time, compared to 36.4% with conventional therapy. No severe hypoglycemia or hyperglycemia was observed, indicating that closed-loop insulin delivery may enhance glycemic control in hospitalized patients.[58]

Bolus calculators in insulin pumps facilitate carbohydrate counting by automatically calculating insulin doses based on carbohydrate intake and accounting for active insulin, preventing insulin stacking and reducing hypoglycemia risk. This automation helps maintain post-meal glucose levels within the desired range. With advancements like closed-loop systems (CLS) and CGM integration, there is a shift toward adjusting insulin delivery rather than increasing carbohydrate intake, especially for weight management.[59]

Automated Insulin Delivery (AID) systems provide options for detailed CC or flexible carbohydrate entry, enhancing insulin dosing accuracy and helping users maintain their glucose levels within the desired range.[17]

Medtronic's MiniMed 780G is the only AID available in India.

Medtronic's MiniMed 780G insulin pumps use hybrid closed-loop systems with carb counting to calculate insulin doses based on carbohydrate intake, glucose levels, and insulin sensitivity. The 780G additionally offers automated correction boluses to manage post-meal glucose spikes, emphasizing the importance of accurate carb counting for optimal diabetes management.

Flex carbohydrate counting with AID

A study assessed glycemic control in adolescents with T1D using two dietary strategies—carbohydrate counting ("flex") and simplified meal announcement ("fix")—while on the MiniMed™ 780G insulin pump for a year. The flex group achieved a higher TIR for BG levels (80.1%) compared to the fix group (72.9%), although HbA1c levels were similar. The study concluded that both methods maintained glycemic control, but carbohydrate counting led to better TIR despite its complexity.[60]

A study assessed glucose control in adolescents with T1D using the MiniMed 780G system by comparing two dietary approaches: simplified meal announcement and precise CC. In a trial involving 34 participants aged 12–18, those using precise carbohydrate counting showed a significantly higher time-in-range for glucose levels (80.3%) compared to the simplified approach (73.5%). Although both methods met glycemic targets, precise carbohydrate counting provided better glucose management, particularly for high glucose levels, and remains an important skill for optimal diabetes control.[61]

Recent Trends in the Use of AID

Current trends in AID systems involve combining with CGM to enable real-time insulin adjustments, incorporating adaptive algorithms for individualized insulin dosing, and facilitating remote monitoring and data sharing. Enhancements in user interfaces and mobile app integration have made these systems more accessible. There's also a growing acceptance among different age groups, a rising interest in hybrid closed-loop systems, and an emphasis on maintaining "time in range" to optimize glucose management.[62] (Table 16.3)

Table 16.3. Globally available AIDs

Device	Manufacturer	Type	Key Features	Availability	Accuracy
MiniMed 780G	Medtronic	Hybrid Closed-Loop System	Automatic basal and bolus insulin delivery, adjustable target glucose settings, Guardian Sensor 4 CGM integration.	Widely available in the US, Europe, and other markets.	Approximately 76-78% TIR (70–180 mg/dL) in clinical studies.
TX2 with Control-IQ	Tandem Diabetes Care	Hybrid Closed-Loop System	Integrates with Dexcom G6 CGM, advanced algorithms for predictive glucose management, touchscreen interface.	Available in the US, Canada, Europe, and other regions.	Approximately 70–75% TIR (70–180 mg/dL) in clinical use.
Omnipod 5	Insulet Corporation	Tubeless Automated Insulin Delivery System	Integrates with Dexcom G6 CGM, wireless tubeless pods, personalized target glucose range settings.	Available in the US, expected expansion to other regions.	Approximately 70-74% TIR (70-180 mg/dL) in clinical studies.
Medtrum A7+	Medtrum	Automated Insulin Delivery (AID) System	Tubeless patch pump, integrates with CGM, predictive glucose management, mobile app control.	Available in Europe and parts of Asia.	Approximately 65–70% TIR (70–180 mg/dL) in clinical use.
YpsoPump with mylife Loop	Ypsomed	Hybrid Closed-Loop System	Compact insulin pump, integrates with Dexcom G6 CGM, customizable bolus calculator, Bluetooth connectivity.	Available in Europe, Australia, and select markets.	Approximately 65–70% TIR (70–180 mg/dL) based on user reports.

16.3.7 Machine learning and Artificial Intelligence

Chaki *et al.* presented an in-depth examination of automated methods for detecting and diagnosing diabetes. Out of 107 studies reviewed, 28 highlighted the advantages of AI assistants for managing DM. The integration of digitization and smart applications has enhanced the digital management and personalization of DM, with AI devices enabling real-time glucose monitoring and better self-management. AI algorithms aid in forecasting glucose levels and emulate human cognitive abilities, while various AI tools, such as chatbots, facilitate DM self-monitoring and personalized care.[63]
Bateja *et al*. (2024) developed a system using an optimized Support Vector Machine (SVM) with Particle Swarm Optimization (PSO) for early diabetes diagnosis, achieving 99.20% accuracy. The system also uses I-DBSCAN for precise clustering of EHR data by symptoms and Collaborative Filtering for personalized medication recommendations, effectively managing large data volumes for early detection and tailored treatment.[64]
Shamanna *et al.*, (2023) assessed the effectiveness of digital twin (DT) technology in managing postprandial hyperglycemia and metabolic dysfunction-associated fatty liver disease (MAFLD) in T2D patients. In a trial with 319 participants, those using DT received tailored meal, activity, and sleep plans, while the control group received standard care. The DT group showed significant improvements in HbA1c levels, achieved a 72.7% remission rate for T2D, and experienced notable reductions in liver fat and fibrosis scores, as well as decreased liver fat percentage as measured by Magnetic Resonance Imaging (MRI). Overall, DT technology significantly enhanced both glycemic control and MAFLD markers over one year.[5]

16.4 CONCLUSIONS AND RECOMMENDATIONS

CLINICAL PEARLS OF PRACTICE

- CGM provides real-time feedback on glucose trends and the impact of food choices, helping improve HbA1c levels and reduce glycemic variability.
- Advanced Automated Insulin Delivery (AID) Systems: Enhance glycaemic control by automatically adjusting insulin doses based on CGM data, increasing Time-in-Range (TIR), and optimizing overall glucose management. These systems lighten the burden of constant monitoring and adjustments, improving glycemic outcomes and quality of life.
- AI-Powered Platforms: Create personalized nutrition plans tailored to real-time glucose data, metabolic responses, and dietary patterns, supporting better long-term diabetes management.
- Mobile Health Applications: Tracking food intake, physical activity, and glucose levels, enabling patients to make informed decisions and adjust behaviours to improve diabetes control.

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Section 17A: Functional Foods in Type 2 Diabetes Mellitus (T2D) Management

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17.1 INTRODUCTION

Functional foods are defined as natural or processed foods containing known or unknown biologically active compounds, which, when consumed in defined, practical, non-toxic quantities, provide clinically established and recognized health benefits for the prevention, management, or treatment of chronic diseases.[1]
Functional foods can have natural items from plant or animal sources or processed products fortified with bioactive compounds such as prebiotics, probiotics, synbiotics, Polyunsaturated Fatty Acids (PUFA), vitamins,[2] minerals, proteins/amino acids, Essential Fatty Acids (EFA), phytonutrients such as polyphenols, flavanols, phenolic acids, phytosterols or nutrient/non-nutrient antioxidants.[3] Based on their bioactive compounds, functional foods may be categorized as foods that improve oxidative stress, reduce inflammation, reduce insulin resistance, reduce glucose absorption, improve insulin secretion, improve lipid profile, have anti-aging properties, enhance digestion, reduce gastric disturbances, reduce symptoms of gastroparesis and alike, which are often reported by people with diabetes[2,4–7] Thus, they may improve the quality of life by working singly or along with medications.[4,5]

17.2 RATIONALE AND SUPPORTING EVIDENCE

The Indian tradition of Ayurveda has long recognized the medicinal properties of food, a concept integral to managing diabetes through functional foods rooted in centuries-old culinary practices.[6] It is important to emphasize the diverse options available to address the multifaceted aspects of Type 2 Diabetes (T2D). In general, plant-based foods are rich in dietary fiber, pigments, bioactive compounds, PUFA, polyphenols, sterols, proteins, sulfated polysaccharides, and antioxidants, which offer multifaceted health benefits. All plant foods have bioactive compounds and, based on their composition, support various aspects of metabolic health, from regulating lipid metabolism to enhancing insulin sensitivity and reducing inflammation.[2,4–10]
Spices such as turmeric (*Curcuma longa*), cinnamon (*Cinnamomum verum*), fenugreek (*Trigonella foenum-graecum*), nuts, and oilseeds are known for their anti-inflammatory and antioxidant properties and are rich in curcumin, galactomannan, diosgenin, 4-hydroxy isoleucine, 3- hydroxy-4,5-dimethyl-2(5H) furanone (sotolone), which contribute to improved insulin sensitivity, better glycemic control, improvement in Gestational Diabetes Mellitus (GDM) and overall metabolic health.[9,10]
Cinnamon *(Cinnamomum verum)* is rich in limonoids, terpenoids, alkaloids, glycosides, diosgenin (steroidal sapinogen), and polyphenols (rhaponticin and isovitexin). Soaking fenugreek seeds (2.5–15 g) overnight and consuming them in the morning improves glycemic

control and increases insulin sensitivity. The bioactive ingredients present in fenugreek seeds are steroids, flavonoids, esters, quinones, phenols, acids, aliphatic alcohol, amides, lactones, aliphatic ketones, and benzodioxols, and it can be consumed as a powder, in capsules, or in tea.[10–23]

Ginger (*Zingiber officinale Roscoe*) is a common and widely used spice rich in various chemical constituents, including phenolic compounds, lipids, polysaccharides, terpenes, raw fibers, and organic acids. The health benefits of ginger have been attributed mainly to its content of phenolic compounds, such as shogaols and gingerols. Significant reductions in Fasting Blood Sugar (FBS), HbA1c, Systolic Blood Pressure (SBP), and Diastolic Blood Pressure (DBP) were found after ginger supplementation in patients with T2D.[24–26]

Garlic (*Allium sativum* L.) is a common spice with many health benefits, purportedly due to its diverse bioactive compounds, such as organic sulfides, saponins, phenolic compounds, and polysaccharides. Garlic contains bioactive compounds, such as allicin, alliin, diallyl sulfide, diallyl disulfide, diallyl trisulfide, ajoene, and S-allyl-cysteine. Raw garlic or its medicinal forms can lower Blood Glucose (BG) levels. Other parameters in blood, such as total cholesterol, Low-Density Lipoprotein (LDL), and High-Density Lipoprotein (HDL), can also be affected by garlic.[27–29]

Bitter gourd *(Momordica charantia),* rich in alkaloids, glycosides, cholesterol, saponins, flavonoids, charantin (insulin-like peptide), polypeptide-p, and vicine, possesses hypoglycemic properties and exerts its beneficial effects via several mechanisms to control and treat diabetes mellitus. Bitter gourd is one of the most commonly used vegetables that contain polypeptide-p or p-insulin and is used to control diabetes naturally.[30–33]

Bhui amla (*Phyllanthus amarus)*, amla *(Phyllanthus emblica)*, tulsi (*Ocimum sanctum*), indian malabar kino/vijaysar bark (*Pterocarpus marsupium)*, jamun (*Eugenia jambolana*), giloy/guduchi leaf and stem (*Tinospora cordifolia)*, ashwagandha/winter cherry/Indian ginseng (*Withania somnifera*) have evidence of enhancing insulin sensitivity and reducing inflammation due to the presence of phytonutrients such as steroids, aliphatics, alkaloids (phyllantine, quinolizidine type, securinine, norsecurinine, isobubbialine, and epibubbialine), glycosides, diterpenoid lactones, flavonoids (quercetin-3-0-glucoside and rutin), tannins (geraniin, amariin, and gallocatechin). Holy basil is rich in oleanolic acid, ursolic acid, rosmarinic acid, eugenol, carvacrol, linalool, and β-caryophyllene. These phytonutrients assist in accelerating the transport of glucose into cells via inhibition of α-glucosidase, α-amylase, and dipeptidyl peptidase-IV enzymes, thus fostering better overall health and reducing the complications associated with T2D. Amla/gooseberries *(Emblica officinalis)* are rich in phenolics, including hydrolyzable tannins (both ellagitannins and gallotannins), anthocyanins, flavonoids, flavonols, phenolic acids, proanthocyanidins, anthocyanins, flavonols, resveratrol. Phenolic fractions lower gene expression for hepatic gluconeogenesis. Other plant-based hypoglycemic functional foods are curry leaves (*Murraya koenigi),* containing polyphenols, alkaloids, and flavonoids (mahanine, mahanimbine, isolongifolene, koenimbine, girinimbine, isomahanine, koenoline, and O-methylmurrayamine). Drumstick leaves *(Moringa oleifera) are* rich in beta carotene, antioxidants, phenolic acids, gallic acid, epigallocatechin gallate, chlorogenic acid isothiocyanates, tannins, flavonoids, and saponins. Bael leaves (*Aegle marmelos (L.) Correa) are* rich in alkaloids, terpenoids, flavonoids, and coumarins. Mulberry leaf extract may be a useful complementary mealtime glucose option for patients with T2D.[34–38] Punarnava *(Boerhavia diffusa L.)* contains punarnavoside, trans-caftaric acid, boerhavia acid), rotenoid (boeravinone A-J), flavonoid (borhaavone, quercetin, kaempferol), isoflavonoid (2′-O-methyl abronisoflavone), alkaloid (punarnavine), steroid (boerhavisterol, *β* -Ecdysone), anthracenes and lignans. Onions (*Allium cepa)* contain flavanol-quercetin, *and garlic (Allium sativum) is* rich in allicin S-allyl cysteine. Basti, *Gokshur* or *Gokharu,* or puncture vine (*Tribulus Terrestris) contains*[39–46] dietary fiber, phenolic compounds, and antioxidants, and bioactive compounds [34–37,47,48] such as gallic acid, ferulic acid,[38,49–53] caffeic acid, zeaxanthin, lutein, and β-carotene.[54–57] Lemon grass (*Cymbopogon citratus*), green tea, and *Rhus coriaria* L. (sumac) sumac also contribute significantly to managing diabetes. These antioxidant-rich foods provide a beneficial effect by reducing the long-term risk of diabetic nephropathy via suppressing hyperglycemia, preventing glycogen accumulation in the proximal tubules, and improving serum and urine parameters (glucose, glycosylated proteins and albumin, and blood urea nitrogen).[58,59]

It is essential to incorporate whole grains such as whole wheat, rye, oat, and barley because their nutritional profiles support glycemic response, insulin sensitivity, and pancreatic beta cell function. They are rich in soluble and insoluble fibers, inulin, β-glucan, resistant starches, and non-carbohydrate functional components, including carotenoids, phytates, phytoestrogens, and phenolic acids such as ferulic acid, vanillic acid, caffeic acid, syringic acid, and p-coumaric acid instead of cumaric acid, which are useful to reduce oxidative stress. Brown rice (*Oryza sativa L.)* offers an advantage over white rice due to the presence of γ-oryzanol; minerals such as magnesium, phosphorus, selenium, thiamine, niacin, and vitamin B6; and natural pigments such as anthocyanin. Germinated brown rice exhibits promising anti-diabetic properties, making them valuable additions to the Medical Nutrition Therapy (MNT) for people with diabetes.[60–67]

Though Millets or *Shree Anna* have a varying Glycemic Index (GI), they have an advantage over any polished grain due to the presence of several phytonutrients. Barnyard millet (*Echinochloa frumentacea*), proso millet (*Panicum miliaceum),* kodo (*Paspalum scrobiculatum*), little millet (*Panicum sumatrense*), foxtail millet (*Setaria italica*), finger millet (*Eleusine corcana),* pearl millet (*Pennisetum glaucum)* are rich in fiber, antioxidants, polyphenols, phenolic acids, flavonoids (tricin, acacetin, 3, 4 Di-OMe luteolin, and 4-OMe tricin), tannins, phytates, anthocyanins,[68–72], calcium, sulfur-containing amino acids (methionine and cysteine) and omega-3 fatty acids. Psuedo cereals such as buckwheat (*Fagopyrum esculentum*),[73–78] amaranth (*Amaranthus*), and bamboo rice (*Phyllostachys bambusoides*) have been associated with reducing inflammation due to the presence of zinc, copper, and manganese; bioflavonoids, rutin, and quercetin.[79–84]

Legumes, including peas, beans, lentils, and peanuts, stand out as powerhouse foods for people with diabetes as they are rich in dietary protein, fiber, antioxidants, bioactive phenolic compounds, such as malvidin-3-glucoside, petunidin-3-glucoside, delphinidin3-glucoside, and delphinidin-3,5-glucoside, and help control LDL cholesterol levels and manage hypertension, further highlighting their value as MNT for people with diabetes. Protein-rich soybeans (*Glycine max)*, with their abundance of phytoestrogens and bioactive peptides (daidzein, genistein, and glycytein), exhibit anti-inflammatory and lipid-lowering properties, making them invaluable components of a diabetes-friendly diet.[85–89]

Colorful berries, local fruits, and vegetables such as red tomatoes (lycopene and chlorogenic acids), apples[1–9], and other regional and seasonal fruits in the diets reduce inflammation.[10,16] They are a repository of antioxidants, fiber, vitamins, carotenoids, procyanidins, and phytochemicals, and they improve glycemic control and cardiovascular health while reducing triglyceride levels and oxidative stress.[90–92]

Jackfruit (*Artocarpus heterophyllus)* and its flour have exhibited glucose-lowering effects. Jackfruit is rich in dietary fiber, carbohydrates, vitamins, and minerals. Carotenoids, proanthocyanidins, flavonoids, volatile acids, sterols, and tannins are some of the phytochemical compounds present in jackfruit.[93,94] Raw bananas and their products, such as flour, are high in resistant starch. Administration of *kepok* banana flour with 4%, 8%, and 12% resistant starch is able to decrease glucose levels, restore body weight loss, and reduce feed intake in streptozotocin-nicotinamide-induced type 2 diabetic rats. Unripe banana flour can be considered a functional food ingredient that may contribute to reduced risks of certain non-communicable diseases owing to its high resistant starch levels.[95,96]

Dairy products containing probiotics alter gut microflora and may be helpful in reducing gut dysbiosis. However, more research is needed to understand the best probiotic strains, doses, and therapy durations for the management of diabetes. In the diet, probiotic-rich foods like yogurt and kefir, as well as prebiotic-rich foods like garlic, onions, and bananas, have shown a positive impact on maintaining gut health and improving glycemic control. Research has found that supplementation with a probiotic yogurt improved glycemic control and lipid profiles in people with diabetes.[97–103]

Dairy products have also been shown to reduce incident diabetes, hypertension, and metabolic syndrome and to be associated with lower mortality. The overall benefits of dairy products, particularly cultured dairy, eg, Yogurt in preventing incidence of T2D, has been summarized in a systematic review.[104–107] Vegetable oils rich in omega-6 and depletion of omega-3 fatty acids (FAs) in daily diets have led to an imbalance between omega-3 and omega-6. The high EPA/AA ratio [eicosapentaenoic acid (EPA) and arachidonic acid (AA)] is a promising indicator of better glycemic control and reduced inflammation. Omega-3 fatty acids from fatty fish (salmon, mackerel), flaxseeds, chia seeds, and walnuts improve cardiovascular health and reduce inflammation. Protein and vitamin-rich fish and seafood reduce the magnitude of age-associated increases in blood pressure, improve glucose homeostasis, help prevent diabetes and metabolic syndrome, and have a positive impact on muscle mass preservation.[53] Fish contains EPA and docosahexaenoic acid (DHA).[108–110]

Flaxseed *(Linum usitatissimum)* is rich in alpha-linolenic acid (ALA), a type of omega-3 FA, and also has lignans (sesamin), which inhibit the production of oxidative stress to slow down AGE-induced β-cell dysfunction and apoptosis, lower blood pressure, and lower blood lipids.[111,112] Chia seeds (*Salvia hispanica) are rich in* omega-3 (n-3) FAs, and have higher amounts of protein, fiber, and antioxidants than other plants. They are a rich source of polyphenols: gallic, caffeic, chlorogenic, cinnamic, and ferulic acids, quercetin, kaempferol, epicatechin, rutin, apigenin, and p-coumaric acid.[113,114]

An intake of 28 g/day of tree nuts such as almonds (*Amygdalus communis L.*), hazelnuts (*Corylus avellana*), walnuts *(Juglans regia*), cashews (*Anacardium occidentale*), pecan nuts (*Carya illinoinensis (Wangenh.),* pistachios (*Pistacia vera*) and peanuts (*Arachis hypogaea),* reduce BG and HbA1c. Studies on cashews and almonds have shown metabolic benefits, including a reduction in blood pressure and an increase in HDL.[115,116] Nuts are rich in proteins, Monounsaturated Fatty Acid (MUFA), fiber, and omega-3 FA. However, allergies and adverse reactions related to nuts are recorded. Intake of 25–30 g fiber/day has shown an improvement in glycemic parameters, lipid levels, body weight, inflammation and a reduction in premature mortality.[117–119]

Blue-green algae Spirulina contain PUFA, polyphenols, sterols, proteins, sulfated polysaccharides, antioxidants, and amino acids (leucine, valine, isoleucine, tryptophan, methionine, phenylalanine, theanine, and lysine).[120–122] (Table 17.1)

Table 17.1. Herbal products in the management of hyperglycemia[1,2]

Herbal product	Active molecule	Part of plant	Dose	FBS fall (mg/dL)	HbA1C fall (%)
Cinnamon[9,14,19,20–22,123,124]	Procyanidin type A polymer	Bark	0.5–6 g	2–111	0–1.2
Gurmar[6,124]	Gymnemic acid	Leaf	0.4–10 g	6–81	0.3–1.5
Cumin[9,18,124]	Thymoquinone	Seed	0.1–0.5 g	3–56	1–1.8
Psyllium[124]	NA	Husk	6.8–10.5 g	20–53	1–1.6
Sesame[124]	Sesamine	Seed	0.2 g or 30 mL	34–52	0.7–1.1
Barberry[92,124]	Berberine	Root, stem, bark	0.9–1.5 g	57–68	1.4–1.9
Aloe[124]	Acemannan	Leaf	600–1000 g	13–44	0.4–0.7
Fenugreek[6,9,18,15,23,124–128]	4-OH isoleucine	Seed	1–100 g	15–41	0.2–1.5
Bael[36–38,49,51,124]	Aegeline	Seed, leaf, fruit pulp	5–20 g	34–41	1.9
Jamun[4,6,124]	Gallic acid	Seed	10 g	18–33	0.4–0.6
Ginger[3,9,24–26,124]	Gingerol, shogaol	Rhizome	1.6–2 g	10–29	0.04–1.1
Little gourd[124]	Pectin	Leaf, fruit	0.5–1 g	20–25	0.6–0.7

Neem[124]	Nimbidiol	Root, bark	1 g	23	1.5
Sweet potato[124]	Anthocyanins	Leaf, tuber	4 g	10–19	0.2–0.3
Amla[5,39,40–44,124]	Gallic acid	Fruit	0.5–10 g	13–15	0.4–0.5
Bitter gourd[6,30–33,124]	Momordin, charantin	Whole plant	0.8–4 g	5–15	0.3
Garlic[3,6,9,27–29,54–56,124]	Allicin	Bulb	0.9–1.5 g	4–10	0.2–0.8
Turmeric[3,9,11–13,20,124]	Curcumin	Rhizome	0.5–2.1 g	2–9	0.02–0.9
Guduchi[124]	Palmatine	Stem	0.5–1.5 g	5–8	0.2–0.5
Jackfruit[93,94,124]	Proanthocyanidin, flavonoids	Flour	30 g	29.45	0.25
Mulberry[50]	Polyhydroxylated alkaloids, flavonoids, polysaccharides, triacetin, gallic acid, chlorogenic acid, 1-deoxynojirimycin, resveratrol, scopoletin, astragaloside.	Leaf extract	3000 mg	16.1 %	0.36

17.3 CONCLUSION AND RECOMMENDATIONS

When discussing dietary recommendations for people with diabetes, it is critical to highlight the diverse range of functional foods available to address the multifaceted aspects of T2D. In certain instances, high-dose supplements containing bioactive components may pose health risks. Conversely, a diet rich in a diverse array of phytochemicals offers potential benefits in the prevention and management of diabetes. It is hypothesized that an optimal blend of various phytochemicals possessing complementary actions may facilitate synergistic interactions, providing an economical and sustainable approach for T2D management. To this end, it is recommended to consume a varied diet inclusive of fruits, vegetables, legumes, whole grains, low-fat dairy products, seeds, nuts, and spices to manage diabetes effectively and enhance the overall quality of life.

A comprehensive diet encompassing these functional foods is pivotal in effectively managing T2D and mitigating the risks of its associated complications. Ayurveda, the Indian traditional medicinal system, describes the use of many such functional foods for the prevention and management of diabetes. Further research is needed to generate evidence on other functional foods in the management of diabetes and its complications.

Clinical Pearls of Practice

- Functional foods play a crucial role in managing diabetes by helping to control BG levels. Many Indian spices, condiments, and vegetables are rich in plant sterols and stanols, offer an array of flavors and nutritional benefits, and aid in managing diabetes, lipid profile, and overall health. Commonly used Indian spices/fruits/vegetables such as Turmeric (Haldi), Cinnamon (Dalchini), Fenugreek (Methi), Ginger (Adrak), Indian Gooseberry (Amla), Bitter gourd (Karela), and many others discussed in this chapter help in regulating BG levels, reduce inflammation and improve insulin sensitivity. The use of fiber-rich foods, omega-3, FAs antioxidants, along with a low-calorie, good-quality, dietary protein diet plan for people with diabetes under the supervision of a nutritionist, is warranted.
- Functional foods offer a wide range of necessary nutrients (antioxidants, polyphenols, fibers, natural prebiotics, and other bioactive compounds) to gear the metabolism toward a positive side in people with diabetes.
- The ingredients discussed can be easily incorporated into day-to-day Indian cooking, which would not only help to add to the nutritive value of food but also lower the GI or glycemic load (GL) of food.
- A combination of the food groups along with the incorporation of functional foods in the daily diets may help in optimizing the health of people with diabetes.

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Section 17B: Meal Replacement Therapy

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17.4 INTRODUCTION

17.4.1 Meal Replacement Therapy

Meal Replacement Therapy (MRT) is a structured intervention involving a Low-Calorie Diet (LCD) prescription to promote effective weight reduction and improve metabolic health. LCD reduces calorie intake by approximately 500 calories daily, while a Very Low-Calorie Diet (VLCD) allows for around 800 calories daily. Meal replacement products are specifically formulated to meet an individual's daily nutritional requirements, including adequate protein, essential fatty acids, carbohydrates, vitamins, minerals, and trace elements, ensuring safe and efficient weight loss. Supervision by a healthcare professional is essential when using MRTs.

For optimal weight reduction, an initial intensive phase is recommended, involving the exclusive consumption of Meal Replacers (MRs) at around 800 kcal per day. Following this phase, gradual weight loss over the next 4 to 8 weeks is advised, with a daily intake of up to 1200 kcal comprising a combination of MRs and 1–2 low-calorie meals. Subsequently, individuals transition into a maintenance phase, limiting calorie consumption to <1500 kcal/day. During this phase, meal replacement products may be gradually phased out or continued as needed, under the guidance of the treating physician, focusing on long-term weight maintenance. Cognitive and behavioral counseling should be integrated into the treatment regimen.[1] The table (17.2) given below summarizes weight loss targets based on comorbidities; however, targets must be individualized in certain conditions such as eating disorders, pregnancy, organ failures, and chemotherapy recipients.[2]

Table 17.2. Weight Loss Targets Based on Comorbidities[2]

Diseases	Weight Loss (%)	Expected Outcomes
Type 2 Diabetes Mellitus (T2D)	5–15	• Reduction in HbA1c. • Reduction in drugs. • Remission of diabetes.
Metabolic Syndrome	7–10	• Prevention of diabetes.
MASLD (Metabolic Associated Steatotic Liver Disease)	7–10	• Reduction in intrahepatocyte fat and NASH resolution (64–90%).
PCOS (Polycystic Ovary Syndrome)	5–15	• Ovulation. • Reduction in insulin resistance and hirsutism.
Dyslipidemia	5–15	• Reduction in triglyceride and LDL - c. • Rise in HDL-c.
Hypertension	5–15	• Lower blood pressure. • Decreased medications.
Sleep apnea	7–11	• Decrease in apnea and hypopnea index.

The ICMR-INDIAB study 2022 advocates decreasing carbohydrate intake (%E) and augmenting protein intake (%E) for remission of diabetes and pre-diabetes. It suggests reducing carbohydrate intake to 49–54%, increasing protein intake to 19–20% for diabetes remission, and reducing carbohydrate intake to 50–56% while increasing protein intake to 18–20% for remission of pre-diabetes to normal glucose tolerance.[3]

17.4.2 Composition of Meal Replacement Therapies

MRs are pre-packaged, portion-controlled foods that substitute meals and/or snacks. They typically contain a mix of macronutrients- carbohydrates, protein, and fat and are often fortified with vitamins, minerals, and bioactive compounds. MRs are formulated to provide a balanced, low-calorie, low-fat diet when consumed with one or more meals or snacks. They are commonly rich in fiber and have a low Glycemic Index (GI). Available in various forms[1,4] such as liquids/shakes, powders, soups, and meal/snack bars, MRs adhere to average macronutrient distribution standards set forth by Codex Alimentarius and regulations outlined by Food Safety and Standards India (Health Supplements, Nutraceuticals, Food for Special Dietary Use), Regulations, 2022.[5,6] (Table 17.3)

Table 17.3. Average Macronutrient Distribution by Codex Alimentarius

Energy	200–400 kcal.
Protein	25–50% of total energy or ≥12 g; ≤ 125 g/day.
Fat	≤ 30% of total energy and not less than 3% of the energy from linoleic acid in the form of glyceride.
Vitamins and Minerals	≥ 25% Recommended Daily allowance (RDA).
Fiber	These products must contain adequate fiber.

Preserving muscle mass is crucial in any weight loss program since lean mass influences the Basal Metabolic Rate (BMR). The objective is to shed fat while retaining muscle mass, thereby sustaining a higher BMR and energy expenditure, which can often decrease during weight loss. Protein-enriched MRTs have effectively maintained lean body mass during weight loss,[6,7] particularly when combined with resistance exercise.[4,8] In India, where protein consumption tends to be lower, MRs containing high protein, moderate carbohydrates, and a low GI (<55) are well-suited for individuals with T2D and can be beneficially incorporated into their diets. (Table 17.4)

Table 17.4. Meal Replacement Therapy

Meal Replacement Therapy	
Types of MRT	**Description**
Partial MRT	Involves replacing one or two meals in a day with meal replacement products.
Total MRT (TMR)	Involves replacing all meals with MRs, making MRs the sole source of daily nutrition. Extensively studied for weight loss enhancement. Significant initial weight loss was observed with LCD using TMR.

17.5 ROLE OF MEAL REPLACERS IN T2D MANAGEMENT

17.5.1 Evidence-Use of MRs in T2D Management

Table 17.5. Use of MRs in T2D Management

Study name	Study design and subjects	Dietary intervention	Outcomes
Look AHEAD Study (2013)[9]	Multi-center, randomized controlled trial individuals with T2D (n=5145) **Partial meal replacement**	Intensive lifestyle intervention (ILI) • 1200–1800 kcal/day and • >175 minutes of moderate-intensity physical activity/week Diabetes support and education (DSE) involved group sessions • Focused on diet, exercise, and social support.	Weight loss was greater in the ILI group compared to the control group throughout. • At year 1–8.6% vs. 0.7% • At study end-6.0% vs. 3.5% Greater reductions in HbA1c in the ILI group Initial improvements in fitness and cardiovascular risk factors ○ Except for LDL cholesterol.
DiRECT (2018)[10]	Open-label, cluster randomized trial individuals with T2D (n=298) **Complete meal replacement**	LCD replacement for 12 weeks followed by structured food reintroduction for 12–20 weeks • 825–853 kcal/day • Participants consumed ○ 59% carbohydrate ○ 13% fat ○ 26% protein ○ 2% fiber	At 12 months • Weight loss of ≥15 kg ○ Intervention group-24% (n = 36) ○ Control group-0% • Mean HbA1c ○ Intervention group decreased by 0.9% ○ Control group increased by 0.1% At 24 months • Weight loss of ≥15 kg ○ Intervention group-11% (n = 36) ○ Control group-2% (n = 36)
Shiau JY *et al.* (2018)[11]	Retrospective cohort study	• Participants consumed ○ 4 MR shakes/day	• Baseline versus 6-month HbA1c levels

	obese individuals with T2D (n=317) **Complete meal replacement**	(900 kcal/day) • Then, the transition to a maintenance diet	○ Significant reductions in all groups ○ HbA1c levels, Group WN < Group WG (Weight-Neutral Medication, WN and Weight-Gaining Medications, WG)
Noronha JC *et al.* **(2019)**[12]	Systematic review and meta-analysis of RCTs	MRT	• Moderate certainty for reductions in ○ Body Weight ○ BMI ○ Body fat ○ Fasting insulin ○ Systolic blood pressure • Low certainty for reductions in ○ Waist circumference ○ HbA1c ○ Fasting glucose

Dharmalingam M *et al.* (2022)[13]	Open-label, Multicenter Randomized Study **Partial meal replacement**	For 12 weeks • PMR group (Partial MRT group) ○ Daily serving of Diabetes diabetes-specific nutrition Supplement (DSNS) + SOC treatment • SOC group (standard of care) ○ SOC alone	PMR group • Significant reduction in ○ Mean HbA1c ○ Body weight ○ Waist circumference • Better Quality of Life (QoL) parameters Both Groups • Significant reductions in ○ Mean fasting plasma glucose ○ Post-prandial glucose
Deshpande N *et al.* (2023)[14]	Prospective, Longitudinal Study **Complete meal replacement**	• LCD ○ 800–830 calories □ Included ○ Shakes ○ Non-Starchy Vegetables ○ Soup ○ Diluted Buttermilk	• Weight reduction • Reduction in body fat % • HbA1c reduction • Improvements in Fasting and Post-Prandial Glucose Levels
Mohan, V *et al.* 2019[15]	Participants = 120 overweight or obese individuals with T2DM, Intervention (IG, n = 60) and control (CG, n = 60) groups. **Partial meal replacement**	12-week intervention BMI ≥23.0–≤26.9 kg/m^2 advised to consume 1 serving of diabetes-specific nutrition supplement BMI ≥27.0–≤30.0 kg/m^2 advised to consume 2 servings of diabetes-specific nutrition supplement in a day.	Compared to the control group, the intervention group showed • significant reduction in HbA1C (IG: −0.95% vs. CG: −0.48%). • fasting blood glucose (IG: −18.47 mg/dL vs. CG: 1.34 mg/dL). • Reduction in postprandial plasma glucose (IG: −29.77 mg/dL vs. CG: −2.64 mg/dL). • Significant reduction from baseline in incremental Area

			under the Curve (AUC) (p = 0.01) in the intervention group (Δ–22 mg) compared to the control group (Δ–7.9 mg).
Gulati S *et al.* 2015[16]	An open label, randomized, crossover study Participants = 40 individuals with T2D. **Partial meal replacement**	Group A (n = 22) diabetes-specific formula—55 g in 210 mL of water; Group B (n = 18) isocaloric meal-42 g of cornflakes in 250 mL of milk.	Compared to the control group (Group B), the intervention group (Group A) showed- • significantly lower area under the curve for blood glucose post-meal at 30 min, 60 min, 120 min, and 180 min. • The increase in serum insulin levels from baseline was lower.
Gulati S *et al.* 2017[17]	Open-label, parallel-arm randomized controlled trial Participants = 122 overweight/obese men and women. **Partial meal replacement**	Control group: Dietary counselling, 60% carbohydrate, 25% fat and 15% protein; Intervention group (HPMR): Dietary counselling, 47% carbohydrate, 24% fat and 29% protein and replace two daily meals (mainly breakfast and dinner) with high protein meal replacer.	Mean reduction in the following were observed in the HPMR group compared with the control group: • Body weight-4·9% • Waist circumference-3·8% • % Body fat-6·3% • Post-oral glucose tolerance test (post-OGTT) BG-7·3% • Fasting serum insulin 3·8 v. 0% • Post-OGTT serum insulin was 50·3 v. 77·3 mU/l • Hs-CRP 16·7 v. 0%

17.5.2 Mechanism

The prominent mechanism underlying T2D remission through LCD is elucidated by the *Twin cycle* hypothesis proposed by Roy Taylor.[18] This hypothesis posits that excessive caloric intake, compounded with insulin resistance, prompts ectopic fat deposition in hepatocytes and pancreatic islets of Langerhans. This accumulation leads to heightened hepatic insulin resistance, diversion of very-low-density lipoproteins (VLDL), diminished first-phase insulin secretion, and heightened inflammation. Hepatic insulin response is compromised by hepatic fat surplus, fostering glucose overproduction. Similarly, pancreatic lipid overload induces metabolic strain, impairing beta-cell function over time. Substantial weight loss effectively reduces pancreatic and hepatic fat levels, normalizing hepatic insulin response and facilitating beta-cell recovery, possibly through redifferentiation. These physiological shifts restore normoglycemia in individuals during the early stages following T2D diagnosis.

17.6 ROLE OF MRS IN DIABETES REMISSION

The management strategy for T2D has evolved substantially, focusing increasingly on achieving complete remission. While emerging evidence indicates the feasibility of T2D remission, comprehensive long-term sustainability data remain scarce. Normalization of glucose levels can be achieved through diverse therapeutic approaches, including bariatric surgery or significant alterations in diet and lifestyle resulting in substantial weight loss, recognized as the primary facilitator of diabetes remission.

17.6.1 Evidence-Meal Replacers in Remission

Table 17.6.

Low-Calorie Diet and Very-Low-Calorie Diet Using MRs in Remission			
Study Name	**Study design and subjects**	**Dietary intervention**	**Outcomes**
Look AHEAD study (2013)[9]	Multi-center, randomized controlled trial In the ILI Group • 2241 out of 4,503 obese adults with T2D **Partial meal replacement**	Energy-restricted low-fat diet • 1200–1800 kcal/day Increased physical activity to • 175 min/week for four years	In the ILI Group -11.5% remission at 1 year, -7.3% at 4 years In DSE Group In Years 1 and 4 • 2% remission
DiRECT Trial [10]	T2D subjects-298 • Intervention Group-149 Study Duration • 0–6 years • 1-year follow-up **Complete meal replacement**	LCD replacement • For 3-months, 825–853 kcal/day • Diet MRT o 59% carbohydrates o 13% fats o 26% proteins o 2% fiber Structured food reintroduction phase • For the next 12–20 weeks	At 12 months • Intervention group o 46% remission • Control group o 4% remission At 24 months • Intervention group o 36% remission • Control group o 3% remission

Umphonsathien M *et al.* (2019)[19]	T2D subjects-20 • BMI 23–30 kg/m^2 • <10 years of diabetes duration **Partial meal replacement**	For initial • 10-weeks o 600 kcal/day Stepwise increase at • 10th week o 800 kcal/day • 11th week o 1000 kcal/day • 12th week - 1200 kcal/day • 13th week - 1500 kcal/day	Mean weight loss • 9.5 ± 1.8 kg Percentage loss of initial body weight 13.3 ± 2.2% At Week, 8th and 12th • 79% remission
Taheri S *et al.* (2020)[20] **DIADEM-I**[20]	T2D subjects-147, <3 years • Intervention arm-70 • Control arm–77 **Complete meal replacement**	Total diet replacement phase • For 12 weeks, 800–820 kcal/day • Diet MRT o 57% carbohydrates o 14% fats o 26% proteins o 3% fiber Structured food re-introduction phase • For the next 12 weeks	At 12 months • Intervention group o Weight loss-11.98 kg o Remission-61% • Control group o Weight loss-3.9 kg o Remission-12%
Bhatt AA *et al.* (2017)[21]	T2D subjects–12 **Partial meal replacement**	For 12 weeks, • LCD o 1000 kcal/day o 60% carbohydrates o 10% fats o 30% proteins • Using 3-servings MR	• Median weight loss-7 kg • Remission-50%

		• One regular meal • 2–3 Small prespecified homemade snacks	
Deshpande N *et al.* (2023)[22]	Participants = 374 • T2D subjects-117 (31.2%) **Complete meal replacement**	3-month structured reversal diet • 800–830 kcal/day • Meal replacement liquid formula and non-starchy veggies/soups/diluted buttermilk and fat	Significant improvement in • Body weight o 85.4 vs 77.7 Kg • BMI o 32.6 vs 29.8 kg/m^2 • Waist circumference o 103.6 vs 98.3 cm • Hip circumference o 109.2 vs 103.8 cm • Body fat % o 41.9 to 37.6 Among T2D subjects • Remission in Diabetes-40% • Insulin-users stopped Insulin-28% • Stopped oral anti-diabetic agents-22% • BP normalized without medications-14% • MASLD Remission attained- 41%

Table 17.7. Guidelines from National and International Bodies

Guidelines from National and International Bodies	
American Diabetes Association 2025[23]	• Use of partial meal replacements or TMRs o An additional strategy for energy restriction. o Potential short-term strategy for weight loss.
Diabetes Canada Clinical Practice Guidelines Expert Working Group, 2022[24]	• Low-calorie total dietary/meal replacement diet o Followed by a structured food reintroduction phase and o Increased physical activity for weight loss maintenance in diabetes remission.
Research Society for the Study of Diabetes in India, 2022[25]	• Meal plans with strategic meal replacements o partial or complete meal replacements o Maybe an option under supervision when feasible.

In clinical practice, LCD and VLCD interventions have shown notable efficacy. However, when implementing such regimens, close supervision by healthcare professionals is essential due to potential adjustments required in medication doses. These dietary approaches are particularly beneficial for individuals diagnosed with T2D within the past six years, preferably within two years, those with well-controlled glycemia, minimal reliance on anti-diabetes medications, good beta cell function, and insulin secretion, and lower visceral fat levels, as well as those with overall good mental health. It is important to note that diabetes remission achieved through these interventions is not a permanent cure, as re-reversal or relapse of diabetes can occur if the diet and lifestyle changes are discontinued. Therefore, individuals must be informed about the possibility of diabetes reappearance and the importance of regular follow-up and maintenance of lifestyle modifications to sustain remission.[26]

17.7 CONCLUSION AND RECOMMENDATIONS

Clinical Pearls of Practice

- A supervised treatment plan for type 2 diabetes is recommended to achieve diabetes remission, involving the use of partial or complete MRT. When incorporated into a structured dietary plan, MRTs effectively
  - Regulate calorie intake and BG levels
  - Help achieve significant weight and fat loss.
  - Help achieve diabetes remission.
- After achieving significant weight loss and diabetes remission using MRTs, a sustainable dietary pattern should be advised to maintain weight loss in the long term and prevent reoccurrence of diabetes.
- MRT offers convenience, making it suitable for individuals with busy lifestyles or poor/limited access to healthy, nutritious meals.
- Adherence is crucial for the success of MRTs.
- Careful selection of suitable candidates for MRT is essential.
- It should be administered under the guidance of a healthcare professional who can customize the approach to meet individual needs and monitor overall dietary intake and health status.

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Section 18: Dietary Patterns

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18.1 INTRODUCTION

India's nutritional landscape has undergone a profound transition driven by industrialization, advancements in the food processing industry, and increased exposure to global cuisines. Economic development, higher disposable incomes, and convenient availability and accessibility to ultra-processed foods have catalyzed a shift away from traditional dietary norms. Contemporary dietary patterns pose an elevated risk for Non-Communicable Diseases (NCDs), notably, Type 2 Diabetes Mellitus (T2D) and cardiovascular diseases, to which Indians exhibit inherent susceptibility. Green *et al.*[1–4] have delineated eleven distinct models of Indian dietary patterns, reflecting the diverse culinary practices across the nation. Traditionally, Indian diets were predominantly vegetarian, with regional variations featuring cereals, millets, pulses, vegetables, and fruits. However, contemporary dietary shifts reveal a rise in the consumption of high-fat, high-sugar foods and increased meat intake. Other studies have noted similar trends and documented decreased cereal intake and increased milk and milk products, sugar, sugar-based sweets, and edible oils.[5,6] However, the consumption of legumes, fruits and vegetables, eggs, meat, and fish has remained the same. Modern Indian diets are characterized by calorie-dense foods lacking in nutrients and bioactive components with anti-inflammatory and/or antioxidant properties.

The presence and prevalence of high-fat, high-salt, fried foods and snacks with trans-fats in diets increase the prevalence of hypertension, diabetes, and dyslipidemia and hamper their effective control. This, coupled with the high prevalence of T2D, prediabetes, and hyperinsulinemia, underscores the need for guidelines to rectify the existing dietary patterns and ensure glycemic control.[7]

18.2 EVIDENCE-BASED DIETARY PATTERNS AVAILABLE GLOBALLY

Evidence-based approaches are crucial for diabetes management and glycemic control. Insulin resistance and the onset of T2D have been associated with increased consumption of sugars, fried foods, and red meat, whereas the intake of vegetables with a high content of antioxidants, fiber, and other nutrients are linked to reduced risk of developing T2D.[8]

Globally, dietary patterns such as the Mediterranean Diet (MD), Dietary Approaches to Stop Hypertension (DASH), and Alternative Healthy Eating Index (AHEI) diets are commonly linked to significant reductions in the risk of developing incident diabetes.[9] As per the Global Dietary Data (2018), only a small fraction of the world population, comprising ten countries (<1%), adhered to an AHEI score above 50.[10] A *Healthy Diet* typically includes vegetables, fruits, seafood, whole grains, legumes, nuts and oilseeds, low-fat dairy, and poultry while limiting intake of red and processed meats, high-fat dairy products, refined grains, and sweets/sugar-sweetened beverages.[11,12]

The MD emphasizes the consumption of substantial amounts of vegetables, fruits, nuts, legumes, and whole-grain cereals while limiting the intake of red meat, dairy products (except for cheese), and saturated fats. Fat intake typically ranges from 30–40% of total energy, with a high ratio of Monounsaturated Fatty Acids (MUFA) to Saturated Fatty Acids (SFA) due to the generous use of olive oil.[13] Adherence to MD has been associated with a reduced risk of progression to diabetes among people with prediabetes.[14,15] Moreover, adherence to MD among people with diabetes has shown improved glycemic control and favourable improvement in cardiovascular risk factors.[16] The DASH diet promotes a high intake of vegetables, fruits, whole grains, fat-free or low-fat dairy products, fish, poultry, beans, and nuts.

The Glycemic Index (GI) categorizes carbohydrates according to their impact on post-consumption Blood Glucose (BG) levels. Foods with a low-GI lead to a gradual rise in BG, which is advantageous for individuals with diabetes. Following a low GI diet, which typically includes traditional foods like fruits, vegetables, legumes, and nuts, has been associated with reduced cholesterol levels, indicating a healthier dietary pattern.[4] Additionally, alternative dietary strategies such as very low-calorie and vegan diets have demonstrated the potential to enhance glycemic control compared to conventional diets.[17]

The growing popularity of a vegan diet prompts investigation into their impact on diabetes management. A 2015 study compared a brown rice-based vegan diet against a conventional diet, revealing improvements in HbA1c levels,[18] and a 2017 study[19] additionally demonstrated improved weight status and reduced medication dosages. A systematic review by Pollakova *et al.* concluded that vegan diets were associated with lower incidence of T2D and resulted in reduced BG values post-intervention, improved glucose homeostasis, reduced body weight, HbA1c, and cardiovascular risk factors that included systolic and diastolic blood pressure, total cholesterol, High-Density Lipoprotein (HDL) cholesterol, Low-Density Lipoprotein (LDL) cholesterol, triglycerides in people with diabetes. However, caution is warranted as vegan diets may lead to deficiencies in proteins, vitamin B_{12}, calcium, vitamin D, iron, zinc, or omega-3 fatty acids. Therefore, careful planning is essential to ensure adequate nutrient intake when adopting such diets.[20]

18.3 EVIDENCE-BASED DATA ON DIETARY PATTERNS IN INDIA – GENERIC

India has the highest prevalence of diabetes mellitus (DM) among developing nations[2,21] and ranks second-highest globally.[2] Indian dietary patterns are predominantly cereal-based, with a notable inclination towards refined cereals. Carbohydrates contribute a substantial proportion of the energy intake,[22] with a shift from whole to refined grain, particularly prominent in urban areas,[23] contributing to the increased prevalence of metabolic syndrome.[24] Findings of a survey by Joshi and the team reported that 64.1% of the energy intake among T2D participants is derived from carbohydrates.[25]

The *What India Eats* Report by the National Institute of Nutrition (2020–21) highlighted that cereals accounted for a higher proportion of energy intake (51.4% in urban and 65.2% in rural regions) compared to the recommended levels (45%) that should come from cereals and millets, while the contribution from pulses, legumes, meat, poultry, and fish fell below the recommended minimum intake of 17% of total energy.[25] A comparison with the EAT-Lancet Reference diet indicated that whole grains significantly exceeded the recommended energy intake.[26] In contrast, the intake of fruits, vegetables, legumes, meat, fish, and eggs was notably lower. Consistently low protein consumption has been observed across India, in both rural and urban areas. Protein sources contributed, on average, only 12% of total energy intake in urban and 13.3% in rural Indian adults.[23] At present, the protein intake in all parts of India primarily comes from plant sources, reflecting a reliance on low-quality dietary protein.[23] (Table 18.1)

Table 18.1. Mean Percentage of Energy from Various Food Groups in Urban and Rural Indian Adults: A Pooled Analysis.

	ICMR- NIN	Actual Consumption	
	"My Plate for the Day" Recommendations (%)	Urban India (%)	Rural India (%)
Cereals and millets	40	51.4	65.2
Pulses and legumes	11	6.1	6.9
Meat, poultry, and fish	6	5.4	4.5
Milk and Milk Products	10	5.1	4.2
Vegetables and GLVs	5	1.5	1.4
Fruits	3	1.1	1
Roots and tubers	1.5	2.7	3
Nuts and oil seeds	8	2	2.9
Visible fats and oils	12	13.7	7
Others	3.5	11.1	4.1

18.4 REGIONAL ETHNIC DIETARY PATTERNS IN INDIA

The typical meal structure in India consists of a blend of cereal and pulse-based dishes.[27] Pulses and legumes serve as the second-most-important source of protein, following cereals, due to the relatively low meat consumption in India.[28–31] The consumption of certain meats, such as beef and pork, is influenced by religious beliefs. Chicken, particularly native varieties, is the most widely consumed meat.[32] Fish and fish product consumption tends to be greater in the coastal regions of the states and union territories.[33] Dairy items like butter, yogurt, and buttermilk are widely consumed across various regions.[34]

A comparison of carbohydrate intake between rural and urban populations shows that rural areas consume significantly more carbohydrates than urban areas. In rural India, 80.3% of carbohydrates come from cereals (rice and wheat) and millet. The daily carbohydrate consumption in urban areas is 289 g/day, while in rural areas, it is 368 g/day. In urban regions, cereals and millets (73.4%) are the primary sources of carbohydrates, followed by processed foods (10.7%). Fat consumption is greater in urban areas (51.6 g/day) compared to rural areas (36 g/day). Among urban populations, the highest fat intake is observed in the northern region, where it accounts for 24%, surpassing that of other urban regions.[23] Animal protein consumption tends to be greater in rural regions than in urban areas. Rural-to-urban migrants have been observed to adopt dietary patterns more akin to urban populations, with higher overall energy and fat intake than those who remain in rural settings.[35] Food diversity, based on expenditure, tends to be greater in rural regions of coastal and western India. However, the intake of fruits and vegetables appears to be lower among rural populations than urban and peri-urban areas.[36] Among the urban population in Eastern India, 65% of individuals with metabolic syndrome have been noted to consume low amounts of fruit.[37] Vegetable intake is lower in rural regions of central, western, and northern areas.[38] The average vegetable consumption per person was 145 g in rural households and 155 g in urban households, while fruit consumption was 15 g and 29 g, respectively.[39] The dietary habits of rural-to-urban migrants closely mirrored those of urban residents, with fruit and vegetable consumption being approximately 80% higher.[35] Convenience foods like chips, biscuits, chocolates, sweets, and juices accounted for approximately 11.1% of energy intake in urban areas and 4.1% in rural areas, highlighting the greater consumption of calorie-dense 'junk food' in urban India.[23] A 35% greater intake of sugar was noted among rural-urban migrants compared to those remaining in rural areas.[35] Economic factors play a significant role in determining energy intake within a population; affluent individuals in both urban and rural regions consumed up to 3000 kcal/day, which is twice the amount consumed by those from less privileged backgrounds.[26] The variations in the consumption of food groups in different regions, between rural and urban, and the prevalence of diabetes are enumerated in Table 18.2.

Different cultural dietary traditions frequently include fasting, which may last for several consecutive days during certain festivals or take place as single-day fasts on special occasions. In India, festivals and celebrations are commonly characterized by elaborate meals, with high-calorie dishes and sweets made with sugar and ghee (clarified butter) being widely enjoyed throughout the country.[40]

Table 18.2. Region-wise Dietary Practices, Macronutrient Intake, and Prevalence of Diabetes across India[23]

India (28 Regions)		Staple-Food Ingredient	Dietary Pattern[b]	Mean Macronutrient Intake per day[c]			Prevalence of Diabetes (%)[c]
				CHO (g)	Protein (g)	Fat (g)	
South	Urban	Rice	Rice Millets Dairy products Fruits Vegetables Snacks Meat.	298	59	50	29
	Rural	Rice		361	64	34	10
North	Urban	Wheat	Pulses Dairy products Fruits Vegetables Snacks.	221	47	67	28
North East	Urban	Rice	Cereals Millets Pulses Meat Dairy products Vegetables Fruits.	457	87	62	26
Central	Urban	Wheat	Cereals Millets Pulses Meat Dairy products Vegetables Fruits.	277	50	50	18
	Rural			400	85	36	5

East	Urban	Cereal-based diets High intake of simple CHO like Rice, Fish, and Meat.	Cereals Pulses Fish Root vegetables Fruits Dairy products Snacks and sweets.	323	58	43	19
	Rural	Cereal-based diets Fish and Meat.		384	59	23	4
West	Urban	Wheat Pulse	Rice, pulse, sweets, snacks, fruits, wheat, dairy	241	48	57	24
			products, sprouts, millets, leafy vegetables, sorghum.				
	Rural	Wheat Pulse		336	70	43	8

Numerical values have been rounded off to the nearest number.
CHO carbohydrates, *g* gram, % percentage.
[a]Adapted from 'Dietary transition in India: temporal and regional trends, 1993–2012'[6]
[b]Adapted from 'Dietary patterns in India: a systemic review'[4]
[c]Adapted from 'What India Eats'[41]

18.5 ANTIOXIDANT, INFLAMMATION- REDUCING FOODS IN INDIAN DIETS

India has a variety of seasonal and regional vegetables and fruits, which are available commercially and locally grown seasonal produce.[42] Plant-derived foods have an abundance of essential nutrients and bioactive compounds, offering antioxidant and anti-inflammatory properties. These components protect us against various NCDs such as DM, cancer, heart disease, and cataracts.[43]
The GI with the defined Glycemic Load (GL) of the diet is important for good BG control in people with diabetes. Including low-GI foods and the right combination of foods in defined portions to blunt the post-meal glycemic response is an important prerequisite. It would be ideal to marry this concept with regional foods and food preparations that are also nutrient-dense and high in antioxidants and anti-inflammatory nutrients. We have attempted to suggest modifications for regional food options commonly consumed in India in Table 18.3. These modifications will help reduce postprandial glucose spikes, which are crucial for maintaining stable BG levels, decreasing oxidative stress, and improving lipid profile. This will also be a step to prevent long-term complications in people with diabetes.[44]

Table 18.3. Suggested Modification for Regional Food Options in India for Better Glycemic Control[45,46]

Food Preparations	**Major Ingredients**	**Nutritional Advantage**	**Suggested Modifications for Decreasing Postprandial Glycemic Response.**
Meal: Breakfast/Snack			
Region: Western India (Gujarat, Maharashtra, Rajasthan, Goa)			
1 Bajra Rabri 	**Pearl millet** (Bajra) flour, buttermilk	Protein quality improved, the probiotic effect of buttermilk.	Could incorporate some pulse flour Add some vegetables to lower the GI.
2 Poha 	Rice Flakes	It is a traditional item but has a high GI.	Adding vegetables/nuts/sprouts to the recipe will increase fiber content and lower GI.
3 Upma 	Durum wheat semolina	Satiating meal with a moderate amount of fiber and protein.	Using quinoa, couscous, barley (*jau*), or whole oats instead of semolina increases fiber content. Instead of semolina (which does not have bran), use whole wheat rava/dalia. One can make the upma with buttermilk instead of water The addition of vegetables will improve

			fiber content and, thereby, GI. Curd as an accompaniment will improve protein quality.
4 Missal/Usal-Pav 	Sprouted moth beans, Indian Bread (Pav).	Plant-based protein and fiber.	Replacing refined flour bread with whole wheat or multi-grain bread. Add some sev, preferably baked sev (crunchy chickpea flour noodles), and supplement with roasted seeds (to add crunch).
5 Tomato Omelette 	Gram flour (besan), Tomato, Eggs.	Good plant-based protein and fiber. Flour has a low GI. Lycopene from tomatoes is a potent Antioxidant (AO).	Consumption with curd (raita) as an accompaniment will improve protein quality. In addition to tomatoes, you can use a mixture of vegetables like finely chopped spinach/fenugreek/onion greens/moringa leaves/cabbage, etc.
6 Handvo 	Rice, split bengal gram (chana dal), black gram (urad dal), yellow pigeon peas lentil (tur dal), and yellow moong dal.	It is a good source of plant-based protein and fiber.	Adding vegetables such as carrots, cabbage, bottle gourds, and soft drumstick leaves will help lower GI.

7 Muthia 	Gram flour (besan), whole wheat flour, semolina, and fenugreek (methi) leaves.	It's a good source of fiber.	Steaming or the use of an *appam* maker instead of deep frying. One can use millet flour or other leafy vegetables.
8 Dhoklas 	Gram flour (besan) or a mix of black gram, rice, and dehusked black gram lentil (urad).	Low GI flour	It can incorporate a variety of vegetables. One can use palak puree to make palak dhokla (sponge cake made of gram flour batter) or can prepare it with whole green grams or can make a sandwich dhokla with green coriander and mint chutney layer. Should not add sugar solution to make the dhokla spongy.
9 Khandvi 	Gram flour (besan), buttermilk.	Low GI flour	Can partially replace besan with flour for the whole mung (green gram) of matki. One can use stuffing with vegetables or even sprouts.
10 Khakhra with Moong/Moth bean 	Wheat flour, gram flour (Besan).	Complete protein	Consume with curd and dry chutneys—peanut, til. Wheat flour can be replaced with whole wheat flour or pulse-based flour, such as green gram, moth beans, or *chorafali.*

11 Ponkh 	Ponkh (tender jowar grain)	High fiber	Adding high-fiber items like sprouted pulses will lower the dish's GL.
12 Moong Dal Chilla 	Yellow gram beans (moong) dal	A good source of plant protein and fiber.	Consumption of curd will improve protein quality. Can replace yellow gram beans with husk or a combination of pulses.
Region: Eastern India (Assam, West Bengal, Mizoram, Manipur, Meghalaya, Arunachal Pradesh, Sikkim)			
13 Bhimkol with Milk 	Bhimkol (locally grown seeded banana) and milk	It is a high biological value protein source with a fair amount of fiber.	Add nuts and exercise portion control.
14 Poita Bhat 	Overnight soaked cooked rice (fermented), curd.	Fermented rice has prebiotic benefits and improves the availability of nutrients. It also lowers GI.	Consumption of high-fiber vegetables.

15 Putharo 	Rice flour, grated coconut.	Coconut is a good source of vitamins, minerals, and MCTs.	Portions must be watched. It can be consumed with vegetable/meat gravies.
16 Daineiiong 	**Brown lentil** (Masoor dal), sesame seeds	High in fiber and a good source of plant protein.	Pairing it with whole-grain flour bread/rotis will help further lower GI.
17 Phale with Lentils, Seasonal Vegetables 	Chicken, refined wheat flour, Seasonal Vegetables.	High biological value protein and fiber content.	Whole wheat flour can be substituted for refined wheat flour. It is usually consumed with chutneys, portions of which must be watched.
Region: Southern India (Andhra Pradesh, Telangana, Tamil Nadu, Kerala, Karnataka)			
18 Puttu, steamed rice cake 	Puttu flour (made with parboiled rice), grated coconut.	Parboiled rice has a low-GI. Coconut is a good source of vitamins, minerals, and MCTs.	Usually eaten with *Kadala* (chickpea gravy), vegetarian and nonvegetarian gravies. The use of vegetables in these preparations can help increase fiber content.

19 Pongal 	Rice, yellow moong dal or red masoor dal.	Cereal pulse combination provides good quality protein.	Replace rice with barley (*jau*), rolled or steel-cut oats, or quinoa to increase fiber content.
20 Idli/dosa/Idiappam 	Parboiled rice, dehusked black gram lentil (Urad dal).	High fiber	Replacing rice with oats, millets, or rava. In idli, the addition of vegetables (finely chopped). Whole dehusked black gram lentil and fenugreek seeds can be added to the batter. Pair it with a protein-rich sambar or chutney. Idiyappam is traditionally eaten with whole kala chana curry, and this combination is good to recommend, with the inclusion of an adequate amount of chana.
21 Khara Avalakki 	Rice flakes	Low calorie and satiating meal.	Adding vegetables/nuts/sprouts to the recipe will increase fiber content and lower GI.

22 Pessarattu 	Green gram lentil, (green moong)	Good plant protein content.	Pair it with a protein-rich sambar or chutney or pulse-based chutney powder.
Region: Northern India (Jammu & Kashmir, Punjab, Haryana, Himachal Pradesh, Uttarakhand)			
23 Sheer Chai with Girda 	Refined wheat flour	The combination provides good-quality protein.	Replace refined flour with whole wheat flour to increase fiber content. One can add fiber, such as some wheat bran or psyllium husk, to the Girda.
24 Gochini Atta Roti 	Gochini atta (wheat and gram flour).	It's a good source of fiber.	Consumption of curd will improve protein quality.
25 Paranthas 	Whole wheat flour	High fiber.	Stuffing them with green leafy vegetables/pulses will improve GI. Consumption of curd will improve protein quality.

26 Sattu Paratha 	Bengal gram flour, wheat flour	High amounts of soluble fiber and protein, Low GI.	Consumption of vegetables and curd will help further lower GI.
Region: Central India (Uttar Pradesh, Madhya Pradesh, Odisha, Jharkhand, Bihar)			
27 Palak Poori with Raita-Aloo Sabji 	Wheat flour, spinach, oil.	Moderate fiber	Control portions of puri and aloo sabzi and consume with a higher proportion of vegetable raita.
28 Mudhi 	Goat head	High protein	Pair with whole-grain preparations and salad.
29 Mandia Jau 	Ragi flour	Moderate GI	Add vegetables and sprouts or whole legumes to the porridge.

30 Dhuska with Ghugni 	Rice, bengal gram dal, oil	Source of complete protein.	Add vegetables to the dough.
31 Dahi Chura 	Rice flakes, curd, jaggery, fruits, and nuts of choice.	High protein, healthy gut bacteria, and a moderate amount of fiber.	Skip the jaggery and use fruits to sweeten and increase the proportion of nuts and seeds.
Meal: Lunch/Dinner			
Region: Western India (Gujarat, Maharashtra, Rajasthan, Goa)			
32 Gatte ka saag 	Gram flour (besan), curd	It's a good source of protein.	Commonly eaten with roti/phulkas.
33 Dal-Roti with Seasonal Vegetables (Brinjal, Tomato, Leafy Vegetables) 	Channa dal, wheat flour.	High fiber	One can use yellow split dal or *chilka wali* moong dal for filling.

34 Bhakri with Koshimbir/Raita 	Rice/jowar/ragi flour, curd	Jowar and ragi or other millets are good sources of fiber, and curd is a good source of animal protein.	Replacing the traditionally used rice flour with jowar or bajra will lower GI.
35 Thalipeeth with Pithla 	Jowar, bajra, besan, whole wheat flour	It's a good source of fiber.	Consumption of curd will improve protein quality. One can add fenugreek leaves, onion greens, moringa leaves, and raw tomatoes.
36 Masala Bhat 	Rice, vegetables- cauliflower, carrot, brinjals,	It's a good source of fiber.	Consumption of curd and vegetables with tiny fried gram flour balls (*boondi*) raita will improve protein quality.
37 Fish Curry 	Fish	Excellent source of omega-3 and protein.	It is usually consumed with rice but can also be had with whole wheat couscous, quinoa, or roti; however, portions must be monitored.
38 Kothambir Vadi 	Coriander leaves, gram flour (besan) Peanuts and or sesame seeds (optional).	Peanuts are a good source of MUFA, PUFA, and fiber.	Steaming can be opted for over frying/roasting. Consumption of curd will improve protein quality.

39 Khichadi-Kadhi 	Rice, yellow moong dal in khichadi kadhi-buttermilk and chana flour(besan)	Cereal pulse combination provides good quality protein. kadhi	The addition of vegetables to this dish will improve fiber content and lower GI. Khichdi can be made with moong dal with skin, mixed pulses, and sprouted field beans.
40 Undhiyo 	Brinjals, beans (papdi), green peas, raw bananas	It's a good source of fiber.	Consumption of rotis made with whole wheat/jowar/bajra.
Region: Eastern India (Assam, West Bengal, Mizoram, Manipur, Meghalaya, Arunachal Pradesh, Sikkim)			
41 Maacher Jhol 	Rohu fish, potato, pointed gourd, ridge gourd.	High protein and moderate fiber.	Consume with unpolished rice or millet.
42 Shukto 	Mixed vegetables (drumsticks, sweet potato, brinjal, french beans, potato, bitter gourd, etc), coconut, mustard, milk.	It is high in fiber and contains healthy fat.	Minimize the use of root vegetables like potatoes and sweet potatoes.

43 Ghugni 	Yellow peas	High protein and fiber	Pair with a salad or add vegetables to the dish
44 Chhurpi 	Homemade cottage cheese, onion, tomato.	High protein	Add assorted vegetables.
45 Lukter 	Dry meat (Beef/Chicken/Prawn) & dried chillies.	The high protein content has a high biological value.	Usually eaten with rice, though it can be replaced with whole grain flour rotis.
Region: Southern India (Andhra Pradesh, Telangana, Tamil Nadu, Kerala, Karnataka)			
46 Ragi Kali/Mudde 	Ragi flour	Moderate GI	Add vegetables to the dough and consume with dals, curd, or lean meat-based curries.

47 Kuzhambu 	Mixed vegetables like drumsticks, pearl onions, brinjals, tamarind.	High fiber, lower in energy	Add dal to the preparation and limit the portion of cereals or millets consumed.
48 Curd Rice 	Rice, curd	High protein, contains gut-friendly bacteria.	Replace white rice with unpolished rice, add grated vegetables, and control portion size.
49 Avial 	Mixed vegetables (drumsticks, carrots, pumpkin, raw banana, etc), coconut.	High fiber, low GI, good quality fats.	Add sprouts or beans and pair with millet-based dishes or low-GI rice.
50 Pulisherry 	Curd, gourd vegetables, and coconut.	High protein, low GI, good quality fats.	Pair with whole-grain preparations.
51 Bisi Bele Bath 	Rice, dal, vegetables	Complete protein, fiber-rich	Add a higher proportion of vegetables and pair with low-fat curd.

52 Pachadi 	Curd, cucumber (or other vegetables like carrot, beetroot, cabbage, etc), and coconut.	High protein, contains gut-friendly bacteria.	Pair with whole-grain preparations.
53 Akki Roti 	Rice flour, carrot, onion	Moderate amount of fiber.	Add millet flour and consume with curd, dal, or pulse chutney powder Can add coriander leaves.
Region: Central India (Uttar Pradesh, Madhya Pradesh, Odisha, Jharkhand, Bihar)			
54 Dum Biryani with Raita 	Basmati rice (aged), Vegetables/meat.	It has a good amount of protein and carbohydrates. The spices used provide anti-inflammatory benefits. Curd will provide additional protein.	Red meat consumption should be monitored and controlled. Use a good number of vegetables in the raita/kachumber; this will improve the fiber content.
55 Bedmi Poori 	Wheat flour, semolina, urad dal	Moderate fiber content.	Pair with vegetables to improve fiber content.

56 Dalma 	Yellow pigeon peas lentil (tur dal), potato, carrot, pumpkin, brinjal, raw papaya, raw banana.	High fiber content.	Often paired with steamed rice or jeera pulao. It can be had with brown rice, unpolished rice, jowar, or ragi roti. Rice should be low-GI rice.
57 Litti Chokha 	Brinjal/tomato, wheat flour, sattu	It has a high fiber content and is rich in antioxidants.	Increased amount of sattu filling and use of whole wheat flour. Preparation in a tandoor is beneficial.

18.6 CHRONO-NUTRITION - TIME RESTRICTED EATING - INTERMITTENT FASTING

Intermittent fasting (IF) synchronizes feeding and fasting cycles with circadian rhythms to optimize metabolism and promote weight loss while improving metabolic health. This approach typically involves structured eating patterns with minimal to zero calorie intake during specific intervals, lasting from 12 hours to several days, following a consistent schedule. Multiple intermittent fasting regimens are available, offering flexibility in implementation.[47]

IF has emerged as a promising approach for reducing adiposity and improving metabolic health.[48] Studies suggest it may also benefit diabetes management, significantly reducing fasting glucose levels, insulin levels, HbA1c, and adipose tissue.[46] In 2023, Nie and coworkers reviewed several studies that tested different patterns of Time-restricted Eating (TRE) interventions.[48] Twenty-seven Randomised Controlled Trials (RCTs) comparing TRE with different eating windows on human metabolic health were reviewed and compared with the normal diet group (non-TRE). The TRE group had certain benefits in reducing weight and fasting insulin. In terms of reducing fasting insulin, the 18:6 group (eating time = 6 h) was better than the 14:10 group (eating time = 10 h) and the 16:8 group (eating time = 8 h) ($P < 0.05$). In terms of reducing fasting glucose, the <6 group was better than the 14:10 group (eating time = 10 h) ($P < 0.05$). There were no statistical variations in weight, HDL, Triglycerides (TG), and LDL across the different modes of TRE ($P > 0.05$). (Table 18.4, 18.5)

Table 18.4. Merits and demerits of TRE

Merits and Demerits of TRE[49–53]	
Merits of TRE	**Demerits of TRE**
It has been shown to reduce body weight, improve glucose tolerance, protect from hepatosteatosis, increase metabolic flexibility, reduce atherogenic lipids and blood pressure, and improve gut function and cardiometabolic health in preclinical studies.	Most evidence comes from short-term studies. Long-term interventions are needed to establish the specificities of IF and TRE that may be used as preventative therapy regimens. It is difficult to separate whether TRE improves health independently of changes in calorie intake.
Rhythmic feeding was sufficient to maintain circadian rhythms.	Studies to date in humans are limited in size and duration.
Small changes like delaying a single breakfast meal by 5 hours have been shown to reduce adipose tissue deposition.	-
The cues from fasting and feeding are stronger signals for regulating peripheral biological clocks than the light-dark cycle.	The majority of TRE studies have also initiated the eating window early in the active phase, presumably to maximize the metabolic benefits.
It is a simple approach with proven benefits that does not require extensive nutrition knowledge or tedious commitment. Individuals with diabetes can consume familiar foods without major changes in dietary habits.	It can be difficult for individuals with eating disorders, hyperacidity, etc. to follow. Can cause health issues (like micronutrient deficiencies, dyslipidemia) if not followed under qualified supervision.
-	Lack of protocol standardization—no consensus about the ideal timing for eating/fasting pattern or the optimal duration of each window[51]
-	Intermittent fasting that situates the eating window during the evening is associated with a significant increase in bodyweight, fat mass, and glycemic levels. These values are associated with a higher risk of obesity and insulin resistance.[51]
-	Seasonal changes are not considered in the selection of the eating window, whereas the activity phase depends on it. Eating hours should be adapted to the season and the length of days to match hormone oscillations and optimize physiological processes.[51]
-	Some adverse events were observed, e.g., flu-like symptoms, back pain, fatigue, constipation, and headaches. Hospitalization was also reported.[53]

Table 18.5. Comparison between intermittent fasting and energy-restrictive food plan[54–56]

	Intermittent Fasting	Energy Restrictive Food Plan
Total energy intake	Can include varied ratios of days of the week with complete fasting (or extremely low energy intake) and energy consumption, or a day divided into fasting and eating window/s.	It prescribes energy restriction based on parameters like body weight, gender, co-morbidities, etc., with small or no change in meal timings.
Effect on weight loss	Both show a positive impact on weight loss with small (statistically insignificant) differences across trials.	
Body composition	Some studies show that IF showed a greater reduction in body fat percentage.	
Cardiometabolic risk factors	Both dietary approaches lead to comparable improvements in blood pressure, cholesterol, and glucose metabolism. IF may provide a slight advantage in reducing fasting insulin levels.	
Adherence and compliance	It has been shown to have better adherence due to the flexibility of food choices.	This may be linked to poor adherence due to restrictions in quantity and type of food.
	However, adherence can vary based on personal preferences.	

Glucose tolerance, mediated by various hormones, usually peaks during the daytime and diminishes as dark hours occur. Optimal meal timing is crucial for managing T2D, focusing on consuming carbohydrate-rich meals earlier in the day to improve postprandial glycemia. However, it's important to note that some individuals undergoing TRE may experience fatigue, dizziness, headache, decreased appetite, upper abdominal pain, dyspepsia, and constipation, requiring careful monitoring. Modifying macronutrient composition by increasing protein and fat content in evening meals can further benefit glycemic control. Encouraging people with diabetes to consume meals early and prioritize low-GI foods in the morning can optimize glycemic response. In contrast, strategic sequencing of food consumption, such as starting with vegetables before main meal items, like meat/dal and rice, may help to reduce postprandial BG, particularly for rice-based meals.[57]

18.7 CHRONO-NUTRITION–GLIMPSE FROM AYURVEDA: DINACHARYA

Ayurveda offers a holistic approach to managing diabetes, incorporating practices like *ritucharya* and *dinacharya*. *Ritucharya* emphasizes adapting to seasonal routines to prevent lifestyle diseases and promote nutritive balance in the body.[57] Ayurveda suggests consuming a diet with minimally processed foods such as barley and pulses like *moong*, lentils, and horse gram, which are suitable for people with diabetes. *Dinacharya,* on the other hand, outlines a daily routine comprising 26 practices, meal and sleep timings, and physical activity recommendations. Specifically, *dinacharya* advises consuming a light and easily digestible dinner at an appropriate time. It is recommended that breakfast should be small but nutritious, and lunch is recommended between 12 and 1 pm, when *Agni* (digestive capacity) is most active. If a nap is taken, it should be brief. Include all six rasas (tastes) in lunch: bitter, salty, sweet, pungent, sour, and pungent. Preferable dinner recommendation is between 6 and 7 pm. A smaller bedtime intake, if any, must be 2–3 hours after dinner.[58]

18.8 NUTRITION TRANSITION AND ITS IMPACT ON DIETARY PATTERNS IN INDIA, RURAL-SEMI-URBAN

Rapid urbanization has contributed to decreased physical activity levels, resulting in a rising prevalence of obesity, atherogenic dyslipidemia, subclinical inflammation, metabolic syndrome, T2D, and coronary heart disease among Indians. The nutrition transition in India over the past three decades witnessed notable changes in dietary patterns, including a 7% decrease in carbohydrate-derived energy and a 6% increase in fat-derived energy.[59] This shift is accompanied by reduced consumption of coarse cereals, pulses, fruits, and vegetables and increased intake of meat products and salt.

Research indicates that maternal nutritional deprivation during pregnancy may result in poor fetal development in low-birth-weight infants, who, with early childhood *catch-up growth*, are more prone to childhood obesity and glucose intolerance as well as NCDs later in life.[60] A comprehensive preventive strategy involving multiple sectors is necessary to address these challenges. This ensures balanced diets for pregnant women, children, and adults, promoting healthy body weights from childhood onwards, thus mitigating the escalation of Diet-related Non-communicable Diseases (DR-NCDs) in India.[60–62]

18.9 NEED TO CREATE EVIDENCE-BASED REGIONAL DIETARY GUIDELINES IN INDIA FOR T2D

Customizing dietary guidelines for managing T2D in India is imperative, as a *One-Size-Fits-All* approach may not be effective. Besides customizing diets to individuals, it's crucial to customize the generic dietary guidelines to the diverse dietary patterns prevalent across Indian regions. The 2024 report of ICMR-NIN provides insights into dietary patterns observed across 16 states in six regions of India, highlighting variations in calorie distribution derived from different food groups.[63] The report underscores that cereals contribute the highest percentage of daily calories, and the intake of vegetables and fruits remains low. Similarly, the intake of protein food groups is also limited, with variations further evident in rural populations. The *My Plate for the Day* reference by ICMR-NIN offers a practical representation of the portions of different food groups in a day, serving as a valuable tool for dietary planning.[64]

A customized My Plate for the Day specific to their condition is warranted to refine further dietary recommendations for people with diabetes. This adaptation could incorporate considerations such as GI, GL nutrient density, and phytochemical content of the commonly consumed foods in different regions. Developing region-specific dietary maps, including food types and preparation methods, in vernacular languages and utilizing technology will enhance their accessibility and effectiveness for people with diabetes in India.

18.10 CONCLUSION AND RECOMMENDATIONS

Clinical Pearls of Practice

Mediterranean-like Indian dietary pattern for diabetes management

- Customized to Indian ethnicity, tailored to region-specific needs for T2D management.
- Consisting of adequate dietary fiber and nutrient-dense carbohydrate foods in restricted amounts, without extremes of a keto diet.
- Moderate protein intake of good quality and invisible fats high in MUFA and omega-3 from nuts and oilseeds.
- Emphasis on whole grain cereals, millets, whole pulses, nuts, and seeds with the inclusion of functional ingredients like spices and condiments.

Customization of "My Plate for the Day" by ICMR-NIN (2024) for T2D

- Consideration of GI and GL.
- Consideration of energy density and nutrient density of commonly consumed foods.
- Consideration of the phytochemical content of food items.
- Region-specific mapping of food types and preparation methods.

Utilization of vernacular languages and digital interfaces for user-friendly access.

Plant food-based dietary pattern

- Emphasis on local millets and seasonal-colored vegetables, including leafy vegetables and fruits, to help achieve the Sustainable Development Goals (SDG).
- Include local millets and seasonal fruits and vegetables of all colors.
- Incorporation of locally available and affordable nuts and oilseeds.
- Explanation of appropriate combination(s) of plant protein sources.

Chrono-nutrition

- Emphasis on early breakfast and early dinner.
- Setting circadian rhythm in line with desired hormonal milieu for BG control.
- Focus on portion control per meal.

Order of eating

- Order of eating: Start with dietary fiber and protein, followed by the remaining meal. A handful of nuts and seeds added as a preload to the meal has been shown to improve postprandial glucose levels.
- Maximizing simple cooking methods in Indian foods to increase resistant starch content to blunt glycemic response and promote beneficial gut microbiota.

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Section 19: Government Policies and Strategies—EAT Right Movement

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19.1 INTRODUCTION

19.1.1 Background on India's Current Food and Nutrition Status

India, a nation of over 1.4 billion people, comprises 28 states and 8 Union Territories. Its population is linguistically and culturally diverse, with over 1,600 spoken mother tongues and 22 officially recognized languages. The vast socio-economic diversity is evident in the per capita income disparity, which ranges from INR 49,000 to INR 472,000. As the world's most populous nation, India faces considerable challenges in implementing equitable and just policies to manage the health of its citizens.

Malnutrition is strikingly unevenly distributed worldwide,[1] with 149 million children estimated to be stunted. Nine out of ten stunted children live in Africa and Asia.[2] Government interventions, such as food assistance programs, nutritional education initiatives, and food labeling and advertising regulations, are crucial in promoting public health and preventing malnutrition-related issues. National and state programs address the root causes of malnutrition, including poverty, food insecurity, and inequitable access to nutritious foods. By implementing comprehensive strategies that integrate healthcare spending and nutritional policies, India can tackle the complex challenges of malnutrition more effectively, ultimately improving health outcomes and overall well-being.

In 2019, India allocated $8.12 billion for prepaid private healthcare spending, $38.55 billion for out-of-pocket expenditures, and $22.13 billion for government health spending, with an additional $0.51 billion in development assistance. The total health expenditure amounted to $69.31 billion. By 2050, projections for the healthcare landscape suggest significant changes: prepaid private spending is expected to rise to $33.04 billion, out-of-pocket spending to $65.95 billion, government health spending to $67.45 billion, and development assistance to $0.56 billion. This results in a projected total health expenditure of $166.99 billion.[3] (Figure 19.1)

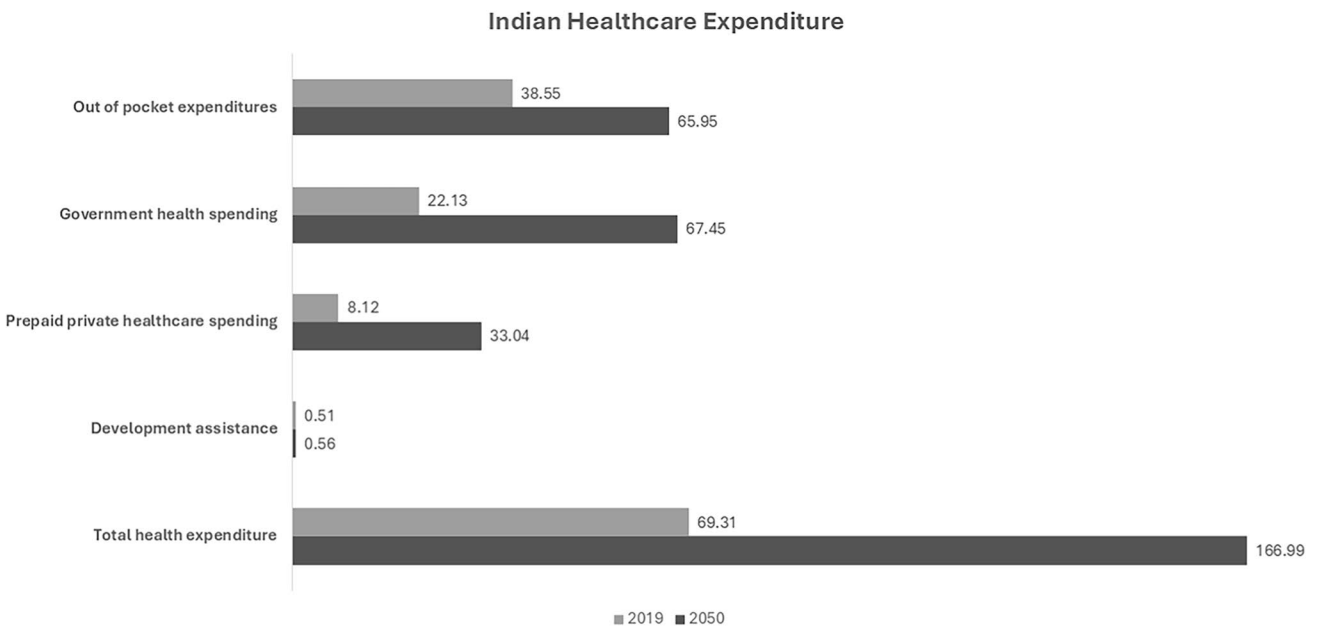

Figure 19.1 Indian healthcare expenditure–2019 (allocated) versus

2050 (projected). All figures in billions ($)

These figures indicate a substantial shift in India's healthcare spending dynamics, highlighting notable private and government contribution increases. This data reflects India's commitment to improving healthcare infrastructure and services to meet the evolving needs of its population.

19.1.2 Importance of Government Policies and Strategies in Addressing Food and Nutrition

Malnutrition, particularly micronutrient deficiencies, severely impede children's survival, growth, and development, contributing to morbidity and mortality in vulnerable populations. This adversely impacts future productivity, hindering national economic growth and overall societal well-being. Addressing this issue necessitates a comprehensive strategy focused on micronutrient interventions, including reducing micronutrient malnourishment through supplementation, food fortification, anemia screening, and raising public awareness about dietary diversification as a long-term strategy.

A systematic approach to addressing regional disparities in micronutrient adequacy is crucial, with a particular focus on vulnerable populations. Screening for multiple deficiencies is essential, especially during critical life stages like pregnancy, lactation, early childhood, adolescence, and old age, where the consequences can be severe and often irreversible. While dietary diversification is preferred, short- and medium-term solutions like supplementation and fortification are necessary to fill nutrient gaps for severely and moderately malnourished children and women.

To address nutrient deficiencies of public health concern, it is crucial to intensify efforts such as iron, folic acid supplementation, calcium supplementation during pregnancy, iodized salt, zinc, Oral Rehydration Salts/Solution (ORS), and Vitamin A supplementation. Policies emphasize the need for outreach programs to reach every beneficiary, necessitating robust monitoring mechanisms. These policies advocate for developing an evidence-based foundation that correlates micronutrient deficiencies with disease burden, particularly in understanding the etiology of anemia. Exploring fortified foods and micronutrient sprinkles through Anganwadi centers and schools is recommended, with caution, to avoid adding multiple layers of interventions simultaneously, such as excess iron during infections.

Acknowledging the complementary roles of various nutrition-sensitive interventions, India's National Health Policy-2017[4] and POSHAN Abhiyaan call for synergy between departments like Women and Child Development, Health and Family Welfare, Education, Water, Sanitation, and Hygiene (WASH), Agriculture, and Food and Civil Supplies.

19.1.3 Brief Overview of the EAT Right Movement[5]

Figure 19.2 Eat right movement booklet

The *EAT Right Movement*, launched by the Food Safety and Standards Authority of India (FSSAI), aims to build a society that embraces safe and nutritious food while encouraging mindful eating practices. Through a multifaceted approach, the movement seeks to empower individuals, promote industry accountability, and establish an enabling policy environment. The *EAT Right Movement* is transforming India's food consumption, production, and distribution approaches by adopting various strategies such as awareness campaigns, capacity building, and regulatory frameworks. (Figure 19.2)

This chapter provides an overview of the *EAT Right Movement*, delving into its origins, objectives, and key components. It explores the various government policies and strategies that support this initiative, such as policy modifications and cross-departmental collaborations. This chapter discusses the movement's alignment with global initiatives such as the United Nations' Sustainable Development Goals (SDGs) and the World Health Organization (WHO) guidelines. This chapter examines the lessons learned from implementing the *EAT Right Movement* to provide insights into its potential and offer recommendations for future interventions. Ultimately, addressing the complexities of India's food system requires a comprehensive and collaborative approach, and the *EAT Right Movement* serves as an important catalyst in shaping a healthier and more sustainable future.

19.1.4 Impact of the International Year of Millets (IYOM)[6]

Nutritionally sound and drought-resistant, millets are a common crop in India. Although millets have been cultivated and consumed for centuries, the Food and Agriculture Organization (FAO) has designated 2023 as the 'Year of Millets' at India's request. This is not the first initiative by the government to bring focus on these Nutri-cereals; millets were earlier promoted from 2011-12 to 2013-14 under the Initiative for Nutritional Security through Intensive Millets Promotion (INSIMP) program— as a sub-scheme of RKVY, later merged as a component of the National Food Security Mission (NFSM) as NFSM-Coarse Cereals from 2014-15.

A Committee was established under Prof. Ramesh Chand's chairmanship, a National Institution for Transforming India (NITI) Aayog member, regarding the *Introduction of Millets* under the Public Distribution System *(PDS) to provide Nutritional Support* in October 2017. After deliberations, the Department of Agriculture and Farmers Welfare (DA and FW) decided that millets like Jowar, Bajra, and Ragi must be promoted through PDS nationwide to improve the nutritional content of the masses' diet. Instead of calling them coarse grains, millets should be positioned as Nutri-cereals, and their benefits need to be popularized amongst the masses through a sustained and effective campaign. Additionally, research should be conducted to develop high-yielding varieties and those with longer shelf life.

19.2. OVERVIEW OF THE FSSAI *EAT RIGHT MOVEMENT*[5]

19.2.1 History and Goals of the Campaign

Eat Right India adopts an integrative, *whole-of-society* approach, uniting all stakeholders - government, food businesses, civil society organizations, experts, development agencies, and citizens - under the *Eat Right India* movement to transform the country's food system and ensure safe, healthy and sustainable food for all Indians through the movement *Eat Right India* or *Sahi Bhojan, Behtar Jeevan*.

The *Eat Right India Logo* represents a healthy *Indian thali* (plate), signifying a balanced and wholesome diet comprising all food groups in the appropriate quantities for good health. Each color in the logo represents a food group and its corresponding nutrient category required by

the body, while the size of its arc represents the proportion of that food group to be consumed for optimum health. The green leaf symbolizes responsible, environmentally sustainable food production and consumption to protect the planet's health. (Figure 19.3)

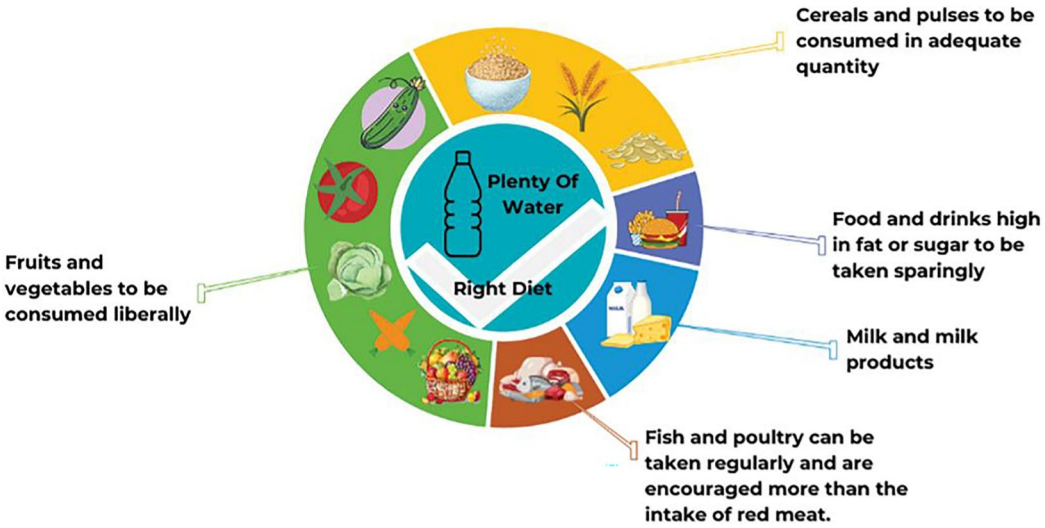

Figure 19.3 Eat Right India Logo. ICMR myplate of the day

The *Eat Right India Movement* is based on Eating Healthy, Eating Safe, and Eating Sustainably. It aligns with other initiatives, such as Ayushman Bharat, POSHAN Abhiyaan, Anemia Mukt Bharat, and the Swachh Bharat Mission, as well as the recently published dietary guidelines for Indians by ICMR (Dietary Guidelines for Indians 2020).[7] The ICMR, 'What India Eats Report (2020),' myplate for 2000 kcal intake a day is about adults' average consumption of calories in urban and rural India.[7] The food groups that people should eat include 250 grams of cereals and millet, 400 grams of colored vegetables, 100 grams of fruits, 85 grams of pulses/eggs/flesh foods, 35 grams of nuts and seeds, and 27 grams of fat/oils.

The new guidelines stress the significance of a balanced diet, urging the consumption of a variety of foods from different groups to ensure nutritional adequacy. Extra care and nutritious food are emphasized during pregnancy and lactation. Breastfeeding exclusively for the first six months is recommended, followed by the introduction of homemade semi-solid foods. Adequate diets for children and adolescents support growth and immunity. Vegetables and legumes are highlighted for their nutrient-rich benefits in preventing deficiencies. Moderation in fat and oil consumption and opting for variety is advised. Quality protein sources are encouraged over supplements for muscle building. Adopting a healthy lifestyle, including regular physical activity, helps prevent obesity-related diseases. Limiting salt intake is crucial for preventing hypertension. Food safety and healthy cooking practices are underscored for overall well-being. Maintaining good hydration and balancing the intake of convenience foods by opting for options lower in fat, sugar, and salt can contribute to a healthier lifestyle. Elderly individuals are encouraged to consume nutrient-rich foods and stay physically active.

19.2.2 Interventions to Address Malnutrition and Micronutrient Deficiencies

The *Eat Right India Movement* includes key initiatives to tackle malnutrition and micronutrient deficiencies. Micronutrient deficiency, or hidden hunger, is a form of undernutrition resulting from insufficient intake or absorption of essential vitamins and minerals to sustain good health and development in children and normal physical and mental function in adults. Causes include poor diet, disease, or increased micronutrient needs during pregnancy and lactation. From a public health standpoint, effective methods to promulgate dietary diversity include food-based strategies.

Staple food fortification adds trace amounts of micronutrients to commonly consumed foods or condiments during processing to help individuals reach recommended micronutrient levels. Food fortification is a simple, scalable, sustainable, and cost-effective public health strategy. The success of the edible salt fortification with iodine is well recognized, as 71 percent of the global population now has access to iodized salt. Iodine-deficient countries have decreased from 54 to 32 since 2003.[8] Other examples of fortification include adding vitamin B, iron, and/or zinc to wheat flour and Vitamin A to cooking oil and sugar. Fortification is particularly effective for urban consumers who buy commercially processed and fortified foods. However, rural consumers, who often have less access to commercially produced foods, benefit less. Therefore, many national health policies advocate subsidizing or mandating fortification to reduce the likelihood of people purchasing cheaper, non-fortified alternatives.

FSSAI has implemented a large-scale program to make fortified staples accessible. Some initiatives include setting standards for five fortified staples - wheat flour, rice, edible oil, milk, and double-fortified salt and providing a logo (+F) to identify fortified foods. Recently, standards for processed foods such as breakfast cereals, bakery wares such as buns, rusk, pasta, noodles, and fruit juices have also been released.

The food fortification program under *Eat Right India* is known for its integrated approach. FSSAI has undertaken numerous capacity development initiatives for manufacturers of premixes and fortified staples. The distribution of fortified rice and wheat is being encouraged with the support of the Food Corporation of India and through the PDS scheme. Consumer awareness is built through the support of various stakeholders, such as the Network of Professionals of Food and Nutrition (NetProFaN), which was constituted by FSSAI as a platform to engage professionals from academia, research, and industry, in supporting the implementation of the Eat Right India movement through evidence-based advocacy, awareness generation, and capacity-building initiatives across the country.

Netprofan is constituted of representatives from 8 major associations, collaborating to advance food safety, nutrition, and public health across India viz, Indian Dietetic Association (IDA), Nutrition Society of India (NSI), Indian Medical Association (IMA), Association of Food Technologists & Scientists of India (AFSTI), Indian Federation of Culinary Associations (IFCA), Association of Analytical Chemists, India Chapter (AOAC), Indian Dental Association (IDA), Indian Association for Parenteral and Enteral Nutrition (IAPEN).

19.2.3 Key Components of the Campaign, Including *Swasth Bharat Yatra, Eat Right Challenge,* and *Eat Right Campus*

The campaign encompasses key components vital for promoting healthy eating habits and ensuring nationwide food safety. The *Swasth Bharat Yatra* is a flagship initiative that organizes rallies, workshops, and events to raise awareness about safe and nutritious eating practices. The *Eat Right Challenge* encourages participation from schools, colleges, and workplaces, motivating individuals to adopt healthier dietary habits through pledges and competitions. Eat Right Campus is an initiative under FSSAI's broader Eat Right India movement, aimed at creating safe, healthy, and sustainable food environments within institutions such as schools, universities, colleges, workplaces, hospitals, tea estates, jails, and anganwadis.

The Eat Right Creativity Challenge engages youth in promoting healthy eating through artistic expression and resources like the Eat Right Toolkit for Schools, and the Yellow Book empower educational institutions to advocate for healthy diets among students. The Hygiene Rating Certification initiative rates food service establishments on their hygiene and food safety practices, promoting transparency and encouraging consumers to make informed choices.

19.2.4 Impact of the Campaign on Food and Nutrition Outcomes

While limited literature exists on the food and nutrition outcomes of the *EAT Right Campaign*, it has significantly transformed the food systems of the country by promoting fortified foods to address micronutrient deficiencies. The campaign fosters collaboration among stakeholders from science, academia, and the general public, focusing on sustainable healthy diets through a *whole-of-society approach* that includes farmers, businesses, consumers, experts, policymakers, and young minds to carry the moment forward. A recent World Bank report reveals that by 2020, FSSAI had identified 82 companies capable of producing 122 fortified products in India, with over 47% of the top 10 companies fortifying their refined edible oil and milk. More than 1,41,480 schools have registered under the Eat Right School initiative. The *Swasth Bharat Yatr*a engaged 1 million participants and over 20,00 volunteer cyclists, covering 20,000 km in 104 days. By 2020, FSSAI operated 54 vans for food safety. The *EAT Right Mela* attracts more than 10,000 citizens annually.[9] However, due to the COVID-19 pandemic, physical health campaigns transitioned to digital platforms. These initiatives are poised to positively impact food and nutrient intake, enhancing the population's nutritional status.

19.3. GOVERNMENT POLICIES AND STRATEGIES TO SUPPORT THE *EAT RIGHT MOVEMENT*

19.3.1 Overview of Policies Related to Holistic Health, Food Standards, Traditional Foods, and *Ayurveda Ahara*

In a nation facing significant malnutrition challenges, the government focuses on nutrition. This has been demonstrated through initiatives such as Integrated Child Development Services (ICDS) and Mid-Day Meal programs, spanning over four decades. A comprehensive nutrition policy wasn't established until 1992 despite addressing specific nutrient deficiencies. The National Nutrition Policy of 1993 marked a pivotal step to ensure adequate nutrition for all, particularly vulnerable groups like children and pregnant women. Prioritizing balanced diets, breastfeeding, and nutrition education, this policy sought to empower communities while advocating multisectoral collaboration for holistic intervention. However, the absence of clear targets posed challenges. Subsequently, the National Nutrition Mission (NNM) launch in 2018, or *Poshan Abhiyan*, aimed at comprehensive malnutrition alleviation through strengthened programs and community interventions facilitated by institutional mechanisms and strategic partnerships, signifying a concerted effort toward improved nutritional outcomes nationwide.

FSSAI, established on August 5, 2011, under the Food Safety and Standards Act, 2006, underscores the government's commitment to safeguarding public health through stringent regulation and supervision of food safety standards in India. FSSAI's mandate includes formulating science-based standards, regulating food product manufacture, storage, distribution, sale, and import, and promoting public awareness and education on food safety and hygiene practices.

The Indian government has implemented various policies to foster holistic health and wellness, ensuring food safety and preserving traditional dietary practices. The National Health Policy emphasizes integrating traditional healthcare systems, including Ayurveda, Yoga, Naturopathy, Unani, Siddha, and Homeopathy (AYUSH), into mainstream healthcare services, providing comprehensive and patient-centered care, addressing not only physical ailments but also mental and spiritual well-being. The Food Safety and Standards Act establishes rigorous regulations overseen by the FSSAI to ensure the safety and quality of food products, including traditional foods, reflecting a commitment to preserving cultural heritage while safeguarding consumer health.

Government initiatives also aim to promote traditional Indian foods, recognizing their nutritional value and cultural significance. These efforts include campaigns to raise awareness about indigenous food crops, culinary traditions, and dietary practices. *Ayurveda Ahara* principles are increasingly being integrated into public health initiatives and policies, advocating for locally sourced, seasonal, and balanced diets aligned with *Ayurveda*. Through investment in research and development, the government seeks to explore the nutritional composition and health benefits of traditional Indian foods and Ayurvedic interventions, generating evidence for informed policy formulation and program implementation.

19.3.2 Introduction of New Policies or Modifications to Existing Policies to Better Support the *EAT Right Movement*

POSHAN *Abhiyaan*, India's National Nutrition Mission, targets malnutrition through community engagement and participation via *Jan Andolan*. It involves conducting awareness campaigns to educate the public on the importance of nutrition and the risks involved via government schemes such as workshops, street plays, pamphlets, and audio-visual aids. Local leaders and influencers help disseminate information effectively and influence positive behavior changes. Training and capacity-building programs equip frontline health workers, Anganwadi workers, and Accredited Social Health Activists (ASHAs) with the necessary skills to deliver nutrition-related services within their communities. The mission emphasizes community mobilization to foster a sense of ownership and responsibility, encouraging active participation in program planning and implementation through community meetings and committees. Establishing mechanisms for monitoring and feedback enhances accountability and transparency in program implementation. Overall, community outreach is pivotal in making POSHAN *Abhiyaan* a sustained effort driven by collective participation, ensuring improved nutritional outcomes, particularly among children and pregnant women nationwide, positively impacting the *EAT Right Movement*.

19.3.3 Collaboration between Government Departments and Agencies to Implement the Campaign and the Complementary Role of Various Nutrition-Sensitive Interventions from Different Departments, Like Women and Child Development, Education, WASH, Agriculture, and Food and Civil Supplies

Collaboration between government departments and agencies is crucial for successfully implementing nutrition campaigns like the *EAT Right Movement*, which emphasizes the complementary roles of various nutrition-sensitive interventions from different sectors. Departments such as Women and Child Development, Education, WASH (Water, Sanitation, and Hygiene), Agriculture, and Food and Civil Supplies each play a vital role in addressing different aspects of nutrition. For instance, Women and Child Development can focus on maternal and child health services, Education can integrate nutrition education into school curricula, WASH can ensure access to clean water and sanitation facilities, agriculture can promote diverse and nutritious food production, and Food and Civil Supplies can facilitate access to affordable and quality food supplies. By coordinating efforts and leveraging resources across sectors, these departments can synergize their interventions, leading to comprehensive and sustainable improvement in nutrition outcomes across India.

19.3.4 Metrics Identified to Measure and Encourage Stakeholders, Such as Inclusion in the State Food Safety Index

Measuring and encouraging stakeholders' efforts within initiatives like the *EAT Right Movement* entails utilizing various metrics, including inclusion in the State Food Safety Index (SFSI). The SFSI is a pivotal metric for assessing states' performance in ensuring food safety and promoting healthy eating) practices, encompassing factors like safe and nutritious food availability, adherence to food safety standards, and public awareness of food safety practices. Monitoring the nutritional quality of the food supply, assessing changes in consumer awareness and behaviors, and tracking local sourcing and sustainable practices provide valuable insights into stakeholders' contributions. Evaluation of policy implementation, compliance, community engagement, and partnerships further illuminates stakeholders' efforts and encourages continuous improvement in promoting healthy eating practices and ensuring food safety across diverse contexts. Through comprehensive monitoring and evaluation frameworks incorporating these metrics, stakeholders can effectively measure progress, identify areas for enhancement, and incentivize actions aligned with the goals of the *EAT Right Movement*.

19.4 INTERNATIONAL ALIGNMENT WITH GLOBAL INITIATIVES

19.4.1 Alignment of the EAT Right Movement with International

Frameworks Such as the SDGs and WHO

The alignment of the *EAT Right Movement* with international frameworks such as the SDGs and WHO is essential for fostering global collaboration and ensuring comprehensive progress towards shared goals. The *EAT Right Movement*, which promotes healthy eating habits of nutritious diets and sustainable food systems, directly contributes to several SDGs, including Goal 2 (Zero Hunger), Goal 3 (Good Health and Well-being), and Goal 12 (Responsible Consumption and Production). The movement addresses key targets for food security, health promotion, environmental sustainability, and responsible consumption patterns outlined in the SDGs. Additionally, the principles endorsed by the WHO, such as promoting healthy diets, preventing NCDs, and ensuring food safety, are inherently embedded within the objectives of the *EAT Right Movement*. By aligning with international frameworks and leveraging their guidelines and recommendations, the *EAT Right Movement* aims to amplify its impact, foster cross-sectoral collaboration, and contribute to global efforts to achieve sustainable development and improve public health outcomes worldwide.

19.4.2 Collaboration with International Organizations and Partnerships to Exchange Knowledge and Best Practices

Collaboration with international organizations and partnerships is invaluable for the *EAT Right Movement* to exchange knowledge and best practices, leverage resources, and drive collective action toward common goals. Partnering with organizations such as the WHO, FAO, United Nations Children's Fund (UNICEF), and World Food Programme (WFP) provides access to expertise, data, and evidence-based interventions in nutrition and food systems. By engaging in international partnerships, the *EAT Right Movemen*t can enhance its effectiveness, broaden its reach, and contribute to global efforts to promote healthy diets, sustainable food systems, and improved nutrition outcomes. Collaboration with international academia is also instrumental in the EAT Right *Movement's* access to cutting-edge research, expertise, and innovation in nutrition and food systems. Partnering with universities, research institutions, and academic networks enables the exchange of scientific knowledge, evidence-based interventions, and best practices in promoting healthy diets and sustainable food production. Academic collaborations can facilitate research collaborations, joint projects, and capacity-building initiatives, fostering interdisciplinary approaches to address complex nutrition challenges. By leveraging the expertise and resources of international academia, the *EAT Right Movement* can strengthen its evidence base, enhance program effectiveness, and contribute to advancing global understanding and action on nutrition and food security.

19.4.3 Case Studies of Successful International Initiatives with Similar Goals and Strategies

Several international initiatives share goals and strategies similar to the *EAT Right Movement,* showcasing successful approaches to promoting healthy diets and improving nutritional outcomes. Brazil's National School Feeding Program (PNAE) focuses on providing nutritious meals to children while supporting local agriculture, integrating nutrition education into school curricula, and involving communities in meal planning.[10] Thailand's Health Promotion Foundation (ThaiHealth) aims to reduce NCDs by promoting healthy lifestyles and implementing multi-sectoral interventions such as media campaigns, community engagement, and policy advocacy to encourage healthier eating choices and behaviors.[11] Japan's Shokuiku (Food Education) Program emphasizes a holistic approach to food education, integrating it into school curricula, fostering community engagement through cooking classes and events, and collaborating with industry stakeholders in promoting healthy eating.[12] These case studies highlight the effectiveness of comprehensive, multi-sectoral approaches, community engagement, and collaboration with diverse stakeholders in achieving success in promoting healthy diets and improving nutrition outcomes, aligning closely with the strategies of the *EAT Right Movement*. Japan has one of the highest numbers of dietitians and has seen significant increases in awareness and healthy diets, leading to increased longevity.

19.5 CHALLENGES AND OPPORTUNITIES IN IMPLEMENTING THE *EAT RIGHT MOVEMENT*

19.5.1 Challenges and Opportunities Related to Limited Resources, Awareness, and Capacity Among Stakeholders

Implementing the *EAT Right movement* faces hurdles due to resource constraints, inadequate awareness, and capacity limitations among stakeholders, particularly in rural areas. While cities have seen progress, rural communities struggle with poor infrastructure and limited access to nutritious food, compounded by a lack of knowledge about healthy eating. According to a report by the FAO, approximately 194.4 million people in India suffer from undernourishment, underscoring the urgency of addressing these challenges.[13]

Government agencies play a crucial role in addressing the challenges of undernutrition in developing countries such as India. They can implement and support various initiatives to mitigate the problem.

1. Policy formulation and implementation - The Government of India launched the National Nutrition Mission (Poshan Abhiyaan) to reduce stunting, undernutrition, anemia, and low birth weight in children. This comprehensive policy aims to improve nutritional outcomes through various interventions.
2. Resource allocation - Allocating funds for nutrition-specific programs, such as the Mid-Day Meal Scheme, which provides nutritious meals to school children. This not only addresses hunger but also improves educational outcomes by increasing school attendance.
3. Infrastructure development - Developing rural infrastructure, such as clean water supply, sanitation facilities, and healthcare centers. Improved infrastructure directly impacts health and nutrition by reducing disease prevalence and increasing access to healthcare services.
4. Public awareness campaigns - Launching mass media campaigns to educate the public about the importance of nutrition, breastfeeding, and hygiene practices. For instance, the *Eat Right India* campaign by the FSSAI promotes healthy eating habits.
5. Collaboration with local governments and Non-governmental Organizations (NGOs) - Partnering with local governments and NGOs to implement grassroots-level interventions. The ICDS scheme works with Anganwadi centers to provide nutrition, health education, and preschool education to children under six and their mothers.
6. Training and capacity building - Training healthcare workers and volunteers to identify and manage undernutrition cases. For instance, training programs for Anganwadi workers under ICDS enhance their capacity to provide effective nutritional support and education.
7. Monitoring and evaluation - Establishing systems to monitor and evaluate nutrition programs. The use of technology, like mobile applications for real-time monitoring of nutritional status and program delivery, helps in tracking progress and making data-driven decisions.
8. Food security programs - Implement food security programs like the PDS, which ensure the supply of essential food grains at subsidized rates to low-income families, thus improving their food intake and nutritional status.

By fulfilling these roles, government agencies can effectively address undernutrition, improve public health, and foster socio-economic development in developing countries.

Empowering women and youth through education and skill-building initiatives can ignite sustainable change. Integrating *EAT Right* principles into existing government schemes can mainstream nutrition interventions.[14] Despite challenges, targeted interventions, government support, and community engagement can overcome barriers and create a healthier, more sustainable food environment, particularly in rural areas.

19.5.2 Opportunities for Public-Private Partnerships and Innovative Solutions to Support the Movement

Opportunities for Public-Private Partnerships (PPPs) and innovative solutions arise as catalysts for advancing the EAT Right Movement. Collaborations between government agencies, food industry stakeholders, and civil society organizations can leverage complementary expertise, resources, and networks to scale interventions and drive systemic change. For instance, initiatives like the Food Fortification Resource Centre (FFRC) facilitate PPPs to address micronutrient deficiencies through fortifying staple foods.[15] Technological innovations offer promising avenues for enhancing food safety, traceability, and consumer engagement.

Industry involvement, through sponsorships in events like *EAT Right melas and walkathons*, signifies a commitment to Corporate Social Responsibility (CSR) and sustainability. These sponsorships not only enhance the company's brand image but also contribute to strengthening its sustainability initiatives. The FSSAI's Food Safety Connect application facilitates stakeholder collaborations, enhancing transparency and accountability in the food supply chain. Leveraging social media platforms can amplify consumer engagement and awareness, driving sustained momentum toward promoting healthy and sustainable food choices.[15]

19.5.3 Lessons Learned from the Implementation of the *EAT Right Movement*

Implementing the *EAT Right Movement* has provided valuable insights, particularly regarding successful engagement strategies for professionals, academia, and grassroots communities. Initiatives such as the *Eat Right Campus and Eat Right School* certification systems have proven effective in promoting healthy eating habits and fostering partnerships between academia and communities. These initiatives have cultivated a culture of health and sustainability within educational settings and provided platforms for active participation in shaping food environments. Addressing awareness and engagement at the grassroots level has emerged as a critical lesson in driving sustained behavior change. Tailored nutrition education and outreach efforts targeting communities, schools, and households have built community trust and credibility, paving the way for long-term acceptance and adoption of *EAT Right* principles.

Moreover, leveraging digital platforms such as the *Food Safety Connect* application and social media has played a crucial role in amplifying the movement's reach and impact. The *Food Safety Connect* application's real-time information on food safety and nutrition has enhanced consumer engagement, while social media platforms have facilitated interactive educational campaigns and targeted messaging. Further channelling these digital tools and platforms will sustain momentum and foster ongoing stakeholder dialogue.

Case studies from international initiatives, such as the Paediatric Nursing Associations of Europe (PNAE) and ThaiHealth, offer valuable lessons in integrating nutrition education, community participation, and policy advocacy to promote healthy diets and combat malnutrition. Furthermore, monitoring and evaluation mechanisms are crucial in assessing program effectiveness, identifying bottlenecks, and course-correcting strategies in real time.[16]

Multi-stakeholder collaboration, grassroots engagement, and innovative communication strategies are essential for the success of the *EAT Right Movement*. By leveraging lessons learned and building upon successful initiatives, the movement can continue driving progress toward promoting healthy diets, sustainable food systems, and improved nutrition outcomes for all.

19.6. CONCLUSION AND RECOMMENDATIONS

19.6.1 Summary of the *EAT Right Movement* and its Importance for Food and Nutrition in India

While the *EAT Right Movement* holds immense potential for improving India's food and nutrition landscape, challenges persist.[9] Limited resources, lack of awareness, and varying capacities among stakeholders pose significant hurdles. However, these challenges present opportunities for innovative solutions and PPPs, which can further strengthen the movement's impact. [9,17]

19.6.2 Recommendations for Future Interventions and Improvements to the Campaign

To enhance the effectiveness of the *Eat Right Campaign*, future interventions should prioritize targeted messaging and outreach tailored to diverse demographics and communities, considering cultural nuances and socio-economic factors within the context of limited available resources. This approach ensures that communication strategies

resonate with the intended audience, promoting greater engagement and behavior change. Investing in comprehensive educational initiatives and practical skills development programs will empower individuals and communities to make healthier food choices and adopt safer food handling practices. Integrating *Eat Right* messaging and interventions into existing health, nutrition, and education programs and forging partnerships with diverse stakeholders, including government agencies, NGOs, and businesses, can mobilize collective action and resources toward promoting healthy eating and food safety at scale. Leveraging technology and media innovation, such as interactive mobile applications and digital storytelling, will enhance engagement and facilitate behavior change among diverse audiences. Establishing robust monitoring and evaluating systems, evidence-based policy advocacy, and regulatory support will ensure accountability and drive sustainable progress toward the campaign's goals.

19.6.3 Call to Action for Increased Awareness of the Movement and its Benefits among Stakeholders

Policy discourse in India revolves around establishing healthcare as a fundamental right akin to education. Efforts need to be synchronized among all stakeholders regarding the readiness of economic and health systems to enforce such a right, considering healthcare's multifaceted nature and intersection with issues like poverty, literacy, and sanitation. Considerations include whether a centralized law is advisable given healthcare's status as a state subject and whether the emphasis should be on enforcing public health standards or ensuring health rights. Ensuring access to healthcare encompasses various aspects, including infrastructure, human resources, and standardized protocols. Multisectoral collaboration is essential to creating an enabling environment where healthcare is truly accessible to all as a fundamental right.

Pearls of Practice

- Implement targeted messaging and outreach strategies tailored to diverse demographics and communities, addressing cultural and socioeconomic nuances for maximum effectiveness.
- Develop comprehensive educational programs and practical skills initiatives to empower individuals and communities.
- Integrate 'Eat Right' messaging into health, nutrition, and education programs through partnerships with diverse stakeholders.
- Leverage technology and media innovation for interactive engagement while establishing robust monitoring systems and advocating for evidence-based policies.

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Section 20: Implementation–Nutrition Prescription, Indian Healthy Plate, Cost-Effective Approaches, Precision Nutrition

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20.0 SUMMARY OF RECOMMENDATIONS

Section 1: Principles of MNT in T2D Management

Medical Nutrition Therapy (MNT) is a cornerstone in the management of Type 2 Diabetes Mellitus (T2D), aiming to optimize metabolic control, manage weight, and thus possibly help in the prevention of long-term complications.[1] In India, the increasing prevalence of T2D

necessitates the development of guidelines tailored to the local dietary habits and lifestyle. A key principle of MNT for T2D is the creation of individualized nutrition plans. These plans consider personal preferences, cultural practices, metabolic goals, and existing health conditions. The Indian Diabetes Educators Project recommends a detailed dietary assessment to tailor nutrition interventions, as individualized plans are more effective in managing blood glucose levels and ensuring patient adherence to dietary recommendations.[2]

A balanced diet that includes a variety of foods from all food groups is essential. The Indian guidelines emphasize the consumption of whole grains, legumes, vegetables, fruits, lean proteins, and healthy fats. Whole grains like brown rice, millet, and whole wheat are encouraged over refined grains due to their lower Glycemic Index (GI) and higher fiber content. The consumption of fruits and vegetables is advocated to ensure adequate intake of vitamins, minerals, and fiber, which aid in maintaining glycemic control and possible reduction in the risk of cardiovascular diseases.[3]

Carbohydrate intake is a significant focus in MNT for T2D. The Indian guidelines recommend that carbohydrates should make up about 50–55% of the total daily calorie intake, with an emphasis on complex carbohydrates. The GI and Glycemic Load (GL) of foods are crucial considerations, as foods with a low glycemic index, such as legumes, whole grains, and certain fruits and vegetables, are preferred because they result in a slower and more controlled rise in Blood Glucose (BG) levels.[4]

Moderation of fat intake, particularly saturated fats and trans fats, is another critical aspect. The guidelines suggest that total fat intake should be 20–25% of the total daily calorie intake, with a focus on increasing the intake of monounsaturated fats, which may have beneficial effects on glycemic control and cardiovascular risk. Protein should account for 15–20% of total daily calories, with a preference for plant-based proteins and lean animal proteins to support overall health and muscle maintenance.[5]

Portion control and meal timing play vital roles in managing T2D. The guidelines advise against large meals that can cause significant postprandial glucose spikes. Meal planning should also consider the distribution of carbohydrate intake throughout the day to prevent hyperglycemia and hypoglycemia.[6]

While primarily a focus of lifestyle management, physical activity is intrinsically linked to MNT. Regular physical activity enhances insulin sensitivity and aids in weight management. The Indian guidelines recommend at least 150 minutes of moderate-intensity aerobic exercise per week, coupled with resistance training.[7] Physical activity should be tailored to the individual's abilities and preferences to ensure adherence and effectiveness.

Behavioural strategies are integral to the successful implementation of MNT. These include education on reading food labels, understanding portion sizes, and recognizing the impact of various foods on BG levels. The guidelines also emphasize the importance of ongoing support from healthcare providers, including regular follow-ups to monitor progress and make necessary adjustments to the nutrition plan.[1,8]

Given the diversity of Indian cuisine and dietary practices, cultural considerations are essential. Traditional Indian diets are rich in carbohydrates and fats, posing challenges for individuals with T2D. Nutrition education should incorporate traditional recipes and cooking methods, suggesting healthier modifications without compromising taste and cultural preferences. For instance, substituting whole grains for refined grains in traditional dishes can help manage BG levels more effectively.[9]

Thus, the management of T2D through MNT involves a multifaceted approach that incorporates individualized nutritious well-balanced meals, carbohydrate management, controlled fat and protein intake, portion control, and physical activity. Behavioural strategies and cultural considerations are also pivotal in ensuring the effectiveness of MNT. By adhering to these principles, individuals with T2D can achieve better glycemic control, improve their quality of life, and reduce the risk of complications.

Section 2: Current Dietary Habits and Their Relevance to Diabetes Management and Prevention

Diabetes is a significant public health concern in India, with the country having one of the highest prevalences of the disease globally. The rising incidence of diabetes in India is largely attributed to the rapid changes in dietary habits and physical activity levels, particularly in urban areas. The economic burden of T2D in India is among the highest in the world, underscoring the urgent need to address this growing health crisis.[9,10]

Dietary factors play a crucial role in both the development and management of diabetes. Increased consumption of energy-dense foods, such as fast foods and junk foods, has contributed to the rise in obesity and diabetes prevalence, particularly in urban Indian populations. Furthermore, the shift from traditional, nutrient-dense diets to more refined and processed foods has been linked to the growing burden of Non-Communicable Diseases (NCDs), including diabetes, in India.

Comprehensive dietary assessment is essential for understanding the dietary patterns and nutrient intakes of Indian populations, which can inform the development of targeted interventions for diabetes prevention and management. National and regional-level studies, such as the National Nutrition Monitoring Bureau (NNMB), National Sample Survey Office (NSSO), National Family Health Survey (NFHS), Indian Council of Medical Research–India Diabetes (ICMR-INDIAB), and the Indian Migration Study (IMS), have provided valuable insights into the dietary habits of Indians, highlighting that diets in India are predominantly cereal-based, with significant regional variations in dietary patterns influenced by cultural, economic, and geographical factors.[11] Urbanization has led to shifts towards diets rich in processed foods, contributing to higher fat and sugar intake and increasing the prevalence of obesity and diabetes.[12] Micronutrient deficiencies, such as iron, vitamin A, and vitamin D, remain prevalent despite adequate calorie intake, highlighting challenges in achieving dietary diversity and nutritional adequacy.

Assessing the dietary intake of individuals with T2D is essential for optimizing individualized treatment plans and empowering patients with the knowledge and skills to make informed dietary choices that support long-term health and well-being.[9] At the clinical level, 24-hour dietary recalls are commonly used to assess dietary intake. These retrospective interviews can provide detailed information on the types and quantities of foods consumed, allowing healthcare professionals to identify dietary patterns and nutrient deficiencies that may contribute to diabetes risk or poor glycemic control.[13] In addition to 24-hour dietary recalls, various dietary assessment tools have been developed to facilitate more accurate and comprehensive dietary data collection. These include food atlases, which provide visual aids to help patients estimate portion sizes, and software programs like EpiNu, which can analyze dietary data and provide personalized feedback on nutrient intake and diet quality. Mobile apps have also emerged as one of the useful tools for monitoring dietary intake, as they allow patients to record their food consumption in real time and receive immediate feedback on their nutrient intake and dietary patterns. The integration of clinical information systems, such as disease registries and electronic medical records, can enhance the effectiveness of these dietary assessment tools by enabling healthcare providers to set personalized goals, monitor patient progress, and identify gaps in care. For older populations with chronic diseases like diabetes, training programs on the use of digital technologies for self-management may help reduce barriers to access and improve patient engagement. Comprehensive dietary assessment and the use of evidence-based dietary assessment tools are essential for understanding the dietary habits of Indian populations and informing the development of targeted interventions for diabetes prevention and management. By addressing the dietary determinants of diabetes, healthcare professionals can play a crucial role in mitigating the growing burden of this chronic disease in India.[14]

Section 3: Energy Balance and Weight Management

The relationship between obesity and the development of NCDs is well-documented.[15] Excess adipose tissue contributes to metabolic dysregulation and inflammation, thereby increasing the risk of T2D and other NCDs. Effective management of weight in individuals with T2D is crucial for improving health outcomes and reducing the risk of complications associated with obesity and related NCDs.

Obesity is a significant risk factor for the development of T2D and exacerbates its progression by increasing insulin resistance and cardiovascular risks. Maintaining a healthy weight is important in managing T2D by improving insulin sensitivity, glycemic control, and overall quality of life. Individuals with T2D who achieve and maintain a healthy weight experience reduced dependency on pharmacological treatments and lower risks of cardiovascular complications.[16,17,18]

Assessing individual body weight and composition involves using various indices, such as Body Mass Index (BMI) and Waist Circumference (WC). BMI serves as an initial screening tool for assessing adiposity, and in the Indian context, specific cut-offs are used to define overweight and obesity, reflecting population-specific variations in body composition and metabolic risks. WC is a measure of abdominal obesity, which is strongly associated with insulin resistance and cardiovascular diseases in individuals with T2D. In Indian guidelines, WC cut-offs are used to identify individuals at increased risk of metabolic complications.

Assessing caloric intake and maintaining energy balance is fundamental to weight management for people with diabetes. Calculating basal metabolic rate and total daily energy expenditure helps determine individual energy requirements for weight maintenance or loss. Even moderate weight loss in combination with increased activity can improve insulin sensitivity and glycemic control in patients with T2D and prevent the development of T2D in high-risk persons.

Setting personalized weight management goals is essential for individuals with T2D. Non-pharmacologic approaches, including dietary modifications and increased physical activity, are central to achieving and maintaining weight loss. Dietary strategies focus on creating a calorie deficit through balanced nutrition, emphasizing whole foods and portion control to improve glycemic control and cardiovascular health. Physical activity complements dietary interventions by increasing energy expenditure and promoting weight loss in individuals with T2D. Structured exercise programs tailored to individual capabilities and preferences enhance metabolic flexibility and cardiovascular fitness.[19,20]

Regular monitoring of weight and body measurements and self-monitoring of food intake and physical activity are integral to assessing progress and adjusting interventions as needed. These practices facilitate adherence to weight management goals and empower individuals with T2D to make informed decisions about their health.

Section 4: Macronutrient Distribution for Diabetes Management

The global burden of T2D has risen dramatically, particularly in regions like Asia, where dietary patterns are heavily carbohydrate-dependent.[21] Traditional diets rich in whole grains, fruits, vegetables, and legumes have been replaced by high intakes of energy-dense, nutrient-poor foods, coupled with low physical activity levels, leading to obesity and insulin resistance and driving diabetes prevalence.[22] Addressing the association between dietary habits and diabetes prevalence is critical for implementing preventive measures and promoting healthier eating behaviors in India. Dietary macronutrients significantly influence glycemic control and overall health. Carbohydrates impact blood glucose levels directly, requiring careful monitoring, while proteins and fats contribute to satiety and metabolic functions. Effective management of T2D necessitates a focus on dietary interventions, particularly macronutrient distribution, to regulate blood glucose levels and mitigate the risk of complications.[23] A well-structured diet is critical for controlling BG levels and preventing the progression of T2D, with the American Diabetes Association (ADA) emphasising the importance of macronutrient balance.[23,24]

The STARCH study showed that 64.1 ± 8.3% (95% CI 63.27 to 64.93) of total calories came from total carbohydrates in the Indian diet, which is higher (above the upper limit) than the recommended guidelines.[23] This finding underscores the need for targeted dietary interventions to address excessive carbohydrate consumption and its impact on glycemic control. Postprandial hyperglycemia is a major challenge while managing diabetes in our populations. While carbohydrate intake is notably high among individuals with diabetes in India, the proportion of calories from fats also plays a significant role in overall dietary quality and metabolic outcomes. Different types of fats (saturated, monounsaturated, polyunsaturated) have varying effects on insulin sensitivity and cardiovascular health.

The prevalence of diabetes in urban Indian adults is about 12.1%, with onset about a decade earlier than their Western counterparts, and the prevalence of T2D being 4–6 times higher in urban than in rural areas.[25] The risk factors peculiar to developing diabetes among Indians include high familial aggregation, central obesity, insulin resistance, and lifestyle changes due to urbanization.

The explosive increase in the prevalence of T2D is due, in large measure, to the adoption of unhealthy lifestyle practices by individuals at risk of developing the disorder, with insufficient physical activity and unhealthy diets emerging as two of the most important modifiable risk factors not only for T2D, but for other chronic NCDs as well.[25,26]

Dietary macronutrient composition plays a crucial role in the management of T2D. Carbohydrates have the most direct impact on blood glucose levels, necessitating careful monitoring and regulation. The Indian diet is characteristically high in carbohydrates, with 64.1 ± 8.3% of total calories coming from carbohydrates, exceeding the recommended upper limit.[27] This high carbohydrate intake contributes to postprandial hyperglycemia, a major challenge in the management of diabetes in the Indian population.

Alongside carbohydrate intake, the proportion of calories from fats also plays a significant role in overall dietary quality and metabolic outcomes. Different types of fats, such as saturated, monounsaturated, and polyunsaturated, have varying effects on insulin sensitivity and cardiovascular health. The optimal macronutrient distribution for individuals with T2D in the Indian context remains an area of active research and debate, with the need to balance glycemic control, insulin sensitivity, and cardiovascular risk factors.

Effective management of T2D requires a multifaceted approach, with dietary interventions being a crucial component. Dietary modifications targeting macronutrient distribution have improved glycemic control and mitigated the risk of diabetes-related complications. The low-carbohydrate, high-fat diet has gained attention as a potential intervention for improving glycemic control and promoting weight loss in individuals with T2D. However, the optimal dietary approach for the Indian population remains to be elucidated, as traditional dietary patterns, cultural factors, and individual preferences play a significant role in the success of any dietary intervention.

Ongoing research explores the efficacy of various dietary approaches, such as the Mediterranean diet, the DASH (Dietary Approaches to Stop Hypertension) diet, and a carbohydrate controlled diet, in managing T2D in the Indian population. These dietary strategies aim to optimize macronutrient distribution, promote weight loss, and improve insulin sensitivity, ultimately contributing to better glycemic control and reduced risk of diabetes-related complications.

The global burden of T2D has risen dramatically, particularly in regions like India, where dietary patterns are heavily carbohydrate dependent. Addressing the association between dietary habits and diabetes prevalence is critical for implementing preventive measures and promoting healthier eating behaviors. Dietary macronutrients significantly influence glycemic control and overall health, with carbohydrates, proteins, and fats playing crucial roles.

Section 5: Dietary Carbohydrates

Understanding the role of dietary carbohydrates is crucial for managing diabetes and promoting overall well-being through strategic dietary choices.[28–29] Patients should be advised to prioritize high-quality carbohydrates, primarily sourced from whole, unprocessed foods such as fruits, vegetables, and whole grains. These choices provide essential nutrients and offer dietary fiber, which aids in glycemic control and promotes satiety.[30]

Personalized nutritional approaches emphasize the importance of balancing carbohydrate intake while maintaining overall nutritional adequacy in individuals with diabetes. This approach advocates for reducing the consumption of refined carbohydrates and sugars, which can adversely impact blood glucose levels. Instead, lean proteins, healthy fats, and non-starchy vegetables are recommended to help stabilize BG levels and enhance overall dietary quality. Furthermore, emphasizing portion control ensures that carbohydrate intake aligns with individual needs and metabolic goals, reinforcing the pertinence of mindful eating habits.[30]

Recent trends in dietary management for diabetes highlight increasing awareness of added sugars and their potential health implications. There is a growing focus on consuming whole, nutrient-dense foods that offer sustained energy and promote overall health. The ICMR has updated its dietary guidelines for 2024, highlighting the importance of including coarse grains as a significant part of the diet.[31]

Collaboration between healthcare professionals and individuals with diabetes is necessary for determining lifestyle strategies and goals. Monitoring carbohydrate intake, whether by carbohydrate counting or experience-based estimation, remains a key strategy in achieving glycemic control. For good health, carbohydrates from vegetables, whole fruits, unpolished grains, legumes, and dairy products should be prioritized over other carbohydrate sources, especially those that contain added fats, sugars, or sodium.[32,,33] The type of carbohydrates, especially the role of the GI and GL, has been another area of discussion.[34] Overall, by prioritizing these dietary principles, individuals with diabetes can effectively manage their condition while supporting their long-term well-being.

Section 6: Dietary Proteins

Incorporating dietary proteins is essential for individuals with diabetes, as it can increase postprandial satiety, aid in weight management, improve insulin sensitivity, and enhance muscle protein synthesis. Proteins play a crucial role in building and maintaining lean body mass, which is vital for metabolic health. Appropriate protein intake can also enhance insulin action, benefiting BG control.[35]

The general recommendation for protein intake in individuals with diabetes is 15–20% of total caloric consumption, with adjustments based on factors such as age, physical activity, presence of sarcopenia, and renal function. Non-vegetarian foods like fish and lean meat, eggs are encouraged due to their high-quality protein content, while red meat consumption should be moderated. Including diverse protein sources such as dairy (whey, casein), soy, eggs, and lean meats can provide a balanced diet.[2]

Monitoring kidney function through markers like urinary albumin, serum creatinine, and estimated glomerular filtration rate (eGFR) is crucial before adopting a high-protein diet, as people with diabetes often have a higher prevalence of sarcopenia, making it important to maintain muscle health through adequate protein intake and physical activity. The recommended protein intake for managing sarcopenia is 1–1.2 grams per kilogram of body weight per day. For those with diabetic kidney disease, a lower protein intake of 0.6–0.8 grams per kilogram of body weight per day is advised to minimize kidney strain and reduce intraglomerular pressure.[35,36] In cases of chronic liver disease, a higher protein intake of 1.2–1.5 grams per kilogram of body weight per day is recommended to prevent and reverse muscle loss in sarcopenic patients. For gestational diabetes mellitus, the recommended protein intake is 20% of the total calories.

General macronutrient advice for the remission of T2D and prevention of prediabetes and normal glucose tolerance includes shifting towards reducing dietary carbohydrate and increasing protein, as highlighted by the ICMR-INDIAB (2022) study.[37] Emphasizing the quality of proteins and favoring plant-based sources over animal proteins is beneficial for a balanced and healthy diet.

Section 7: Dietary Fats

Managing diabetes requires a comprehensive approach, with dietary fat intake playing a crucial role in overall health and cardiovascular risk reduction.[32] The types of dietary fats consumed are essential, as they can have varying effects on health outcomes.

Saturated fats, which are solid at room temperature and found in animal products and certain oils, can raise low-density lipoprotein (LDL) cholesterol levels and increase the risk of heart disease. In contrast, unsaturated fats, including monounsaturated (MUFA) and polyunsaturated (PUFA) fats, are beneficial for heart health. MUFAs, found in sesame oil, groundnut oil, ricebran oil, mustard oil and olive oil , can help lower bad cholesterol levels, while PUFAs, such as the essential omega-3 and omega-6 fatty acids found in fish, flaxseeds, walnuts and chia seeds, are crucial for brain function, cell growth, and regulating inflammation and metabolism.[38,39]

Current guidelines recommend that total fat consumption should constitute between 20% to 25% of total daily calories to maintain a balanced macronutrient profile. Saturated fat intake should be limited to less than 10% of total calories, with an even stricter recommendation (< 7%) for individuals with elevated lipid levels to help reduce LDL cholesterol levels and lower cardiovascular risk. Trans fat intake should be minimized to less than 1% of total calories or avoided altogether due to its adverse effects on heart health.[3]

Regarding dietary cholesterol, individuals with diabetes are advised to consume less than 300 mg per day if their cholesterol levels are normal and less than 200 mg per day if they have dyslipidemia or are at risk for cardiovascular disease. In terms of PUFA, the recommended intake of omega-3 (n-3) should range from 0.6% to 1.2% of daily energy intake, while omega-6 (n-6) should constitute around 3% of total energy per day to maintain a balanced ratio between these essential fatty acids for optimal health benefits.[40]

These dietary fat guidelines are crucial for individuals with diabetes to manage lipid profiles effectively and reduce the risk of cardiovascular complications associated with the disease. For personalized advice, consulting with healthcare providers or dietitians is recommended to tailor dietary recommendations based on individual health status and goals.

Section 8: Micronutrients

Micronutrients, which encompass vitamins and minerals, play a crucial role in managing diabetes by supporting various physiological functions essential for energy metabolism, antioxidation, immunity, cellular functioning, and growth. Deficiencies in these micronutrients can significantly impact the health and quality of life of individuals with diabetes. Thus, individuals with T2D must aim to meet their Recommended Dietary Allowances (RDAs) for vitamins and minerals through dietary sources and supplements when necessary to address any identified deficiencies.[41]

A balanced diet encompassing all food groups is essential in maintaining optimal health and preventing complications associated with diabetes. Emphasis should be placed on incorporating foods naturally rich in key micronutrients. Leafy green vegetables are excellent sources of vitamin K, which is essential for blood clotting and bone health,[42] while Indian gooseberry and citrus fruits provide vitamin C, an important antioxidant that supports immune function and enhances iron absorption. Nuts and seeds are rich in vitamin E, another antioxidant

that helps protect cells from damage. Fortified foods can help meet the requirements for vitamins D and B_{12}, which are commonly deficient in people with diabetes, as vitamin D is vital for bone health and immune function, and vitamin B_{12} is crucial for nerve function and red blood cell formation.

Mineral-rich foods are also crucial in managing diabetes. Dairy products are excellent sources of calcium, which is necessary for bone health and cardiovascular function. Red meat and beans provide iron, which is critical for oxygen transport in the blood. Nuts, seeds and leafy greens offer magnesium, a mineral involved in over 300 enzymatic reactions, including glucose metabolism. Bananas and potatoes contribute potassium, which helps regulate blood pressure and fluid balance.[41,42]

Clinicians and healthcare providers should provide personalized T2D counseling tailored to individual dietary preferences, cultural backgrounds, and medical histories to optimize overall nutritional status and health outcomes for people with diabetes. This personalized approach ensures that dietary recommendations are practical and sustainable, leading to better adherence and improved health.[1,43]

In summary, a strategic focus on micronutrient intake through a balanced diet and appropriate supplementation is vital for managing diabetes effectively. By addressing specific nutrient deficiencies and ensuring a comprehensive intake of essential vitamins and minerals, individuals with diabetes can significantly enhance their health and quality of life.

Section 9: Oral Antidiabetic Agents (OADA): Associated Nutritional Considerations

The management of diabetes mellitus often involves the use of oral antidiabetic agents (OADAs), which play a critical role in regulating BG levels. However, these medications can also have various nutritional implications that healthcare professionals must meticulously assess, monitor, and manage to enhance treatment outcomes and mitigate adverse effects.[44] OADA, such as metformin, alpha-glucosidase inhibitors (AGA), and glucagon-like peptide-1 (GLP-1) receptor agonists, can interact with specific nutrients, altering their absorption, metabolism, and utilization within the body. For example, metformin, a widely used first-line OADA, has been associated with decreased absorption of vitamin B12 and folate, particularly in vegans and vegetarians, which can lead to deficiencies if not properly monitored and supplemented.[45] Patients taking AGA develop more Gastrointestinal (GI) side effects if it is not started in a lower dose.. For patients taking GLP-1 receptor agonists, GI side effects are a major concern initially, which can be minimised by consuming smaller meals with low fat. Furthermore, it is crucial to emphasize the importance of adequate protein and calcium intake to maintain and prevent the loss of skeletal muscle lean mass. Thus, monitoring nutrient levels is essential to identify and address any deficiencies arising from these drug-nutrient interactions.[46] A balanced diet with moderate carbohydrate intake (avoid very low-carbohydrate or ketogenic diets), proper hydration, and sufficient protein and calcium can help optimize metabolic and musculoskeletal health while minimizing risks associated with Sodium-glucose cotransporter 2 inhibitor (SGLT2i) therapy.

In addition to the management of specific nutrient-drug interactions, healthcare professionals should also consider the broader dietary implications of OADA. For instance, certain medications may have an impact on appetite, food preferences, or GI function, which can influence the patient's ability to adhere to a healthy, balanced diet. Providing guidance on appropriate dietary modifications can help alleviate these issues and enhance the overall effectiveness of the treatment regimen.[47]

Section 10: Alcohol Management

Moderate alcohol consumption can have varying impacts on individuals, particularly those managing conditions like prediabetes, diabetes, and hypertension. According to the World Health Organization (WHO), there is no universally safe threshold for alcohol consumption in terms of human health.[48] While some studies suggest potential cardiovascular benefits and reduced diabetes risk associated with modest alcohol intake, especially red wine, in older adults, these effects may not be applicable across all age groups and to all individuals. Also, those who start drinking in moderation may gradually go on to drink more than the recommended amounts of alcohol on an episodic or regular basis, and both of these situations carry more harm. Also, the effects of alcohol vary with the timing of food intake with respect to alcohol intake, the quality and quantity of food taken with alcohol intake, and the pharmacotherapy going on for T2D. As all of these variables are very difficult to adhere to, individuals may be harmed rather than benefitted, and hence, we do not recommend individuals with T2D to initiate or continue with alcohol intake. However, for those who drink, ADA 2025guidelines recommend up to two standard drinks per day for men, roughly equivalent to 20 grams of alcohol, and one standard drink per day for women, approximately 10 grams of alcohol. Standard drink sizes vary based on the type of alcohol but generally include measures like 285 mL of full-strength beer, 425 mL of low-strength beer, 100 mL of wine, 30 mL of spirits, or a 275 mL bottle of ready-to-drink beverage containing 5% alcohol. It is also advised for all individuals, including those with diabetes, to have at least two alcohol-free days per week to mitigate potential risks.[32,49,50]

Alcohol intake can potentially worsen hyperglycemia and hypertension in some individuals. Exceeding these recommended limits can heighten the risk of liver diseases, cardiovascular complications, mental health issues, and accidents. For individuals with diabetes, monitoring alcohol intake is crucial to avoid exacerbating health conditions such as hypoglycemia. It is generally recommended to consume alcohol with or shortly after meals to help keep blood glucose levels stable and minimize alcohol-induced hypoglycemia.

Individuals with diabetes should plan alcohol consumption carefully, ensuring adequate food intake, particularly carbohydrates, and avoiding strenuous activities that could adversely affect blood glucose levels. Opting for alcohol types with low sugar or carb content, such as light beers, red and white wines, and distilled spirits, while avoiding high-sugar options like cocktails and dessert wines is advisable.

A balanced meal with protein before drinking alcohol can help manage blood glucose levels effectively.[51] If blood glucose levels drop below 70 mg/dL, individuals should follow the "15–15 rule": consume 15 grams of carbohydrates and recheck levels after 15 minutes, repeating as necessary until levels stabilize above 70 mg/dL.[52] It is essential to consume a snack or meal once stabilized to prevent further drops in BG levels. Individuals who experience severe hypoglycemia despite these measures may require glucagon injections.

Excessive alcohol consumption significantly increases the risk of complications in diabetics and can lead to overall poorer health outcomes. Therefore, individuals with diabetes should limit their alcohol intake and seek support for alcohol cessation if necessary to optimize their health and well-being.

Section 11: Nutritive and Non-Nutritive Sweeteners

The management of diabetes, a chronic condition characterized by the body's inability to regulate BG levels effectively, has long been a critical area of research and clinical practice. Within this context, the role of sweeteners, both nutritive and non-nutritive, has garnered significant attention. Nutritive sweeteners, such as sucrose and glucose-fructose syrups, provide caloric content and contribute to the overall energy intake. In contrast, Non-Nutritive Sweeteners (NNS), also known as artificial or low-calorie sweeteners, are chemicals that impart the sweet taste of sugar without the associated caloric load. These NNS, including sucralose, aspartame, saccharin, and stevia-derived compounds, have been widely adopted as potential alternatives for individuals with diabetes to manage BG levels and facilitate weight control.

The utilization of NNS in population with diabetes has been the subject of ongoing debate. While some studies have suggested the potential benefits of NNS in improving glycemic control and reducing the risk of tooth decay, others have raised concerns about their potential to induce metabolic derangements and disrupt the gut microbiome.[53] NNS may have the counterintuitive effect of inducing metabolic derangements, potentially including disruptions to the gut microbiome. In general, the available evidence suggests that the use of NNS in moderation, as part of an overall balanced diet and healthy lifestyle, is likely safe for the general population. However, individuals with diabetes may need to consider their sweetener intake and consult with healthcare providers carefully.[2] Ultimately, the choice of sweetener should be a personal one based on individual preferences, dietary needs, and a thorough understanding of the potential benefits and limitations of each option. It is important to note that the research on the effects of NNS in the context of diabetes is still evolving, and the long-term consequences remain an area of active investigation. Further studies are needed to better understand the personalized microbial responses to NNS, as well as the optimal dosages and intervention protocols, particularly for the population with diabetes

Section 12: T2D in Different Types of Diabetes

MNT is essential for managing T2D across various special populations, where individualized care is crucial due to distinct physiological and developmental requirements.[54] Early intervention in children with T2D is vital for promoting healthy growth and maintaining glycemic control. Adolescents face unique challenges due to hormonal changes and social pressures, necessitating tailored strategies. Young adults transitioning from pediatric to adult care also require support to balance lifestyle demands with effective diabetes management. Lean individuals with atypical forms of T2D need specialized nutrition plans, while elderly patients often deal with complex comorbidities and functional limitations that must be considered in their care. Women at different life stages—such as those with Polycystic Ovary Syndrome (PCOS), those who are pregnant or lactating, and those who are undergoing menopause—require targeted nutritional strategies for optimal health outcomes.

The rise in T2D prevalence among children is largely linked to increasing obesity rates, influenced by genetic factors (e.g., a 90% concordance rate in monozygotic twins) and environmental aspects like unhealthy diets and sedentary lifestyles. Maternal health, particularly gestational diabetes, also plays a significant role. For children with T2D, a recommended 7–10% reduction in BMI can be beneficial, while those without diabetes but with obesity may prevent T2D by achieving a BMI reduction of at least 0.5 kg/m².[54]

Appropriate nutritional intake is crucial during early childhood—a critical period for growth and development. This age group often experiences food behaviors such as transient preferences and food refusal, which can also occur in older children, where food neophobia negatively affects diabetes management adherence. Studies indicate that children with Type 1 Diabetes (T1D) often consume excessive dietary fat, particularly saturated fat, and insufficient fruits and vegetables.[55,56] With obesity rates among adolescents rising by 2.3% annually, contributing to an elevated risk of T2D, studies like SEARCH and TODAY underscore the importance of addressing central obesity and sedentary behaviors. Managing the comorbid physiological, cognitive, and emotional symptoms presents challenges for many teenagers and their families.[54]

For young adults moving from pediatric to adult care, strategic support is essential for managing diabetes alongside lifestyle changes. Lean individuals with atypical T2D require unique nutrition plans, while elderly patients often face the dual challenges of comorbidities and functional limitations. Dietary adherence can be enhanced by improving medication knowledge tailored to different age groups and individuals with comorbidities.

PCOS is a complex endocrine disorder affecting women's reproductive health, characterized by insulin resistance, hyperandrogenism, irregular menstruation, and infertility.[57,58] Effective PCOS management necessitates a multidisciplinary approach, particularly focusing on dietary and exercise interventions, as obesity is a common comorbidity. Implementing a hypocaloric, low-glycemic index diet and regular physical activity can result in a 5–10% weight loss, enhancing insulin sensitivity and restoring ovulation. Emphasizing balanced meals rich in protein, healthy fats, and low-GI carbohydrates can help minimize postprandial glucose spikes, while nutrient-dense foods provide anti-inflammatory benefits.[59]

Pre-conception nutrition is vital for optimizing reproductive health, with education on glycemic control and overall wellness improving fertility outcomes. Dietary modifications, weight management, and increased physical activity have been linked to enhanced ovulation and sperm quality, paving the way for healthy pregnancies.[59,60] During pregnancy, nutritional needs increase to support maternal metabolism and fetal development, with recommended gestational weight gain for women with a normal BMI suggesting an increase of 11 to 16 kg.[61] Proper nutrient intake is crucial, as imbalances can lead to fetal growth restrictions and other complications.[62]

Energy requirements rise by approximately 350 kcal/day in the second and third trimesters.[63] A nutrient-dense diet, rich in proteins, micronutrients, and omega-3 fatty acids, is essential for preventing complications. Registered dietitians and nutritionists can assist in crafting individualized food plans based on age, activity level, trimester, and weight gain.[64]

The postpartum period, often called the 'fourth trimester,' is critical for infants and mothers.[65] The WHO estimates that a well-nourished mother can produce about 850 mL of milk daily. Exclusive breastfeeding for the first six months is recommended for its nutritional and immunological benefits. Moreover, breastfeeding may lower BG levels and reduce the risk of future T2D in women with a history of gestational diabetes. Therefore, supporting women in their breastfeeding efforts is crucial, as it offers long-term metabolic benefits for both mother and child.

Menopause signifies a significant hormonal transition impacting overall health.[66] Nutritional management during this phase is vital for alleviating menopausal symptoms and preventing chronic diseases, such as cardiovascular issues and osteoporosis. A diet rich in calcium, vitamin D, and protein, emphasizing fresh fruits, vegetables, whole grains, and healthy fats, can promote heart health.[67] Managing hyperglycemia during pregnancy also requires balanced nutrition to maintain optimal blood glucose levels, often involving reduced portion sizes and increased fiber intake. Consulting healthcare professionals can facilitate tailored plans for menopausal women and those experiencing hyperglycemia during pregnancy.[66] In conclusion, it is vital to manage T2D across different life stages, especially for women during pregnancy, lactation, and menopause. Individualized nutritional approaches are essential for addressing the unique physiological and lifestyle needs of these populations, ultimately optimizing glycemic control and improving overall health outcomes.

Section 13: MNT and Anti-Diabetic Agents

MNT is crucial in managing diabetes, aiming to enhance glycemic control and overall health through personalized dietary strategies. When combined with anti-diabetic agents, MNT can optimize therapeutic outcomes, increase the effectiveness of medications, and reduce complications.

Anti-diabetic agents are categorized based on their mechanisms of action and include insulin, sulfonylureas, biguanides, thiazolidinediones, Dipeptidyl Peptidase 4 (DPP-4) inhibitors, SGLT2 inhibitors, and GLP-1 receptor agonists. Each category has distinct properties and effects on blood glucose levels, making them suitable for different patient needs and conditions.[68]

The pharmacokinetics of anti-diabetic agents, including their absorption, distribution, metabolism, and excretion, are vital in determining their

efficacy and safety. Agents such as insulin and sulfonylureas can cause hypoglycemia. These agents increase insulin secretion or replace insulin, lowering blood glucose levels.[69] MNT for patients using these medications emphasizes the importance of consistent carbohydrate intake to prevent hypoglycemia. Regular monitoring and balanced meals are critical. On the other hand, agents that do not typically cause hypoglycemia include SGLT2 inhibitors and GLP-1 receptor agonists. SGLT2 inhibitors prevent glucose reabsorption in the kidneys, promoting glucose excretion through urine. This class of drugs does not typically lead to hypoglycemia when used alone and is associated with weight loss and a modest blood pressure reduction. They also have cardiovascular and renal benefits, making them a valuable option for many patients. GLP-1 receptor agonists enhance insulin secretion in response to meals and inhibit glucagon release. They slow gastric emptying and promote satiety, aiding in weight loss and improving glycemic control without significantly increasing hypoglycemia risk.[70] These agents are particularly beneficial for people who overweight or obese.

Insulin therapy is categorized into different types based on the duration of action and timing relative to meals. Basal insulin provides a constant insulin level to manage blood glucose throughout the day and night. It is often combined with rapid-acting insulin for meal coverage in intensive insulin therapy. This regimen mimics the body's natural insulin response and allows for flexibility in meal timing. Premixed insulin combines intermediate-acting and short-acting insulin in a single injection, simplifying the insulin regimen but requiring careful meal planning to match the insulin action profile.[71] This type is suitable for patients with a fixed daily routine. Basal-bolus therapy involves multiple daily injections of basal and rapid-acting insulins, providing the most flexibility and closest mimicry of natural insulin patterns. It requires diligent carbohydrate counting and frequent blood glucose monitoring, making it suitable for motivated patients.

Adjustments to anti-diabetic agents may be necessary based on efficacy, side effects, patient adherence, and changes in glycemic control. Dosages may be modified or medications switched to achieve optimal outcomes. Nutrition therapy must be tailored to the type of anti-diabetic medication the patient is using. Patients on sulfonylureas, which increase insulin secretion, must carefully manage their carbohydrate intake to avoid hypoglycemia.[72] Emphasizing regular meals and snacks with balanced carbohydrate distribution is essential. Low-GI foods can help stabilize BG levels, while consistent meal timing can prevent fluctuations.

In summary, MNT combined with anti-diabetic agents forms the basis of effective diabetes management. Personalized dietary strategies tailored to the specific medication regimen enhance therapeutic outcomes, reduce the risk of complications, and improve the quality of life for individuals with diabetes.

Section 14: MNT in Diabetes Complications

Managing dietary modifications personalized to diabetes-related complications such as nephropathy, hypertension, cardiovascular disease (CVD), stroke, neuropathy, and retinopathy is essential for improving health outcomes and quality of life for individuals with diabetes. Effective management involves a comprehensive approach that combines efforts to control BG, blood pressure (BP), and blood lipid levels, along with other lifestyle factors, including physical activity, nutrition, and stress management.

Nephropathy and hypertension:

For individuals with diabetic nephropathy, managing protein intake is crucial to preserving kidney function. It is recommended to consume high-quality protein sources such as lean meats, fish, and legumes while moderating intake to no more than 0.8 g/kg of desirable body weight per day for those with albuminuria or a reduced estimated glomerular filtration rate (eGFR).[73] Controlling sodium intake is essential to managing BP and fluid balance, with an emphasis on potassium-rich foods like bananas and leafy greens to counteract sodium's effects.

Cardiovascular disease and stroke:

Dietary strategies to reduce CVD and stroke risk in diabetes focus on managing lipid levels and overall cardiovascular health. Consuming omega-3 fatty acids from sources like fatty fish and nuts improves lipid profiles and reduces cardiovascular risk. Limiting saturated fats found in processed and red meats and replacing them with plant-based proteins like legumes, beans and nuts helps reduce LDL cholesterol levels and lowers CVD risk.[74]

Neuropathy and retinopathy:

Stable BG control through a diet rich in fiber from vegetables, fruits, legumes, and whole grains is critical for managing diabetic neuropathy and retinopathy. Fiber-rich foods help regulate BG levels, improve insulin sensitivity, and reduce inflammation associated with nerve and eye complications. Antioxidant-rich foods such as leafy greens, carrots, and berries protect against oxidative stress and support eye health in individuals with diabetic retinopathy.[75]

While vitamin and mineral supplements may be necessary for some individuals with diabetes, meeting nutrient needs through a balanced diet is generally recommended. Caution is advised against excessive use of supplements without clinical indication, as this may pose health risks. Managing salt intake by avoiding adding salt during cooking or at the table and reducing consumption of ultra-processed, pre-packaged foods high in sodium helps manage BP and kidney health.

These dietary modifications, supported by current research and guidelines, aim to improve overall health outcomes and reduce the risk of complications associated with diabetes in the Indian population.

Section 15: MNT in Special Situations

The management of diabetes extends beyond routine care to encompass specific situations like sick days and religious fasting, where careful planning and education are essential.[33] Addressing these challenges involves navigating dietary adjustments, medication management, and lifestyle modifications to ensure stable BG levels and minimize complications.

The management of special situations in diabetes care, such as sick days, requires comprehensive education during initial consultations. Healthcare providers emphasize the importance of preparedness for acute illness, focusing on hydration, electrolyte balance, and ensuring adequate carbohydrate intake through liquids, oral nutrition supplements, or enteral feeding if necessary to prevent complications like hypoglycemia and ketoacidosis.[76] Education on recognizing symptoms and vigilant monitoring for hypoglycemia is essential, with regular follow-up sessions to reinforce understanding and address concerns.

In managing hypoglycemia, consistent meal schedules are crucial for individuals on insulin therapy to prevent BG fluctuations. Delayed meals can lead to hypoglycemia, necessitating the carrying of carbohydrate-containing snacks to prevent episodes. It's vital to consider meal composition, as foods rich in fat, protein, and fiber can affect carbohydrate absorption and insulin dosing. Protein intake, although not directly affecting BG levels, can influence insulin sensitivity and response, requiring careful management in meal planning.

Religious fasting presents unique challenges, with healthcare providers emphasizing balanced nutrition and controlled carbohydrate intake to maintain stable BG levels. Individuals are advised to consume slowly absorbed, low-GI foods and adapt cooking methods to minimize oil use during fasting periods.[77] Regular BG monitoring and adjustments in medication dosages are recommended to manage fasting-related changes effectively.

Traveling with diabetes requires meticulous planning to ensure optimal health during journeys. Pre-travel advice focuses on diabetes management, medication adherence, and documentation of medical conditions and supplies. Recommendations include carrying adequate insulin, glucose monitoring devices, and emergency medications in carry-on luggage, with specific guidance for insulin pump users to notify airlines in advance and ensure compatibility with security procedures.[78] Healthcare providers educate travelers on managing diabetes

in unfamiliar environments, minimizing risks, and optimizing health outcomes during travel.
Thus, effective management of diabetes in special situations involves tailored approaches that address individual needs and preferences.

Section 16: Integrating MNT and Technology in the Management of Diabetes

The use of artificial intelligence and technology in personalized nutrition plans is revolutionizing the management of chronic conditions like diabetes, particularly T2D.[79] Personalized nutrition plans are created by integrating individual patient data, such as BG levels, dietary preferences, and metabolic responses, often sourced from Continuous Glucose Monitors (CGMs) or glucometers. This approach ensures that dietary recommendations are specifically tailored to meet each patient's unique needs, optimizing their blood glucose control and overall health. By incorporating real-time data from Continuous Glucose Monitors, these plans can be continuously updated to reflect the patient's current glucose patterns and dietary behaviours.
Precision nutrition is a concept that aims to prevent and manage chronic diseases by creating dietary plans grounded in genetic, metabolic, and environmental factors. Advances in genomics, metabolomics, and research on the gut microbiome have expanded the scope and effectiveness of precision nutrition, particularly for diabetes management. Nutrigenomics identifies genetic variations that affect nutrient metabolism, allowing for more specific and targeted dietary strategies. Similarly, metabolomics and microbiome studies reveal individualized metabolic patterns, enabling precise interventions that can improve blood glucose control. A study evaluating the Twin Precision Nutrition Program, which utilized digital twin technology and CGM for personalized dietary management in patients with T2D, demonstrated significant improvements in glycemic control and overall health outcomes.[80]
In the near future, we are likely to see the development of mobile applications that create personalized 1-day, 7-day, or 30-day meal plans based on an individual's preferences, socio-economic status, and even their pantry inventory. This evolution in healthcare technology allows for more dynamic and responsive nutritional interventions, further improving patient outcomes.
Precision nutrition has the potential to tackle both challenges in healthcare, as personalized recommendations have been shown to increase compliance, and predictions of the direction and magnitude of an individual's response to food allow for the development of more effective recommendations tailored to their specific needs and metabolism. Aided by a wealth of data now gathered via wearable devices, smartphones, and diagnostic tests, precision nutrition holds the promise of a more cost-effective approach to health promotion.[81] Advanced computational methods and data analytics platforms could help shape the development of health platforms, tailor future nutritional recommendations for promoting health, and accelerate the translation of the recommendations into the clinic.[80]
While some aspects of this vision date back to the inception of the Human Genome Project, precision medicine now expands beyond the restrictions of genomics to encompass a wide range of data sources increasingly available to clinicians. The development of the field has been underpinned by some striking successes, particularly in cancer, where molecular profiling is increasingly routine, and in asthma, where the identification of predictive biomarkers has enabled patient stratification for tailored therapies.
As precision nutrition continues to advance, it has the potential to further enhance our understanding and application of nutrition and significantly impact outcomes such as health maintenance, resilience and restoration, fertility, physical capacity, and cognitive performance.

Section 17: Functional Foods and Meal Replacement Therapy (MRT)

Functional foods, which provide health benefits beyond basic nutrition, are critical in managing T2D and its associated comorbidities. These foods contain bioactive compounds that aid in regulating BG levels, reducing inflammation, and improving overall health.[82] Key functional foods include high-fiber foods, omega-3 fatty acids, probiotics, antioxidant-rich foods, and certain herbs and spices. Fiber-rich foods, such as whole grains, legumes, fruits, and vegetables, slow glucose absorption and help maintain stable BG levels. Omega-3 fatty acids, found in fatty fish, flaxseeds, and walnuts, reduce inflammation and lower the risk of cardiovascular diseases, which are common among individuals with diabetes. Consuming yogurt, kefir, and other fermented foods can enhance gut health, which is linked to improved glycemic control.[83] Berries, nuts, and dark chocolate contain antioxidants that help mitigate oxidative stress, a factor contributing to diabetes complications. Additionally, spices like cinnamon, turmeric, and ginger have demonstrated potential in improving insulin sensitivity and reducing BG levels.
Meal Replacers (MRs) are pre-packaged foods, including shakes, bars, and ready-to-eat meals, designed to provide balanced nutrition while controlling caloric intake.[84] They are formulated to include essential nutrients in precise quantities, making them a convenient dietary option for individuals seeking to manage their weight and health conditions like T2D.[85] MRs typically contain a balanced mix of macronutrients—proteins, fats, and carbohydrates—as well as vitamins and minerals. The exact composition varies depending on the product, but they are generally designed to be low in calories and high in essential nutrients. The inclusion of fiber and protein helps in promoting satiety, while the controlled carbohydrate content aids in maintaining steady BG levels.
MRT can be classified into two types: partial and complete. In partial meal replacement, one or two meals per day are replaced with MR products, while the remaining meals consist of regular food.[86] This method allows for dietary flexibility and gradual changes in eating habits. Complete meal replacement involves replacing all meals with MR products for a specified period and is often used for rapid weight loss and strict dietary control. MR play a significant role in managing T2D by aiding in weight loss, improving glycemic control, and providing balanced nutrition. Weight management is crucial for improving insulin sensitivity and reducing the risk of diabetes-related complications. Research indicates that meal replacers can effectively support T2D management. Studies have shown that individuals using MR products experience significant weight loss and improved glycemic control compared to those following conventional low-calorie diets. Moreover, meal replacers can help in reducing HbA1c levels, a marker of long-term blood glucose control, thereby lowering the risk of complications associated with diabetes.[87] The primary mechanism by which meal replacers aid in T2D management is through caloric restriction and nutritional balance. By providing controlled portions with known caloric content, MR products help create a caloric deficit, which is essential for weight loss. Additionally, the balanced macronutrient composition ensures that individuals receive adequate nutrition, preventing nutrient deficiencies. For optimal results, it is recommended to use meal replacers as part of a comprehensive diabetes management plan that includes regular physical activity, medication (if prescribed), and regular monitoring of BG levels. Healthcare providers should tailor the use of MR products to individual needs, preferences, and health goals, ensuring that dietary plans are sustainable and effective. Recent evidence suggests that MRs can play a pivotal role in achieving diabetes remission, particularly through low-calorie and very-low-calorie diets. Remission is defined as achieving normal BG levels without the need for diabetes medication.[88]
Studies have demonstrated that Low-calorie Diets (LCD) and Very low-calorie Diets (VLCD) using meal replacers can induce diabetes remission in a significant number of patients. The DiRECT trial, for instance, showed that nearly half of the participants who followed a VLCD using MR products achieved diabetes remission after one year.[89] The rapid weight loss resulting from these diets leads to a reduction in liver and pancreatic fat, thereby improving insulin sensitivity and beta-cell function. Functional foods and meal replacers are invaluable tools in the management and potential remission of T2D and its comorbidities. By leveraging the health benefits of specific foods and the convenience of MR

products, individuals can achieve better glycemic control, improved nutritional status, and enhanced overall well-being. Future research should continue to explore the long-term effects and optimal use of these dietary strategies to further improve outcomes for people with diabetes.

Section 18: Dietary Patterns

India's dietary patterns are diverse and are influenced by regional, cultural, and religious practices. Generic dietary data indicate a transition from traditional diets rich in whole grains, fruits, and vegetables to more processed foods high in sugars, fats, and refined carbohydrates. This shift has been associated with an increasing prevalence of diet-related diseases such as obesity and T2D.[90,91] Evidence-based research in India emphasizes the need to return to traditional dietary patterns, which are naturally rich in fiber, antioxidants, and essential nutrients, to combat these health issues.

India's diverse ethnic groups follow distinct dietary patterns that are largely plant-based and include various spices, legumes, and whole grains. For instance, the traditional South Indian diet includes rice, lentils, and vegetables, often spiced with turmeric, cumin, and curry leaves, which have anti-inflammatory properties.[92] In contrast, North Indian diets often feature wheat-based roti, legumes, dairy products, and spices like garam masala. These regional diets are intrinsically nutritious, promoting a balanced intake of macronutrients and micronutrients essential for health.[93]

Indian diets are naturally rich in antioxidant and anti-inflammatory foods due to the abundant use of spices and plant-based ingredients. Turmeric, which contains curcumin, is a powerful anti-inflammatory agent commonly used in Indian cooking.[94] Other spices like ginger, garlic, and cumin also possess significant anti-inflammatory and antioxidant properties. Additionally, fruits such as amla (Indian gooseberry) and vegetables like spinach and fenugreek are high in antioxidants, which help combat oxidative stress and inflammation.[95]

Chrono-nutrition involves aligning food intake with the body's circadian rhythms. Intermittent fasting (IF) and Time-Restricted Eating (TRE) are popular approaches within this framework. IF typically involves cycles of fasting and eating, such as the 16/8 method, where one fasts for 16 hours and eats during an 8-hour window. Studies have shown that IF can improve metabolic health, promote weight loss, and enhance insulin sensitivity.[96,97] TRE, which limits food intake to specific times of the day, has similar benefits by aligning eating patterns with the body's natural rhythms, potentially reducing the risk of chronic diseases.

Ayurveda, an ancient Indian system of medicine, emphasizes the concept of 'dinacharya', or daily routine, which aligns daily activities, including eating, with natural cycles. According to ayurveda, the optimal times for eating are during Kapha (6–10 AM and 6–10 PM), Pitta (10 AM–2 PM), and Vata (2–6 PM) periods, which correspond to different bodily functions and metabolic rates.[98] This traditional practice parallels modern chrono-nutrition principles, suggesting that eating in harmony with circadian rhythms can enhance digestion, metabolism, and overall health.

India is experiencing a nutrition transition characterized by a shift from traditional, nutrient-dense diets to Western-style diets high in fats, sugars, and processed foods.[99] This transition is more pronounced in urban and semi-urban areas, where lifestyle changes and increased access to processed foods have led to rising rates of obesity and T2D. In rural areas, while traditional diets persist, the influence of modern dietary habits is growing, posing a risk of similar health issues over time.

Incorporating principles from both modern nutrition science and traditional dietary practices can help in formulating effective dietary recommendations that address the specific needs of different regions and communities.

Section 19 Government Policies and Strategies–EAT Right Movement

India faces significant challenges in food and nutrition, with varying regional disparities and nutritional deficiencies affecting a large segment of its population. Government policies and strategies play a crucial role in addressing these issues, aiming to improve public health outcomes and promote sustainable dietary practices nationwide.

The EAT Right Movement represents a pivotal initiative in this effort, launched to revolutionize India's food system through comprehensive strategies and campaigns. Anchored by the Indian Food Safety and Standards Authority of India (FSSAI), this movement emphasises the importance of safe and nutritious food choices, aligning with global health guidelines and sustainable development objectives.

Central to the EAT Right Movement is the Swasth Bharat Yatra, a nationwide campaign that promotes healthy eating habits and raises awareness about food safety.[100] This initiative engages citizens through mass participation events and educational programs, encouraging behavioural changes towards more nutritious diets. Additionally, initiatives like the Eat Right Challenge and Eat Right Campus integrate health-conscious practices into daily routines, particularly among youth and educational institutions.

The impact of these initiatives is notable, with improved food and nutrition outcomes observed in communities actively participating in the movement. Metrics such as the State Food Safety Index measure progress and incentivize stakeholders to uphold food safety standards and dietary guidelines. Government policies complement the EAT Right Movement by focusing on holistic health approaches, enhancing food standards, and promoting traditional and Ayurvedic dietary practices. Recent policy introductions and modifications aim to support these efforts by integrating nutrition-sensitive interventions across various sectors, including women and child development, education, WASH (Water, Sanitation, and Hygiene), agriculture, and food and civil supplies.

Collaboration between government departments and agencies is critical for the movement's success, ensuring coordinated efforts and leveraging diverse expertise. This collaborative approach not only enhances implementation efficiency but also fosters synergies with international frameworks such as the Sustainable Development Goals (SDGs) and WHO guidelines. Furthermore, partnerships with international organizations facilitate knowledge exchange and the adoption of best practices from successful global initiatives. Case studies highlight effective strategies from other countries, offering insights into adapting and scaling successful models within the Indian context.

Despite progress, challenges persist, including limited resources, awareness gaps, and varying capacities among stakeholders. Addressing these challenges requires innovative solutions and public-private partnerships to augment the movement's impact and sustainability. Recommendations emphasize the need for continuous awareness campaigns, enhanced stakeholder engagement, and policy refinements to optimize outcomes. Increased awareness among stakeholders about the benefits of healthy eating and food safety remains a critical call to action, ensuring sustained momentum and a broader societal impact.

20.1 NUTRITION PRESCRIPTION

Nutrition prescription plays a critical role in the management of diabetes due to its direct impact on glycemic control, weight management, and overall health. Effective dietary strategies can significantly influence the course of the disease, reducing the risk of complications and improving the quality of life for individuals with diabetes.[3]

One of the primary benefits of a nutrition prescription is the optimization of glycemic control. Tailored dietary plans help regulate BG levels by focusing on the consumption of low-glycemic index foods, adequate

fiber, and balanced macronutrient distribution. This approach helps prevent sharp spikes and drops in blood glucose levels, which are common in diabetes and can lead to both acute and long-term health issues. Consistent glycemic control reduces the risk of complications such as neuropathy, nephropathy, and retinopathy, which are associated with poorly managed diabetes.[101]

Another key aspect is weight management. Obesity and excess body weight are major risk factors for T2D and can exacerbate insulin resistance. Personalized nutrition plans often include strategies for calorie control, portion management, and the incorporation of physical activity to promote weight loss or maintenance. Achieving and maintaining a healthy weight can enhance insulin sensitivity and improve metabolic health, making diabetes management more effective.[33]

Furthermore, nutrition prescriptions are essential for addressing individual variability in metabolic responses to food. Traditional dietary guidelines may not be suitable for everyone due to differences in genetics, microbiome composition, and lifestyle factors. Personalized nutrition takes into account these individual differences, providing more targeted and effective dietary recommendations.

In addition to physical health benefits, tailored nutrition prescriptions can improve adherence to dietary changes. When dietary recommendations align with an individual's preferences, cultural practices, and lifestyle, they are more likely to be sustainable in the long term. This increases the likelihood of adherence, which is crucial for the effective management of diabetes.

20.2 INDIAN HEALTHY PLATE

The Indian Healthy Plate, conceptualized by the ICMR, serves as a comprehensive dietary guideline aimed at promoting balanced nutrition and overall health among the Indian population. Given India's diverse culinary traditions and nutritional challenges, the ICMR's guidelines provide a culturally sensitive and scientifically sound approach to healthy eating.[102,103]

The Indian Healthy Plate is designed to ensure a balanced intake of macronutrients and micronutrients. Vegetables and fruits should occupy half of the plate, with a recommended intake of at least 300 grams of vegetables and 100 grams of fruits per day. A mix of colours and types is encouraged to provide a wide range of vitamins, minerals, and antioxidants. Preparation methods such as raw, steamed, or lightly cooked are preferred to retain nutritional value and maximize health benefits.

Cereals and grains should make up about one-quarter of the plate, with a daily intake of around 270–300 grams. The latest 2024 dietary guidelines for Indians emphasise that 50% of cereals should come from millet. Whole grains like brown rice, whole wheat, broken wheat, barley and millet such as ragi, bajra, and jowar are recommended over refined grains. Millets are particularly highlighted due to their high nutritional value and resilience in various growing conditions. Unpolished milletsare rich in dietary fiber, which aids in digestion, helps maintain stable blood glucose levels, and provides sustained energy.[104]

Proteins should constitute the remaining quarter of the plate, with an emphasis on a daily intake of about 50–75 grams of protein. This can be achieved through a balance of plant-based proteins (such as 60 grams of legumes or lentils) and animal-based proteins (such as 100 grams of fish, 90 grams of poultry, or 150 grams of dairy products). Including a variety of protein sources ensures a complete amino acid profile, which is crucial for bodily functions.

Fats should be included sparingly, with a recommendation to consume about 20–30 grams of visible fats per day. Healthy fats from sources like nuts, seeds, avocados, and oils such as olive, mustard, or coconut oil are preferred. These fats provide essential fatty acids and help in the absorption of fat-soluble vitamins. Trans fats and excessive saturated fats should be avoided to reduce the risk of cardiovascular diseases. Instead of deep-frying, using methods like sautéing with minimal oil or grilling can help manage fat intake.[31]

Dairy or dairy alternatives should be included in the daily diet, with a recommended intake of about 300 grams per day. Sources like milk, yogurt, and cheese provide essential calcium and vitamin D, which are crucial for bone health. For those who are lactose intolerant or vegan, fortified plant-based alternatives like almond or soy milk are good options. These alternatives often come fortified with calcium and vitamin D, ensuring that individuals still meet their nutritional requirements.

Adequate water intake is emphasized, with a recommendation of 8–10 glasses (approximately 2–2.5 litres) per day. Other beverages, such as herbal teas and unsweetened lemon water, buttermilk, can also be part of a healthy hydration strategy, providing additional nutrients and electrolytes.

Adopting the Indian Healthy Plate model offers numerous health benefits. The plate ensures a balanced intake of essential nutrients, helping to prevent deficiencies and malnutrition.

Paying attention to portion sizes helps avoid overeating. Using smaller plates and bowls can naturally limit portion sizes and help maintain a balanced diet.[105] Additionally, serving food in the kitchen rather than at the table can prevent second helpings and encourage mindful eating.

Healthier cooking methods such as steaming, grilling, and sautéing with minimal oil are recommended over deep-frying and excessive use of ghee (clarified butter). These methods preserve the nutritional integrity of the food while reducing unnecessary fat intake.[106,107]

Further, the emphasis on locally sourced and seasonal produce supports sustainable agriculture and reduces environmental impact. By choosing foods that are in season and locally available, individuals can reduce their carbon footprint and support local farmers.

Healthy snacks such as fruits, nuts, seeds, egg, and plain yogurt can be incorporated between meals to keep energy levels stable and prevent overeating at main meals. Choosing nutrient-dense snacks over processed foods can contribute to overall dietary quality.[108] Practising mindful eating by paying attention to hunger and fullness cues can improve digestion and prevent overeating. Taking time to enjoy meals without distractions like TV or mobile phones is encouraged, as it allows individuals to focus on their food and appreciate the eating experience.[109,110]

While the Indian Healthy Plate offers a robust framework for healthy eating, several challenges may arise in its implementation. Fresh fruits, vegetables, and whole grains may not be accessible or affordable for everyone. Solutions include promoting community gardens, supporting local farmers' markets, and providing subsidies for healthy foods. Governments and NGOs can play a crucial role in making nutritious food more accessible to all segments of the population. Taste preferences and traditional dietary patterns may make it difficult for some individuals to adopt new eating habits. Education and awareness programs can help highlight the health benefits of a healthy plate and provide recipes that align with cultural preferences. Community leaders and influencers can also help promote healthy eating practices by setting positive examples.

Recent 2024 dietary guidelines issued by the ICMR-National Institute of Nutrition (ICMR-NIN) for the Indian population further emphasize the importance of a balanced diet tailored to Indian dietary habits and lifestyles. The guidelines advocate for locally available and seasonal foods to ensure nutritional adequacy and freshness while promoting adequate hydration through water and other fluids. It recommends limiting salt, sugar, and saturated fat intake to prevent chronic diseases such as hypertension, diabetes, and heart disease. They also integrate dietary recommendations with physical activity guidelines to promote overall health and well-being. Specific advice is provided regarding nutrients such as calcium, iron, vitamin D, vitamin B_{12}, and omega-3 fatty acids to address prevalent deficiencies in the Indian population.

Thus, the Indian Healthy Plate is more than just a dietary guideline; it is a comprehensive lifestyle approach that can significantly improve the quality of life for millions of Indians.

20.3 COST-EFFECTIVE APPROACHES

Combating diabetes in India requires a multifaceted approach that is both cost-effective and scalable, considering the diverse socioeconomic conditions across the country. Diabetes, primarily Type 2, has become a growing public health concern in India, driven by factors such as urbanization, changing dietary patterns, sedentary lifestyles, and genetic predisposition. To address this issue, it is crucial to implement strategies that are economically viable and can reach a broad segment of the population. Some of the cost-effective approaches to prevent and manage diabetes in India include focusing on promoting healthy diets, encouraging physical activity, early detection and screening, affordable medication and treatment, education and self-management, policy and advocacy, community engagement, and research and data collection.

Promotion of healthy diets is the basis of diabetes prevention and management. Educating the public about the importance of a balanced diet rich in vegetables, fruits, whole grains, and lean proteins can help prevent and manage diabetes. Utilizing mass media, social media, and community-based programs to spread awareness can be highly effective.[111] Promoting traditional Indian diets that include whole grains like millets (ragi, bajra, and jowar), pulses, and fresh vegetables can be both culturally acceptable and nutritionally beneficial. These foods are often more affordable and accessible compared to processed foods. Additionally, government subsidies on healthy foods and agricultural policies that support the production and distribution of fruits, vegetables, and whole grains can make these foods more affordable and accessible.

Encouraging physical activity is another critical component. Organizing community exercise sessions such as yoga, walking groups, and sports activities can encourage physical activity. These programs can be led by trained volunteers or health workers and conducted in local parks, community centers, and schools.[112] Encouraging employers to implement wellness programs that include physical activities, health check-ups, and educational sessions on diabetes can reach a large segment of the adult population. Improving public infrastructure to support physical activities, such as creating safe walking and cycling paths, public parks, and sports facilities, can encourage more people to engage in regular exercise.[113,114]

Early detection and screening are crucial for managing diabetes effectively. Training community health workers to conduct regular screenings for diabetes, especially in high-risk populations, can facilitate early detection and management.[115] These workers can use simple, low-cost tools like glucometers to measure blood glucose levels. Deploying mobile health units to rural and underserved areas can bring screening and basic healthcare services directly to those in need. These units can also provide education and resources for diabetes management. Implementing screening programs in schools to detect early signs of diabetes in children can help in taking timely preventive measures.[9]

Affordable medication and treatment are vital to ensuring widespread diabetes management. Promoting the use of generic medications for diabetes can significantly reduce costs. The government can negotiate with pharmaceutical companies to lower prices and ensure the availability of essential diabetes drugs.[116] Providing subsidies or financial assistance for diabetes medications and supplies, such as insulin and test strips, can help reduce the financial burden on patients.[117] Leveraging telemedicine to provide diabetes care and management advice can reduce the need for frequent in-person visits, making healthcare more accessible and affordable, especially for those in remote areas.

Education and self-management are essential for effective diabetes control. Conducting educational workshops and seminars for patients on self-management of diabetes, including diet, exercise, and medication adherence, can empower individuals to take control of their health. Establishing support groups for people with diabetes can provide emotional support, share practical advice, and encourage adherence to treatment plans. Utilizing mobile apps and online platforms to provide education, reminders, and support for diabetes management can be cost-effective and widely accessible.

Policy and advocacy play a significant role in creating an environment that supports diabetes prevention and management.[118] Advocating for and implementing public health policies that address the risk factors for diabetes, such as regulating the marketing of sugary foods and beverages, can help create an environment that supports healthy living. Expanding insurance coverage to include diabetes prevention and management services can make healthcare more affordable and accessible. Implementing taxes on sugary beverages and junk food can reduce their consumption and generate revenue that can be used for public health initiatives.[33]

Community engagement is also critical for the success of diabetes prevention programs. Engaging local leaders, celebrities, and influencers to promote diabetes awareness and healthy lifestyles can leverage their reach and impact to influence public behavior. Collaborating with cultural and religious institutions to disseminate information and encourage healthy behaviors can be particularly effective in communities where these institutions have significant influence.[115,119]

Research and data collection are essential for tailoring interventions to specific needs and measuring their effectiveness. Conducting large-scale epidemiological studies to identify the prevalence and risk factors of diabetes in different regions can help tailor interventions to specific needs. Developing robust health information systems to track diabetes cases, treatment outcomes, and risk factors can facilitate better planning and resource allocation.

In conclusion, combating diabetes in India requires a comprehensive approach that addresses prevention, early detection, treatment, and management in a cost-effective manner.

20.4 PRECISION NUTRITION

Precision nutrition acknowledges the individual variability in response to dietary and weight-loss interventions, challenging the traditional 'one-size-fits-all' approach of population-based dietary guidelines. These guidelines often fail to consider the unique metabolic responses, genetic backgrounds, and lifestyle factors of individuals.[33,120] By incorporating personalized factors such as genetic makeup, microbiome composition, and metabolic profile, precision nutrition aims to optimize dietary interventions for better glycemic control and weight management. Diabetes is a complex disorder characterized by a continuum of glycemic alterations, ranging from insulin resistance and impaired glucose tolerance to T2D. Precision nutrition seeks to address these underlying pathophysiological processes by providing personalized dietary recommendations that can modulate insulin sensitivity, reduce inflammation, and improve beta-cell function.[33,121] By targeting these specific mechanisms, precision nutrition holds the potential to halt or even reverse the progression of diabetes.

While personalized dietary interventions are crucial, population-based dietary advice still retains value, particularly in preventing diabetes and its complications. General recommendations, such as increasing the intake of fruits, vegetables, whole grains, and lean proteins, have been shown to reduce the risk of developing diabetes. Precision nutrition can build upon these guidelines by incorporating individual-level factors to enhance the efficacy of dietary interventions. Transitioning from population-based to targeted dietary recommendations involves recognizing individual-level factors as key drivers of how food intake affects disease risk. These factors include genetic predisposition, gut microbiota composition, metabolic status, and personal preferences and behaviours. Precision nutrition aims to provide tailored advice that aligns with these factors, thereby enhancing adherence and effectiveness.[34,121]

The interaction between individuals and their food environment is complex, influenced by social and environmental pressures. Factors such as socioeconomic status, cultural norms, food availability, and marketing significantly impact dietary choices and health outcomes. Precision nutrition acknowledges these external factors and aims to develop realistic and sustainable dietary interventions that fit within an individual's social and environmental context. Although precision

nutrition is still in its early stages, its potential is significant. Extensive research is needed to validate the initial promising results and to develop practical tools for implementing personalized dietary advice on a large scale. If successful, precision nutrition could revolutionize the prevention and management of diabetes, offering a frontline intervention that is both effective and personalized. The transition from generalized dietary advice to precision nutrition represents a major shift in managing diabetes. By considering the unique needs of individuals and the complex interplay between genetics, metabolism, and environment, precision nutrition holds the promise of more effective and personalized dietary interventions. However, its full realization will depend on continued research and validation.

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List of Abbreviations

Acronym	Definition
AA	Arachidonic Acid
ACEIs	Angiotensin Converting Enzyme Inhibitors
ACP	American College of Physicians
ADA	American Diabetes Association
ADI	Acceptable Daily Intake
ADP	Air Displacement Plethysmography
AGI	Alpha-Glucosidase Inhibitors
AHA	American Heart Association
AHEAD	Action for Health in Diabetes
ALA	Alpha-linolenic Acid
AMDR	Appropriate Macronutrient Distribution Range
ARBs	Angiotensin II Receptor Blockers
ASA	Automated-Self-Administered
AS	Artificial Sweeteners
BCA	Body Composition Analysis
BBs	Beta-blockers
BFM	Body Fat Mass
BG	Blood Glucose
BIA	Bioelectrical Impedance Analysis
BMI	Body Mass Index
BMR	Basal Metabolic Rate
BP	Blood Pressure
CAD	Coronary artery disease
CDC	Centers for Disease Control and Prevention
CCBs	Calcium Channel Blockers
CHD	Coronary Heart Disease
CKD	Chronic Kidney Disease
CLA	Conjugated Linoleic Acids
CLD	Chronic Liver Disease
CNNS	Comprehensive National Nutrition Survey
Coq10	Coenzyme Q10
CT	Computed Tomography
CURES	Chennai Urban Rural Epidemiology Study
CVD	Cardiovascular diseases
DASH	Dietary Approaches to Stop Hypertension
DBP	Diastolic Blood Pressure
DEXA	Dual Energy X-ray Absorptiometry
DHA	Docosahexaenoic Acid
DHS	Demographic Health Survey
DINGS	Diabetes in India Nutritional Guidelines Study
DKD	Diabetic Kidney Disease
DKA	Diabetic Ketoacidosis
DM	Diabetes Mellitus
DNA	Deoxyribonucleic Acid
DN	Diabetic Nephropathy
DPP	Diabetes Prevention Program
DR	Diabetic Retinopathy
DSMES	Diabetes Self-Management Education & Support
DSNF	Diabetes Specific Nutritional Formulas
DSE	Diabetes support and education
EAR	Estimated Average Requirement
EFA	Essential Fatty Acids
EPA	Eicosapentaenoic Acid
ESA	Essential Fatty Acids
EVOO	Extra Virgin Olive Oil
FA	Fatty Acids
FAO	Food and Agriculture Organization
FBG	Fasting Blood Glucose
FDA	Food and Drug Administration
FFQ	Food Frequency Questionnaire
FPG	Fasting Plasma Glucose
FSSAI	Food Safety and Standards Authority of India
GCPR	Good Clinical Practice Recommendations
GDM	Gestational Diabetes Mellitus
GERD	Gastric Esophageal Reflux Disease
GI	Glycemic Index
GL	Glycemic Load
GLP-1	Glucagon-Like Peptide-1
GLP-1 RA	Glucagon-like Peptide-1 Receptor agonists
GV	Glycemic variability
GWG	Gestational Weight Gain
H2RAs	H2 Receptor Antagonists
HbA1c	Hemoglobin A1c
HBsAg	Hepatitis B Surface Antigen
HDL	High-density Lipoprotein
HFCS	High Fructose Corn Syrup
Hs-CRP	High-sensitivity C-reactive Protein
HTN	Hypertension
IBD	Inflammatory bowel disease
IBS	Irritable bowel syndrome
ICMR	Indian Council of Medical Research
ICMR-NIN	Indian Council of Medical Research - National Institute of Nutrition
ICKD	Indian CKD
IDF	International Diabetes Federation
IDQS	Indian Diet Quality Score
IF	Intrinsic Factor
IHDS	India Human Development Survey
IGF	Insulin-like Growth Factor
IMS	Indian Migrants Study
IUGR	Intrauterine Growth Restriction
LBW	Low Birth Weight
LCFA	Long-chain Fatty Acids
LCPUFAs	Long-chain Polyunsaturated Fatty Acids
LDL	Low-density Lipoprotein
MASLD	Metabolic dysfunction-Associated Steatotic Liver Disease
MetS	Metabolic Syndrome
MI	Myocardial Infarction
MCT	Medium-Chain Triglycerides
MNCP	Nutrition Care Process
MNT	Medical Nutrition Therapy
MRI	Magnetic Resonance Imaging
MST	Malnutrition Screening Tool
MUFA	Monounsaturated Fatty Acids
MUST	Malnutrition Universal Screening Tool
NAC	N-acetylcysteine
NAFLD	Nonalcoholic Fatty Liver Disease
NCDs	Non-communicable Diseases
NCP	Nutrition Care Process
NCT	National Capital Territory
NDDS	Novel Drug delivery System
NDD	Newly Diagnosed Diabetes
NFHS	National Family Health Survey
NGT	Normal Glucose Tolerance
NIN	National Institute of Nutrition
NNMB	National Nutrition Monitoring Bureau
NNS	Non-nutritive Sweeteners
NPPCD	National Program for Prevention and Control of Diabetes
NS	Nutritive Sweeteners
NSSO	National Sample Survey Office
OADA	Oral Anti-Diabetic Agents
PAL	Physical Activity Level
PAR	Physical Activity Ratio
PCOS	Polycystic Ovary Syndrome

PE	Protein-to-Energy
PIH	Pregnancy-induced Hypertension
PPDM	Post-pancreatitis Diabetes Mellitus
PPIs	Proton Pump Inhibitors
PUFA	Polyunsaturated Fatty Acid
PVD	Peripheral Vascular Disease
PWO	People with Obesity
Q10	Coenzyme Q10
RDA	Recommended Dietary Allowance
RD	Registered Dietitians
RNA	Ribonucleic Acid
RSSDI	Research Society for the Study of Diabetes in In
RTA	Renal Tubular Acidosis
SFA	Saturated Fatty Acid
SGLT-2i	Sodium-Glucose Transporter-2 Inhibitors
SMBG	Self-monitoring of Blood Glucose
SMI	Skeletal Mass Index
SMM	Skeletal Muscle Mass
SBP	Systolic Blood Pressure
T1D	Type 1 Diabetes Mellitus
T2D	Type 2 Diabetes Mellitus
TAF	Type, Amount, and Frequency
TEE	Total Energy Expenditure
TFA	Trans Fatty Acids
TPN	Total Parenteral Nutrition
TZD	Thiazolidinediones
UKPDS	UK Prospective Diabetes Study
UTI	Urinary Tract Infections
USFA	Unsaturated Fatty Acids
VLDL	Very Low-density Lipoprotein
VLCD	Very Low-Calorie Diet
WC	Waist Circumference
W-HtR	Waist-to-Height Ratio
W-HR	Waist-to-Hip Ratio
WHO	World Health Organization