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Narrative Review of Prevention Strategies for Type 2 Diabetes

Mukamana Sandra Gisele

School of Applied Health Sciences Kampala International University Uganda

ABSTRACT

Type 2 diabetes mellitus (T2DM) represents a major and escalating global public health challenge, driven largely by modifiable lifestyle and environmental factors. This narrative review synthesizes current evidence on prevention strategies for T2DM across individual, clinical, community, and policy levels. Lifestyle modification, particularly dietary change, weight management, physical activity, and behavioral support, remains the cornerstone of primary prevention and has demonstrated sustained risk reduction in diverse populations. Pharmacologic interventions, including metformin and newer agents such as GLP-1 receptor agonists, offer additional benefit for individuals at high metabolic risk when combined with lifestyle approaches. Surgical interventions, notably bariatric and metabolic surgery, provide effective risk reduction in selected populations with severe obesity. Beyond individual-level interventions, community- and policy-based strategies targeting food environments, urban planning, public health education, and screening programs play a critical role in shaping population-wide risk profiles. However, significant challenges persist, including inequities in access, long-term adherence, variability in outcomes, and gaps in implementation and evaluation. Addressing these challenges requires integrated, culturally tailored, and sustainable prevention frameworks supported by translational research and cross-sector collaboration. Strengthening the reach and equity of evidence-based interventions is essential to curb the growing global burden of type 2 diabetes.

Keywords: Type 2 diabetes; Diabetes prevention; Lifestyle modification; Pharmacological interventions; Public health strategies.

INTRODUCTION

Type 2 diabetes is a prevalent global health issue associated with several non-contagious diseases [1]. The World Health Organization estimates that more than 422 million people suffer from diabetes, with projections of 642 million by 2040, making it the seventh leading cause of mortality, causing 1.5–2.0 million deaths annually. The disease reduces life expectancy by four to ten years, leading to debilitating complications. Diabetes differs from other chronic diseases because it can be prevented and treated through pharmacological and non-pharmacological strategies [3]. Type 2 diabetes is mainly attributable to altered diets and physical inactivity resulting from socio-economic development and urbanization [2]. More than 75% of the risks of developing type 2 diabetes could be prevented by behavioural and pharmacological interventions through dietary measures and/or physical activity [1]. Two essential conditions are necessary to prevent the disease: knowledge of the cause to regulate and reduce input, and the ability to continuously monitor the disease. Prevention needs to be implemented at the earliest stage of the disease: the lifestyle modification for diet and weight management could be teaching adherence to a specific dietary pattern accordingly, instead of solely advising reduction of carbohydrate, energy, nutrition-by-amount or weight monitoring [2].

Primary Prevention through Lifestyle Modification

Preventive interventions for type 2 diabetes fall broadly into two domains: universal lifestyle modifications targeting the general population and personalized pharmacologic or medical approaches directed at individuals with significant metabolic or cardiovascular risk [4]. Modifying lifestyle behaviours broadly, diet, physical activity, and behavioural support prevents type 2 diabetes in unselected populations with overweight and obesity

at high risk of progression [3]. Numerous randomized controlled trials in diverse countries have examined the efficacy of intensive lifestyle interventions with structured behavioural support. Consistent evidence demonstrates that a combination of dietary modification, increased physical activity, and behavioural support prevents type 2 diabetes onset over at least five years [6]. The risk reduction depends on the degree of weight lost and sustained, with 5%–10% of initial weight typically recommended. Maintenance of dietary and physical activity performance remains a challenge, with individual and group coaching significantly improving adherence [2]. Increasingly, digital behaviour-change tools including video consultations, web apps, and wearable facilitate access and scalability [12].

Diet and Weight Management

The relationship between diet and type 2 diabetes is bi-directional. People with a high dietary glycemic load have an increased risk of developing type 2 diabetes [3], which is relevant to preventive strategies. It is also a well-established fact that improvement in cardiorespiratory fitness can prevent type 2 diabetes; therefore, it emerges as an additional target with less attention devoted to it [4]. Three independent lifestyle factors influence the risk of developing type 2 diabetes: dietary pattern, physical activity level, and cardiorespiratory fitness [7]. Weight trajectory affects and interacts with all of them. If other risk factors are present, maintaining an average weight together with a regular exercise program and improved dietary patterns can become a method for high-risk individuals to escape from the progression to diabetic status [2].

Physical Activity

The protective benefit of physical activity against type 2 diabetes onset varies by type and intensity [1]. The ongoing Diabetes Prevention Program Outcomes Study has confirmed that combined aerobic and resistance exercise, both undertaken with intensity levels consistent with recommendations, lowers incident diabetes risk among at-risk individuals [5]. At no less than 150 minutes per week, both aerobic and/or resistance training facilitate weight loss, lower progression risk, and sustain longer-term weight loss [6]. Kcal/day expenditure from physical activity also delivers significant, independent benefits when controlling for BMI [7]. Post along multiple and diverse trajectories, weight status and pattern typify the burden of diabetes and its early-stage progression. During the pre-diabetic stage, larger population shares typically remain below key intervention thresholds [7]. Targeting high-risk populations offers an opportunity while contributor-changing actions appear unlikely. Time-limited engagement motivates behaviour change in areas unlikely to persist [3]. Lifestyle modifications affecting weight trajectory substantially mitigate subsequent onset. Comprehensive discussions of behaviour-support portfolios offer an opportunity to bolster current action in these dimensions [8].

Behavioral Support and Adherence

Successful behavioral support programs encourage individuals to anticipate and overcome barriers to lifestyle change. Such planning promotes interval modifications, which aid in goal adherence; proactive and range goals also assist adherence [8]. The Diabetes Prevention Program (DPP) intervention successfully increased planning activity by training participants to identify potential barriers to regular self-monitoring and develop preventive strategies. Supportive feedback and personal reassurances from peers further enhanced planning [9]. The Detecting Diabetes Early (DIDE) trial in New Zealand incorporated similar elements [3]. During programs aimed at weight loss or diabetes prevention, early relapse is common. Relapse prevention techniques help deepen understanding of situational cues influencing health behaviors and establish coping responses, which may prevent rebound increases in body mass or worsening of glucose control [6]. The DPP developed a structured strategy to promote these techniques [3]. Digital supports (e.g., apps and text messaging) facilitate wider access to coaching [10]. The DIDE trial employed a digital tool with online modules and a health diary to encourage self-directed learning outside sessions. These instruments have yet to undergo rigorous evaluation [1].

Pharmacologic and Medical Interventions for High-risk Individuals

To enable prevention strategies, individuals at high risk of developing type 2 diabetes must be identified. Multiple clinical guidelines and risk stratification tools can be employed to assess an individual's risk [4]. Daily consumption of traditional dietary patterns and certain supplemental foods have been shown to significantly reduce risk of development [3]. Among the cohort of people at high risk, pharmacologic intervention in combination with lifestyle change has the greatest potential to reduce risk. Consequently, a summary of pharmacologic agents with evidence of preventive action is provided, including metformin and GLP-1 receptor agonists [2].

Metabolic and Cardiovascular Risk Stratification

Global estimates from the International Diabetes Federation indicate that 537 million adults aged 20–79 years are living with diabetes [3]. Type 2 diabetes mellitus accounts for 90% to 95% of all cases. Additional 1.8 billion individuals are classified as being at high risk of developing type 2 diabetes [4]. Progression from prediabetes to overt type 2 diabetes may be delayed, prevented, or reversed through strategies that improve lifestyle risk factors or through pharmacological means [2].Diabetes prevention strategies are focused on populations at high risk,

requiring the identification of individuals with increased likelihood of future disease [11]. Risk can be evaluated using computerized prediction models based on risk factors, blood-based biomarkers, or a combination of both [4]. Risk prediction methods can then be used to identify at-risk individuals who qualify for pharmacological or therapeutic interception approaches [11].

Pharmacologic Agents with Preventive Evidence

Type 2 diabetes mellitus (T2DM) is a serious condition associated with substantial morbidity and mortality. Contemporary estimates suggest that there are 422 million people with diabetes globally, leading to 1.5 million deaths each year [14]. Approximately 90% of these individuals have type 2 diabetes (T2DM), which also has associated serious complications, such as heart disease, chronic kidney disease, peripheral neuropathy, and lower limb amputations, causing additional morbidity and mortality [12]. Half of adults with diabetes are undiagnosed and unaware of their condition, further exacerbating the problem. The rapid increase in diabetes prevalence can be partially explained by the alarming rise in overweight and obesity rates [2]. Obesity is a key modifiable risk factor for development of T2DM and offers opportunities for prevention [1]. Primary prevention from developing T2DM is defined as 1) prevention or postponement of the onset of T2DM for the first time in a previously non-diabetic individual who has the risk of developing T2DM, or 2) prevention or postponement of the onset of T2DM in a person who had already isolated diabetes [6]. Pharmacological prevention of T2DM is an area of active research, especially for high-risk individuals.

Surgical Options in Specific Populations

Bariatric or metabolic surgery may reduce the risk of developing type 2 diabetes for specific populations who are either severely obese (BMI $\geq$ 35 kg/m^2) with a significant comorbidity burden or moderately obese (BMI 30 to 34.9 kg/m^2) but with additional diabetes-related risk factors or high-risk anthropometric measures like waist circumference [13]. Surgical intervention is likely to prevent the onset of diabetes regardless of the population in question. But other underlying factors, including age, gender, and presence of associated comorbidities, do influence the degree of expected diabetes risk reduction [14].

Community and Policy-level Strategies

Making healthy food choices can be made easier through policies that directly influence the food environment. Nutrition-related policies promoting access to healthy and affordable foods or limiting access to unhealthy foods can positively impact obesity and diabetes [16]. These policies address obstacles to food access (high prices, limited availability), regulate marketing or nutrition labeling (food pricing, marketing of unhealthy foods, nutrition information), mandate product reformulation, or create school and workplace policies. Zoning regulations, land-use planning, urban design, and transportation infrastructure also affect food environments through siting standards for food retail outlets and transportation access to grocery stores [12]. Urban design and land-use policies improve opportunities for physical activity and restrict unhealthy food exposure through food outlet buffering [1]. Public education campaigns are effective in increasing knowledge, awareness, and motivation to adopt healthy eating habits [15]. Public campaigns addressing obesity and related risk factors emphasize proper nutrition to limit calorie intake and encourage physical activity. Mass media campaigns targeting children reinforce the consumption of fruits and vegetables to prevent consumption of unhealthy foods [7]. Successful health education campaigns reach large segments of the population, sustain exposure over time, use a combination of channels, and adapt to local situations. Cultural tailoring, involving adaptation of messages to local specificities or the needs of specific communities, improves the relevance and effectiveness of campaigns [5]. The ease of access to diabetes screening remains a public health concern in several settings [2]. In many countries, no screening is available, screening age is above 45 years, or meso-level screening (e.g., within schools) is absent [2]. Combining screenings for cholesterol, hypertension, and diabetes is common, allowing easier integration with other preventive measures [1]. Pathways to link to preventive services after a positive screening are seldom implemented. Several approaches of community- and policy-level intervention address the prevention of type 2 diabetes [1]. The mass media can be exploited by governments to spread educational campaigns and provide advice on healthy lifestyles [12]. Community levels are characterized by associations able to promote healthy lifestyles and environments. For example, schools, companies, non-profit organizations, children's competencies, and doctors form community levels supporting comprehensive community interventions with the potential to reach wide segments of the population [13].

Food Environments and Urban Planning

Urban planning for healthy food access can reduce type 2 diabetes incidence. Consideration of the built environment, community design, and access to nutritious foods can predict risk [6]. Food environments define availability and promote certain dietary behaviors. Physical and sociocultural influences affect intake, reinforced by marketing and pricing strategies [3]. Siting of fast-food outlets near schools, dish proximity at home, and price discounts drive consumption patterns. Urbanization increases food-related diseases; spatial analyses link the built environment to diabetes prevalence [16]. Pricing and availability substantially influence choices. Community

design impacts dietary patterns; the current model favors calorie-dense, nutrient-poor offerings and highly processed options. Modifications would be more efficacious combined with education and taxes [1].

Public Health Campaigns and Education

Successful diabetes prevention initiatives can feature public health campaigns reaching broad audiences, alongside programs targeting high-risk individuals, such as the US National Diabetes Prevention Program [3]. Campaigns should integrate the following key principles: enrich educational outreach through partnerships with health agencies, expand coverage using mass media, ensure cultural appropriateness, maintain scientific accuracy, prioritize lifelong risk awareness, and critically evaluate effects [1]. The potential for public health messaging to affect dietary choices and activity levels, alongside lifestyle-oriented risk perception, prompts careful examination of campaign modalities [13]. Prospective studies indicate that shared knowledge of prediabetes status and its relationship to diabetes risk increases motivation to adopt lifestyle changes [15]. Interventions integrating risk assessment with education and dietary/social marketing achieve strong formative

Screening Programs and Linkage to Care

Screening programs for type 2 diabetes aim to identify individuals with high risk in the general population so that they can be targeted for early intervention [2]. Community-based lifestyle modification programs, which allow for recruitment and referral of at-risk individuals, have been successful in countries such as Finland, Greece, Japan, India, and Australia [3]. Long-term follow-up studies have confirmed sustained reductions in diabetes incidence with continued lifestyle modifications and support [1]. The Finnish Diabetes Prevention Study and the Indian Diabetes Prevention Programme, for example, have demonstrated that lifestyle intervention prevents and delays type 2 diabetes for many years, resulting in public health benefits and cost savings [17]. During these programs, participants are screened for eligibility, and decision-support tools for diabetes prevention are integrated into the healthcare system to enable streamlined referral to intensive lifestyle support [15].

Implementation Challenges and Gaps in Evidence

Interventions addressing the above factors are often hampered by unacceptable implementation challenges. A broad array of international studies, although inconsistent in their findings, has identified the major influences undermining prevention efforts for individuals at high risk of progression to type 2 diabetes [14]. The most frequently cited are the equity and access gap, long-term sustainability and adherence gap, and heterogeneity of effects and outcomes gap [18]. The variation in the treatment of individual components that constitutes successful type 2 diabetes prevention reflects differences in the practice of health care systems, which, in turn, are shaped by the socio-cultural context of governments [12]. Because the disease is driven by multiple causes, the complex nature of prevention compounds the adaptation challenge and has led to a pronounced effort within some countries to focus on the entire multiple prevention/promotion spectrum through broad policy formulations to heighten awareness, mobilise many disciplines and sectors, and improve understanding of prevention [11].

Equity and Access

A critical barrier to the effectiveness of existing diabetes prevention initiatives is their limited equity and access [10]. Disparities by socio-economic status, race, ethnicity, geography, and language across high- and low-intervention communities can affect adoption and impede eligibility for certain pharmacotherapy or surgical options [19]. Public health campaigns, education strategies, and screening programs are frequently not executed in regions or populations where the interventions are most needed [11]. Individuals with lower incomes are disproportionately unable to introduce lifestyle-determinant changes because of greater structural and economic constraints [12]. This systemic conundrum creates a state of affairs where disproportionate risk is distributed across community clusters while the distribution of intervention resources is concentrated in a few privileged areas [14]. This inequity in health-status access and individual lifestyle adaptation ability must be considered holistically in the design process for an effective diabetes intervention implementation plan [12].

Long-term Sustainability and Adherence

Type 2 diabetes (T2D) is a chronic condition affecting more than 400 million people worldwide, incurring enormous social and economic costs. Globally, its prevalence is rising alongside marked increases in obesity and sedentary lifestyles [13]. A large and growing body of evidence supports ongoing lifestyle change among those at risk. Multi-centre screening initiatives to identify high-risk individuals for preventive intervention within several high-income countries are advancing in parallel [11]. Substantial evidence has demonstrated that T2D incidence can be reduced through lifestyle change and that the benefits persist long after the formal intervention [14]. Long-term follow-up of several effectiveness studies has shown that lifestyle interventions delivered at community level can still produce reductions in T2D incidence several years after the cessation of intensive support. Programmes built upon the US Diabetes Prevention Program (DPP) model have been demonstrated to achieve both community-wide reach and enduring efficacy in diverse settings in different continents [1].

Measurement of Outcomes and Heterogeneity of Effects

Synthesis of evidence regarding type 2 diabetes prevention interventions indicates limited progress in extending advantages to the general population, underscoring the need to enhance the reach of existing preventive strategies [20]. Interventions expected to address the most combustible determinants of escalation among population subgroups thus far have not been broadly applied [21]. A critical element of type 2 diabetes prevention assessments involves agreement on outcome metrics central to intervention effectiveness [13]. Primary outcomes of high relevance include incidence of diabetes, reversion of hyperglycemia status, and accumulation of excess weight subsequent to preventive initiation, whereas intermediate markers consist of sex, age, ethnicity, baseline weight measurement, Body Mass Index (BMI), waist circumference, physical activity and sedentary duration, daily cluster and timing of meals, and dietary intake of energy, fiber, carbohydrates, and fat[12]. Observational issues influencing follow-up duration interact with considerable variability in primary and intermediate outcome indicators across diverse population segments and a general consensus on the significance of ensuring that conducted trials offer insight directly applicable to target populations [21].

Future Directions and Research Priorities

Globally, type 2 diabetes (T2DM) continues to rise in incidence and prevalence, despite sustained public health efforts to control it. A recent World Health Organization report affirms that diet, physical activity, and obesity are modifiable risk factors for T2DM [11]. Changing these risk factors has been shown to reduce the incidence of T2DM by 40% to 70% 11 and can also have a positive impact on other metabolic disorders, such as hypertension and dyslipidemia [19]. T2DM can occur when there is interplay between an individual's genetic predisposition for it and external factors influencing its potential manifestation [18]. Consequently, three urgent research priorities and methodological needs have been identified for T2DM prevention: (1) identifying and addressing the knowledge gaps in the literature that limit program implementation; (2) the need for nested intervention studies to explore T2DM prevention in different populations; and (3) the establishment of translational research pathways to ensure that community best practices translate into health care delivery [13].

CONCLUSION

Type 2 diabetes is a largely preventable chronic disease with profound individual, societal, and economic consequences. Evidence from randomized trials, long-term cohort studies, and community-based interventions consistently demonstrates that early and sustained lifestyle modification supported by behavioral strategies can significantly delay or prevent the onset of T2DM. Pharmacological and surgical interventions further expand prevention options for individuals at elevated risk, particularly when lifestyle measures alone are insufficient. Importantly, prevention must extend beyond individual behavior change to encompass community and policy-level actions that reshape food environments, promote physical activity, enhance access to screening, and support healthy choices across the life course. Despite robust evidence supporting prevention, real-world implementation remains uneven. Persistent inequities in access, challenges in long-term adherence, and heterogeneity in intervention outcomes limit the population-level impact of current strategies. Future efforts must prioritize equitable delivery, culturally sensitive program design, and integration of prevention pathways into health systems. Advancing translational and implementation research will be critical to bridge the gap between evidence and practice. A comprehensive, multi-level approach that aligns clinical care, public health policy, and community engagement offers the most promising path toward reducing the global burden of type 2 diabetes

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