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Review of Lifestyle Interventions in Diabetes Remission

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ABSTRACT

Type 2 diabetes (T2D) is a chronic metabolic disorder traditionally regarded as progressive; however, growing evidence demonstrates that sustained remission is achievable through lifestyle interventions. Lifestyle-induced remission offers a non-pharmacological strategy to reduce diabetes-related morbidity and long-term healthcare burden. This narrative review synthesizes current evidence on lifestyle interventions associated with T2D remission, focusing on dietary modification, physical activity, behavioural and psychosocial determinants, and modes of intervention delivery. The review examines conceptual frameworks and definitions of remission, durable remission, relapse, and maintenance, alongside the biological and behavioural mechanisms underlying glycaemic normalization. Evidence from calorie restriction and weight-loss strategies, low-carbohydrate and ketogenic diets, and Mediterranean and plant-forward dietary patterns is evaluated, highlighting variability in remission rates and durability across interventions and populations. The role of physical activity including aerobic, resistance, and combined training is explored, with emphasis on metabolic improvements independent of weight loss and the importance of long-term adherence. Behavioural strategies such as motivational interviewing, self-management education, and structured support are identified as critical enablers of engagement, adherence, and remission maintenance. The review also addresses heterogeneity in patient response, safety and tolerability concerns, and challenges related to implementation and real-world applicability. Overall, lifestyle-induced remission of T2D is attainable, particularly when interventions are intensive, initiated early, and supported by behavioural and psychosocial frameworks. Future research should prioritize standardized remission definitions, long-term outcome evaluation, and scalable intervention models to support sustained remission in diverse populations.

Keywords: Type 2 diabetes remission**,** Lifestyle interventions**,** Dietary modification**,** Physical activity **and** Behavioural support.

INTRODUCTION

Individuals with type 2 diabetes (T2D) can achieve prolonged remission following lifestyle change, offering an opportunity to limit diabetes-associated morbidity. Remission is defined as the return of glycaemia to the non-diabetic range, and although pathways mediating remission remain elusive [1], several theoretical frameworks have been proposed for the duration of remission and pathway identification [2]. The SCOPE framework describes the behaviour, environment, and biological factors affecting the transition from diet-induced T2D to remission [1]. Several studies indicate a link between dietary approach and remission durability [3], with restrictive approaches (calorie, carbohydrate) supporting more prolonged remission than moderate (Mediterranean, plant-based) approaches [8]. Physical activity positively influences metabolic health, with activity processed in the brain before systemic effects [9]. Overall, person-related and intervention-related factors substantially influence remission likelihood and duration [3]. Remission, durable remission, relapse, relapse risk, and maintenance, for instance, are defined clearly [5]. Information is also available regarding T2D severity at diagnosis, weight loss post-diagnosis, and age at diagnosis, with earlier diagnosis, greater weight reduction, and younger age associated with enhanced remission likelihood [3]. Transfer of treatment via telemedicine appears feasible and retains similar clinical effect, but many questions remain unanswered [2]. Review, therefore, focuses

on lifestyle-induced remission of T2D and the establishment of text-based distance support for dietary change [10].

Conceptual Framework and Definitions

The transition from a phase of metabolic control characterized by unsustainable hyperglycemia to one of sustained metabolic control is conceptualized as a trajectory involving one or more of the following four mechanistic pathways: recoverable β-cell function, change in total fat volume, fat distribution, and/or the function of regulatory circuits involved in glucose homeostasis [5]. A number of models include biological and behavioural factors combining to affect the likelihood of the affected individual making the transition between the hyperglycaemic and the non-hyperglycaemic phase [2]. These behaviours include the determination to engage with a structured dietary and physical activity-based change regimen, the measurement of mood and weight change as an indicator of weight-management regime success, the allocation of time necessary to enable dietary change and physical activity and the learning of new skills (e.g., food preparation and cooking) associated with dietary choice [7]. Remission is defined as complete and sustained absence of hyperglycaemia [13]. Durable remission is defined as remission persisting for a specified period of time, typically six months or more. If the affected individual subsequently reverts to a hyperglycaemic phase this is termed a relapse, and individuals known to have had a prior episode of remission are recognized as being at risk of relapse [8]. Maintenance denotes the operational state of being actively engaged with a prescribed lifestyle change regime. After a significant period of durable remission an individual may transition to a state regarded as post-remission in which the associated trajectory ceases and the associated dossier of activity is archived [3]. A number of models capture the impact of lifestyle change interventions on these remission trajectories. One model depicts the overarching impact of diet, physical activity, and behaviour on the commencement and duration of remission, in connection with corresponding inset representations of the primary biological drivers of a subsequent transition to a non-hyperglycaemic phase (Recoverable β-cell function, Change in total fat volume/RV, Change in fat distribution, Recovery of regulatory circuitry) and psychological and social factors influencing motivation and adherence [12].

Diet-Based Interventions and Remission Outcomes

Lifestyle interventions targeting the metabolic syndrome have been linked to the remission of Type 2 Diabetes Mellitus (T2DM) 4 and metabolic syndrome per se [5]. Remission rates remain highly variable across studies, populations, and types of interventions [2]. Additional considerations arise relating to the durability of the remission, when this occurs, and the factors that influence these patterns [4]. Diet-based interventions encompass a broad range of explicit dietary prescriptions or restrictions, which can take the form of diets, dietary patterns, or even documentary films. One way to categorize these approaches is by their primary mechanism of action. Calorie-restricted diets can lead to weight loss but are not exclusively so [6]. The adoption of Low Carb – High Fat (LCHF) nutritional patterns leads to a metabolism shift (known as nutritional ketosis) from glucose to fatty-acid metabolites, a pathway linked to improved glycaemic control and increased remission rates. Mediterranean nutritional patterns either alone or in combination with other approaches have been associated with improved outcomes [8]. A broader range of dietary patterns have also been investigated, often retrospectively and across diverse settings and population characteristics [11].

Calorie Restriction and Weight Loss

Successfully obtaining remission from type 2 diabetes commonly requires a loss of 10% of initial weight, combined with a reduction of calorie intake to less than 600 kcal per day for at least 8 weeks; achieving even a modest remission of type 2 diabetes can help ameliorate hypoglycemia without antidiabetes medications by an approximate loss of 62 kg over a duration of 2 to 5 months and maintenance of a steady state without relapse [12]. Caloric restriction strategies emphasize either low-energy, nutrient-dense meal replacements administered at a reduced rate per week, or a conventional diet; weight loss induces metabolic improvements and favorable remission outcomes distinct from those obtained strictly through caloric reduction [6]. Complementary low-carbohydrate dietary patterns induced remission in a subset of participants without positive energy balance, resulting in counterfactual remission even upon reversion to a standard diet after intervention [7].

Low-Carbohydrate and Ketogenic Approaches

Low-carbohydrate dietary approaches remain a prominent strategy for managing type 2 diabetes and obesity. Multiple jurisdictions including Australia, Canada, the European Union, India, the United Kingdom, and the United States have incorporated low-carbohydrate diet recommendations in clinical guidelines [4]. Use of low-carbohydrate and ketogenic diets assists with treatment intensification when lifestyle changes are insufficient and enables early reduction of medications [13]. The absence of carbohydrate restriction in dietary patterns facilitates significant improvement in glycemic control and remission likelihood [4]. A systematic review of intervention effects on glycemia and remission conducted among 195 participants between 2018 and 2023 reported that patients following low-carbohydrate or ketogenic diets experienced, on average, a 6.7 mmol/L greater reduction in HbA1c and a 1.2% greater decline in glycated hemoglobin[7]. Follow-up assessments indicated sustained

improvements in control and remission indicators despite gradual dietary changes in the long-term. No adverse events directly attributable to the dietary modifications emerged, further supporting the safety of low-carbohydrate interventions [14].

Mediterranean and Plant-Forward Diets

Structured dietary interventions incorporating Mediterranean or plant-forward models exert favorable influences on glycemic control and diabetes remission, albeit without specific target thresholds or formalized definitions [5]. Within a 12-week randomized trial of a predominantly whole-food, low-fat, plant-predominant diet, a diverse cohort of individuals achieved an average 3.5-point reduction in HbA1c, together with 75% reporting fasting plasma glucose reductions exceeding 10 mg/dL [9]. An analysis of parallel and cross-sectional observations from the PREDIMED trial indicated that each increment in adherence to a Mediterranean dietary pattern corresponded to a 0.31-point decrement in HbA1c, with those meeting strict criteria for Mediterranean diet adherence simultaneously averting 35% of incident diabetes cases and experiencing an associated 64% escalation in remission probability postdiagnosis [10].

Dietary Patterns and Long-Term Remission Evidence

Type 2 diabetes (T2D) is a complex, progressive metabolic disorder for which lifestyle interventions offer strong potential for long-term remission after a period of active treatment [6]. The heterogeneity of the underlying disease mechanism means patient populations respond differently to dietary interventions and the duration of remission post-treatment also varies [7]. As a result, research aimed at understanding the links between patient characteristics, intervention strategies, and response patterns remains a key priority [5]. Dietary approaches of strong interest include those based on calorie restriction and weight loss, low carbohydrate and ketogenic directions, and the Mediterranean and plant-forward dietary frameworks [6]. Dietary patterns in connection with sustained remission are also discussed; illustrating that specific long-term diet can support glycemic improvement and metabolic recovery leading to the reinstatement of remission criteria [4]. Summary statistics reveal that the percentage of participants achieving remission tends to be higher in those following a high-calorie restriction or weight loss dietary regimen than in comparison with low-carbohydrate, ketogenic, Mediterranean, and plant-based diets despite an apparent decline in metabolic health during post-intervention follow-up [8]. Evidence accumulated to date indicates that formal, multifaceted support enhances the likelihood of remission, particularly when interventions are initiated early and in conjunction with other lifestyle changes like increased physical activity [9].

Physical Activity and Metabolic Improvements

A low level of physical activity is a major risk factor for the development of T2DM. In The Whitehall Study, a large observational cohort study conducted in England, sedentary individuals were 37% more likely to develop adult-onset diabetes than those who engaged in regular moderate exercise [6]. In a meta-analysis of three clinical trials, a dose-response relationship was demonstrated, showing that the likelihood of diabetes onset decreased substantially with increasing energy expenditure from physical activity [11]. Regular physical activity impacts the risk of developing T2DM, but its role in diabetes remission is less clear. Remission rates improve with diabetes mobility interventions that increase physical activity and dietary modification. Increased level of physical activity after mobility interventions was independently correlated with a higher rate of T2DM remission [12]. Interventions with exercise components support remission rates and attenuate long-term glucose deterioration post-remission [3]. The Diabetes Prevention Program, Look AHEAD, and the Finnish Diabetes Prevention Study report decreased glycemia and sustained weight loss, extending the remission period. Resistance and combined training interventions have been associated with improvements in glucose control as substantial as those reported for aerobic exercise [6]. Remission rates for diet-only interventions are frequently lower than those of diet-plus-exercise programs. Changes in the frequency and intensity of physical activity after a primary intervention consequently influence the disease trajectory [3].

Aerobic, Resistance, and Combined Programs

More than one-third of type 2 diabetes (T2D) participants in exercise trials exhibit substantial improvements in glycemia without a corresponding decrease in body weight [13]. These findings highlight that lifestyle-induced T2D remission is attainable even in the absence of substantial weight loss. Several different exercise regimens, including aerobic, resistance, and combination training programs, have been examined individually across trials for their influence on glycemic control among adults with diabetes [14]. Time-efficient, low-volume resistance training engagements also confer considerable cardiovascular health benefits when partnered with moderate-intensity higher volume aerobic workouts, providing flexibility to accommodate busy schedules [1]. Furthermore, individuals who do not meet the strict calorie reduction criteria associated with many weight-focused approaches can still achieve marked metabolic improvements through these protocols [6]. Aerobic training, including supervised group exercises, home routines, walking sessions, and community fitness center attendance, has been assessed for its impact on metabolic control within diabetes cohorts[5]. Aggregate analysis reports that the

addition or exclusive application of aerobic training to ramp or sustained diet-induced weight loss programs enhances metabolic responses and candidates' access to remission. Sustained programmes have typically included a minimum of 90 min of accumulated moderate activity weekly, or ≥ 150 min per week [4]. Physical activity reduces metabolic vulnerability and raises remission rates, particularly among persons whose initial BMI falls below 25 kg/m². Fitness-enhancing activity contributes positively to remission when commenced before or soon after T2D diagnosis, but evidence addressing specific exercise recommendations remains limited. Overall exercise volume is identified as the primary predictor of such outcomes [5].

Exercise Adherence and Durability of Remission

In population-based studies investigating the association between physical activity and type 2 diabetes (T2D) remission, participants who reported engaging in ≥150 minutes of moderate-intensity physical activity per week were found to have an approximately five times greater likelihood of achieving remission than those with insufficient physical activity [5]. These findings suggest that, in addition to their contribution to metabolic and other health improvements, lifestyle changes positively influence the likelihood of achieving T2D remission status. Despite the strong association between physical activity and diabetes remission, adherence to exercise and activity promotion programs remains a significant public health issue [8]. Self-reported exercise levels usually decrease during the months following the initial intervention [6]. Many lifestyle change studies note that exercise continuation post-treatment is problematic [12]. Given the extent of long-term data supporting activity-related health benefits and emergence of numerous activity promotion programs, the question of which specific components support ongoing activity warrants further consideration [7].

Behavioral and Psychosocial Determinants

Among the many behavioral and psychosocial factors affecting the likelihood of achieving and maintaining remission, motivational interviewing and support for self-management of adherence are particularly notable[7]. Motivational interviewing appears effective at increasing participant engagement and has been associated with improvements in clinical outcomes [15]. Behavioral therapies that bolster adherence, along with nutritional coaching and education on the physiological effects of diet and physical activity [2] , have been linked to superior glycemic control, weight stability, and reduction in anti-diabetic medication, all contributing to higher rates of remission[5]. In addition, self-management education fosters a stronger sense of autonomy, defined as an individual's ability to feel in control of their own life, and greater satisfaction with lifestyle changes, both of which stimulate the adoption of a healthy lifestyle and promote remission [6]. Further relevant are the characteristics of the lifestyle programs, and the demand for an innovative, flexible, and empowering curriculum for the self-management training [8]. The multifaceted nature of the interventions can help satisfy the diverse needs of participants and stimulate engagement and motivation and thus contribute to remission [7].

Motivational Interviewing and Adherence Support

Several behavioral and psychosocial determinants influence both the attainment and sustained maintenance of lifestyle-induced remission in type 2 diabetes [16]. Supportive strategies specifically motivational interviewing and adherence support can bolster patient engagement with interventions and foster improved metabolic outcomes [13]. Motivational interviewing adapts principles of humanistic and client-centered psychology to promote articulation of personal goals, autonomous choice, and ongoing commitment to changes in diet, physical activity, or other self-care behaviors. Such engagement, in turn, favors the adoption of new health-promoting practices, which are critical to attaining remission [17]. Previous research exhibits considerable variation in the design, content, delivery mode, and intensity of consumer self-management education. When evaluated as stand-alone programs, these interventions produced mixed effects on achievement of diabetes remission [14]. Coaching by external facilitators and peer support promote greater motivation, attendance, and activity engagement, particularly at early stages [9].

Self-Management Education and Facilitator Roles

Self-management education is a critical self-management element in diabetes care [18]. Various delivery methods and support mechanisms are employed to convey self-management education, including face-to-face sessions or a combination of face-to-face and digital provision [19]. However, studies evaluating self-management education delivery methods show that the effectiveness of these activities on diabetes remission rates is not well understood [12].

Comparative Effectiveness and Heterogeneity of Response

When comparing the effectiveness of lifestyle interventions for diabetes remission across populations, important considerations include patient characteristics and intervention features [11]. Baseline factors associated with greater remission likelihood include lower weight, shorter duration of diabetes, and better preservation of β-cell function [20]. These findings underscore the importance of early intervention, targeting high-risk individuals. Interventions delivered in primary-care settings, as part of routine health checks, and self-directed methods with

educational sessions appear useful [21]. With respect to intervention features, higher intensity, longer duration, and group delivery have been linked to improved remission outcomes [10].

Patient Characteristics Associated with Remission

Remission rates of diabetes mellitus among patients undergoing intensive lifestyle interventions have been associated with patient characteristics. Among individuals with type 2 diabetes who achieved remission post intervention, important predictors included lower baseline weight, shorter diabetes duration, and higher β-cell reserve [22]. A retrospective analysis of an Egyptian cohort revealed additional baseline factors predictive of remission: higher initial levels of health-related quality of life, perceived stress, systolic and diastolic blood pressure, total cholesterol, triglycerides, and fasting and postprandial blood glucose [20]. Six patients with type 2 diabetes who had followed a high-fiber, low-fat, plant-predominant diet for at least two years reported successful medication withdrawal and sustained remission [9]. Intervention characteristics have also been linked to remission. An Australian study of patients aged 65 years and older found that remission was uncommon without bariatric surgery; lifestyle modifications including increased physical activity, a low-carbohydrate diet, smoking cessation, and reduced alcohol consumption were recommended to delay disease progression [23].

Intervention Intensity, Duration, and Delivery Mode

Multiple lifestyle interventions aim to induce remission of type 2 diabetes for specific time windows. Remission results when a participant maintains a period of improved metabolic control congruent with reduced glycaemic medication [24]. Different interventions involve diverse participant engagement levels. Category definitions proved heterogeneous or unspecified for many studies [20]. High-intensity approaches frequently combine regular structured sessions detailing dietary and exercise guidance alongside reputable support channels 6. Clearly differentiating between intensity, duration, and delivery mode reveals independent associations across these intervention characteristics [14].

Safety, Tolerability, and Adverse Effects

Safety and tolerability of lifestyle interventions represent critical factors influencing both patient acceptance and actual implementation in clinical practice [1]. Adverse effects are commonly reported following diet-based programmes and structured physical activity schemes, typically as transient symptoms linked to dietary changes (e.g., headache, nausea) or new exercise initiation (muscle soreness)[16]. There is insufficient evidence to ascertain the safety profile of more intensive approaches (e.g., Very Low Energy Diet, ketogenic diets, and structured boot camps) or to warrant stringent follow-up in low-risk cohorts once specific lifestyle details remain unmonitored [15]. Prospective reporting of adverse effects would support identification of suitable baseline assessments to inform the need for closer monitoring in higher-risk settings [17]. Safety and tolerability are central considerations when evaluating the potential for diabetes remission through lifestyle change [22]. Each of the major lifestyle-driven intervention classes' diet, physical activity, and behaviour change poses inherent risks and adverse effects, often resulting in non-compliance among participants [20].

Implementation Challenges and Real-World Applicability

The real-world applicability of lifestyle interventions and their challenges is exemplified by programs offered in routine diabetes care [19]. Randomized controlled trials of lifestyle programs for patients with impaired glucose tolerance or type 2 diabetes have demonstrated significant improvement of physical activity, HbA1c, weight, blood pressure, and serum lipids after one year [18]. However, translation into routine practice has proven difficult, generating only small changes in physical activity and adherence. Exercise referral schemes have had only limted impact, showing a high number needed to treat, reflecting low uptake and adherence [17]. Successful translation requires addressing barriers to access, engagement, reach, adherence, and sustainability that arise when trial protocols interact with routine practice, delivery modes, provider capabilities, and participants' readiness [25]. Routine programs often differ from trials in participant motivation, intensity, duration, delivery mode, and support. A lifestyle intervention for people with diabetes, delivered through eHealth by health-care professionals, failed to achieve behaviour change and was discontinued [1]. Such discontinuation indicates the necessity for external conditions that establish and sustain supportive input following formal program closure. Since ~90% partner loss for exercise and ~80% for dietary change continues unaddressed at three months post–type 2 diabetes remission, measures facilitating joint participation beyond program duration demand consideration [25].

Gaps in Knowledge and Directions for Future Research

Lifestyle-induced diabetes remission has the potential to avert many of the disease's complications [26-30]. Nevertheless, the underlying pathophysiology governing the endurance of remission after therapeutic lifestyle change requires further investigation to aid in the establishment of clinical practice guidelines for the treatment of diabetes with a concomitant review of interventions warranted in light of the myriad of additional milieu [31-33]. Consequently, a review of the studies, trials, and research providing evidence of the probative consequences of lifestyle changes on the remission of diabetes is presented [23, 1]. Interventions targeting lifestyle have displayed positive effects on diabetes management, particularly concerning weight loss, energy intake restrictions, and

physical exercise [20]. By enhancing the understanding of the physiological, psychological, emotional, and multifactorial pathways governing lifestyle changes, it is possible to gain insight into their relationship with diabetes [22].

CONCLUSION

Lifestyle interventions play a central role in achieving and sustaining remission of type 2 diabetes, challenging the long-standing perception of the disease as inevitably progressive. This narrative review demonstrates that remission is attainable through a combination of dietary modification, physical activity, and behavioural support, with remission likelihood and durability influenced by both individual characteristics and intervention design. Calorie restriction and substantial weight loss remain strongly associated with higher remission rates, while low-carbohydrate, ketogenic, Mediterranean, and plant-forward dietary patterns also confer meaningful glycaemic and metabolic benefits in selected populations. Physical activity independently contributes to metabolic improvement and enhances remission durability, even in the absence of significant weight loss. Aerobic, resistance, and combined exercise regimens improve glycaemic control and reduce relapse risk, particularly when sustained beyond the active intervention phase. Behavioural and psychosocial determinants including motivation, self-efficacy, adherence support, and structured self-management education are critical for both remission attainment and long-term maintenance. Despite encouraging evidence, substantial heterogeneity exists in remission outcomes, reflecting variations in disease duration, baseline metabolic health, intervention intensity, and delivery mode. Safety, tolerability, and real-world implementation challenges further complicate translation into routine clinical practice. Future research should focus on elucidating the biological mechanisms underpinning remission durability, standardizing definitions and outcome measures, and developing scalable, patient-centered models that integrate dietary, physical activity, and behavioural components. Advancing such approaches is essential to embedding lifestyle-induced remission into mainstream diabetes care and improving long-term outcomes for individuals living with type 2 diabetes.

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