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Biopsychosocial Aspects of Weight Management in Type 1 Diabetes: a Review and Next Steps

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Abstract

Purpose of Review—This review aims to summarize the type 1 diabetes (T1D) and weight literature with an emphasis on barriers associated with weight management, the unique T1D-specific factors that impact weight loss success, maladaptive and adaptive strategies for weight loss, and interventions to promote weight loss.

Recent Findings—Weight gain is associated with intensive insulin therapy. Overweight and obese weight status in individuals with T1D is higher than the general population and prevalence is rising. A variety of demographic (e.g., female sex), clinical (e.g., greater insulin needs), environmental (e.g., skipping meals), and psychosocial (e.g., depression, stress) factors are associated with overweight/obese weight status in T1D. Fear of hypoglycemia is a significant

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barrier to engagement in physical activity. Studies evaluating adaptive weight loss strategies in people with T1D are limited.

Summary—There is a growing literature highlighting the prevalence and seriousness of overweight and obesity among both youth and adults with T1D. There is an urgent need to develop evidence-based weight management guidelines and interventions that address the unique concerns of individuals with T1D and that concurrently address glycemic control.

Keywords

Physical activity; Interventions; Weight status; Diet; Bariatric surgery; Insulin management; Overweight; Obesity; Body mass index

Introduction

The role of obesity as both a predisposing condition for type 2 diabetes (T2D) and a comorbidity that negatively impacts health outcomes has been unequivocally established. It is not surprising that lifestyle and behavior-based strategies to combat obesity in T2D have been a major focus in healthcare and research [1–4]. In sharp contrast, overweight and obesity have only recently been recognized as a health concern in people with type 1 diabetes (T1D). As a result, there is a paucity of research in this area and specific guidelines on how to successfully implement and achieve optimal weight status in T1D are lacking. This review summarizes the T1D literature with an emphasis on barriers associated with weight management, the unique T1D-specific factors that impact weight loss success, maladaptive and adaptive strategies for weight loss, and interventions to promote weight loss. The overall purpose of this review is to stimulate more research in an understudied yet important area of care for individuals with T1D.

The Role of Insulin in Weight Gain

The Diabetes Control and Complications Trial (DCCT) demonstrated that intensive insulin therapy, the standard of care in T1D, results in optimal glycemic control and reduction of long-term complications in T1D [5]. The amount of insulin needed to maintain glycemic control increases in puberty [6] and with longer T1D duration and older age [7]. The DCCT—Epidemiology of Diabetes Interventions and Complications (EDIC) study also demonstrated that increased insulin needs are associated with more T1D complications [8, 9] and weight gain and higher weight status across time in individuals with T1D [10–12, 13••] because of the anabolic and lipogenic actions of insulin [14]. These findings further highlight the need to decrease insulin needs, which can be accomplished through engagement in physical activity [15].

Weight Status in Type 1 Diabetes

Adults

The prevalence of overweight and obesity in adults with T1D are the same or higher than the general population [16]. For example, the T1D Exchange Clinic Registry (i.e., T1D Exchange) found that 50% of adults with T1D are overweight/obese [17], which is similar to

other large-scale studies including 57% in the Coronary Artery Calcification in Type 1 Diabetes Study (CACTI) [18] and 65% in the Pittsburgh Epidemiology of Diabetes Complications Study [19]. In addition, a study involving an Israeli cohort of men and women found that 53 and 60%, respectively, were overweight/obese [14].

Children/Adolescents

The T1D Exchange recently documented that 36% of adolescents with T1D are overweight/obese [20, 21•], which is consistent with the SEARCH for Diabetes in Youth Study [22] and other US T1D samples [23, 24] but higher than the general population [25]. In addition, Canadian and Polish studies of children and adolescents with T1D found that 35 and 30%, respectively, were overweight/obese [26, 27]. These rates are much lower than an Israeli cohort of children and adolescents with T1D, of whom 66% of boys and 61% of girls were overweight/obese [14].

Biopsychosocial Factors Related to Weight Status

Demographic

Many studies have shown that girls and women with T1D are more likely to be overweight and/or obese than are boys and men [21•, 24, 27, 28]. However, Duca and colleagues recently reported that 68 and 59% of men and women were in the overweight/obese weight categories, respectively, with more men classified as obese and more women as overweight [29].

Race/ethnicity has also been implicated in overweight/obese status. The T1D Exchange showed that in adolescents with T1D, the highest rates of combined overweight/obese status occur in Hispanic/Latino participants [21•]. Moreover, Black/African American participants had the highest rates of obesity (18%), whereas Hispanic/Latino participants had the highest representation in the overweight status (30%) [21•]. In addition, older age, being of Hispanic/Latino race/ethnicity, having a parent with high school education or lower [24], and lower household income have been shown to be related to overweight/obese status [21•].

Clinical

Studies have shown that longer T1D duration [21•, 24], higher A1C [21•, 23, 26], and greater insulin doses [21•, 28] are associated with overweight/obese status. Among those who use multiple daily injections, long-acting insulin doses are positively associated with waist-to-hip ratios [30]. Studies investigating insulin pump use and weight gain are mixed; some studies have demonstrated that insulin pump use and higher basal rates lead to overweight/obese status, [13•, 28], whereas others have not [31, 32].

Environmental/Lifestyle

Youth with T1D who skip breakfast and dinner are more likely to be overweight [33, 34]. In addition, in families that have a child with T1D, parental weight status has been shown to be significantly associated with their children's weight status [23].

Daily television viewing has been found to be related to risk for obesity in preschool-aged children in the general population [35]. Recently, Patton and colleagues found that young children with T1D consumed more grams of fat when watching television during mealtimes than those who did not [36]. Girls with T1D who spend more time watching television have poorer weight indicators and metabolic profiles (i.e., higher waist-to-hip ratios and fat mass and leptin levels, lower HDL-C levels) [30] and are more likely to be overweight [33]. Although research on food labels has been linked to nutrition knowledge in diabetes [37], the relation between consumption of packaged foods and weight has not been investigated. Moreover, although better diet quality is associated with better glycemic control [12], no studies have investigated poor diet quality with regard to fast food or restaurant meals and weight status in T1D.

Psychosocial

Psychosocial factors associated with overweight and obesity in the general population such as depression, anxiety, stress, low self-esteem, body image dissatisfaction, social withdrawal, lower quality of life and bullying have not been studied extensively in T1D [38]. Of the few studies that have investigated psychosocial factors in individuals with T1D, depressive symptoms [39, 40], higher stress [24], lower quality of life [24, 30, 41], low social support [42], poor self-esteem [42], and negative body image [42] were found to be associated with higher BMI and/or overweight and/or obese weight status. Importantly, girls who are overweight/obese are at greater risk of experiencing psychosocial challenges than are boys [24, 42].

Physical Activity and Individuals with T1D

Physical Activity Recommendations

Engagement in regular physical activity is recommended to improve overall health in individuals with T1D [43]. The American Diabetes Association (ADA) Standards of Medical Care recommends that children and adolescents with T1D engage in 60 min per day or more of moderate- or vigorous-intensity aerobic activity, with vigorous muscle- and bone-strengthening activities at least 3 days per week in combination with tailoring the insulin regimen to activity and meals/snacks to avoid hypoglycemia [44]. For most adults with T1D, engagement in 150 min or more of moderately to vigorously intense physical activity per week, spread across at least 3 days per week with no more than two consecutive days without activity, is recommended. Despite ADA and the International Society for Pediatric and Adolescent Diabetes [45••] recommendations, it is not clear what form, duration, and intensity of physical activity should be recommended for individuals with T1D who have the goal to lose excess weight and to maintain weight loss [15]. It is also important to note that the primary role of physical activity should be in the maintenance of weight loss, not initial weight loss.

Individuals with T1D Do Not Meet Physical Activity Recommendations

Several studies have demonstrated that children with T1D engage in less physical activity than do their peers without T1D [46–48]. The T1D Exchange showed that among adults, 12% reported that they did not engage in any physical activity, 55% reported engagement in

physical activity 1 to 4 days per week, and 33% reported engaging in physical activity 5 days or more per week. Specifically, older adults and those with higher BMI and longer T1D duration tend not to engage in any physical activity [38].

Biological Impact of Physical Activity on T1D Health Outcomes

Although the specific role of physical activity in the daily management of blood glucose and prevention of long-term complications is not well understood [44], physical activity in individuals with T1D leads to improvements in BMI, triglycerides, and cholesterol for children and adolescents [49] and decreased retinopathy and microalbuminuria for adults [50••]. However, physical activity generally does not lead to significant reductions in A1C [15, 51], which may be attributable to increased food consumption prior to physical activity, either as a source of fuel or as a strategy to prevent exercise-induced hypoglycemia, and rebound hyperglycemia following exercise [15].

Barriers to Physical Activity

Fear of hypoglycemia is the most common barrier to physical activity for children/adolescents and adults with T1D [43, 52–55], and several studies have demonstrated increased risk of hypoglycemia resulting from exercise [56–58]. Lack of time and work schedules for adults and parents are also barriers [53, 59]. Thus, clinical recommendations for exercise may need to incorporate specific strategies to mitigate the risk of hypoglycemia associated with changes in activity level. Other barriers to physical activity for adults include lack of motivation, embarrassment about weight, lack of access to a gym, frustration with exercise-induced hypoglycemia [59], and lack of social support to engage in physical activity [52, 53].

For children and adolescents specifically, the reduction or elimination of physical education in the school environment and participation in sedentary extracurricular activities reduces participation in physical activity [60]. In addition, loss of T1D control and external temperature are barriers to physical activity for children and adolescents [53]. Finally, although a broader obesogenic environment (i.e., neighborhood) cannot necessarily be changed, limited access to parks and recreation and low perceived safety are associated with higher body mass index in girls and boys [61] and need to be taken into account as barriers to weight loss in children and adolescents with T1D. In addition, boys who live in neighborhoods or attend schools in neighborhoods with more fast food restaurants have been found to eat more frequently at them [62]. Thus, interventions that focus solely on food consumption or physical activity are not likely to be effective.

Unique Barriers to Weight Loss in Individuals with T1D

Focus on Food and Dietary Restraint

The process of glycemic management in T1D may interfere with achieving and maintaining healthy weight via unintended consequences of dietary restriction. Dietary restraint refers to intentional and sustained restriction of caloric intake to achieve weight loss or maintenance [63]. T1D is described as a food culture of dietary restraint in that a strict dietary regimen [64, 65] characterized by carbohydrate counting drives imposed food preoccupation [66],

which may result in challenges that revolve around food [67, 68]. Self-report measures of dietary restraint in individuals with T1D showed that higher dietary restraint is associated with poorer glycemic control [55].

Sustained dietary restraint is associated with overeating when self-control is disrupted, which may contribute to disordered eating behaviors and bingeing. The extreme attention paid to food in T1D and its biological addictive pathways could also be a factor in weight status, although this has not been studied to date [69]. The majority of research has focused on the role of food in the development of disturbed eating behaviors and insulin restriction in efforts to lose weight; more research is needed to understand the role of food as a factor contributing to overweight/obese status in T1D. Finally, it is possible that the change from a rigid carbohydrate prescription to a more flexible carbohydrate counting approach may result in increased calorie consumption.

Hypoglycemia

Recurrent hypoglycemia and its associated intense hunger and permission to eat discouraged sugary foods may lead to overeating, guilt, justification for bingeing on restricted foods, and possibly more episodes of hypoglycemia, creating a self-perpetuating cycle of disordered eating behavior resembling binge eating disorder and bulimia [70]. Moreover, brain regions may be activated that are involved in reward, craving, and food intake thereby disrupting physiological hunger cues [71]. Thus, food addiction can result in individuals with T1D if they develop a habit of craving and consuming highly enjoyable processed foods such as sugar especially during hypoglycemic episodes [69], which can promote overeating [72] and worsened glycemic control [65, 66].

Maladaptive Weight Management Strategies

An increasing amount of clinical and research attention is being paid to disturbed eating behaviors and eating disorders in individuals with T1D as a maladaptive approach to losing weight. Unfortunately, insulin manipulation in the form of complete omission or intentional under-dosing results in rapid weight loss and thus is an effective but dangerous way to lose weight [64, 73].

Without adequate insulin, chronic hyperglycemia causes dehydration and loss of lean body tissue. As a result, glucose is excreted through urine preventing it from being used by muscle and fat, which leads to further deterioration of glycemic control, the breakdown of muscle and fat for energy, and ketogenesis [74]. Increased caloric intake in the absence of appropriate insulin administration may prevent weight gain but will also promote deleterious medical outcomes including higher rates of diabetic ketoacidosis, nephropathy, and neuropathy [74]. Moreover, morbidity is significant with a threefold increase in relative risk of death for individuals who restrict insulin [74].

Most studies on the prevalence of disordered eating behaviors and eating disorders in individuals with T1D have focused on adolescent and young adult females [75, 76]. Some studies estimate that 20–40% of youth with T1D have engaged in insulin manipulation to promote weight loss [66, 68], which can persist into adulthood [77]. Although most studies

focus on women with T1D who are at 2.4 times higher risk for developing disordered eating behaviors or eating disorders [78], Neumark-Sztainer and colleagues found that as many as 16% of males engaged in unhealthy weight control practices [79]. In contrast, the SEARCH for Diabetes in Youth study showed that among youth who had attempted to lose weight, insulin restriction was the least common (4.2%) maladaptive approach (e.g., fasting, diet aids, vomiting/laxative use) reported [80]. Consistent with other studies, insulin restriction was more common in females [80].

Hypoglycemia and fear of hypoglycemia have also been implicated as having roles in the onset of disordered eating behaviors and eating disorders in patients with T1D. Other risk factors specifically associated with the onset of disordered eating behaviors and eating disorders in individuals with T1D include female sex, higher BMI, infrequent family meals and high family attention to weight status, depression, low self-esteem, and body dissatisfaction [65, 66, 68]. The extent to which women with T1D define their self-worth by their physical appearance in the context of lower quality of life has also been found to be associated with engagement in insulin restriction [81]. In addition, fear of hypoglycemia and individuals' concomitant purposeful maintenance of hyperglycemia has led some to inadvertently discover the relationship between hyperglycemia and weight loss, which can trigger intentional insulin manipulation [82].

Adaptive Weight Loss Strategies and Interventions

Successful weight loss strategies address both behavioral and psychosocial elements, grounded in established theoretical frameworks to promote behavior change, such as the Health Belief Model, Transtheoretical Model, and Theory of Reasoned Action [83]. Self-monitoring of dietary intake and weight status, use of caloric restriction, fewer calories from fat, and increased levels of physical activity contribute to sustained weight loss and weight gain prevention in the general population [83, 84].

Dietary Interventions

According to the ADA's Nutrition Therapy Recommendations, individualization of dietary recommendations is needed to account for metabolic status, clinical goals, preferences, and sociocultural considerations [85]. The role of carbohydrates in weight loss remains unknown for individuals with T1D. On average, individuals with T1D consume 45% of calories from carbohydrates [86, 87], significantly less than the general US population [88]. Further, in T1D, higher intake of carbohydrates is associated longitudinally with higher A1C [89]. In T2D, a 1-year hypocaloric low-carbohydrate (14%) diet was effective in promoting weight loss, improving glycemic control and variability, and improving cardiovascular risk factors [90]. Thus, it is reasonable to consider that in T1D, a lower carbohydrate diet may be acceptable and beneficial in promoting weight loss and glycemic control. However, prospective, randomized clinical trials are needed to understand the energy and macronutrient requirements in lean versus overweight/obese individuals with T1D.

Physical Activity Interventions

Two recent systematic reviews of physical-activity interventions in children and adolescents [91] and adults [92] highlight the paucity of well-designed research in this area. In addition, these reviews were not able to determine the true effect of physical activity on health outcomes in children and adolescents because of insufficient data reporting [91] and on glycemic control in adults because of limitations in study designs [92]. However, MacMillan and colleagues found that the physical activity interventions included in their review resulted in a significant reduction (-0.85%) in A1C in children and adolescents, concluding that longer duration of intervention programs (≥ 12 weeks), more frequent activity (≥ 3 sessions per week), longer activity duration (≥ 60 min per session), and resistance exercise, in addition to aerobic activity, may be most effective at reducing A1C [91]. In adults, rigorously designed studies to determine ideal duration, intensity, and type of exercise on glycemic control are needed [92].

Since these reviews were conducted, three pilot and feasibility studies in children and adolescents are underway. One study involves the ActivPals Program, which is based on social cognitive theory and emphasizes the importance of self-efficacy and setting realistic goals [93]. Other important aspects of ActivPals include tailoring to the participant's baseline activity, activity preferences, and local opportunities using role modeling, peer support, and self-monitoring devices. Supporting Kids with Diabetes in Physical Activity (SKIP) and Steps to Active Kids with Diabetes (STAK-D) are other interventions that have been developed [94]. Both are also based on social cognitive theory and include educational materials, physical activity diaries, and goal-setting strategies. SKIP includes group activity sessions, whereas STAK-D does not because it is internet based.

Although several studies have demonstrated physical and psychological health benefits of exercise interventions in patients with T1D (e.g., lower total insulin dosage and glycemic control, and better quality of life) [95–98], to date, no studies describing lifestyle modification interventions to decrease obesity in youth or adults have been published.

Bariatric Surgery

As a more extreme alternative to the lifestyle modification interventions described previously, bariatric surgery is emerging as a possibly effective treatment for obesity in T1D [99, 100]. Several recent reviews concluded that bariatric surgery in adults with T1D results in weight loss, better insulin sensitivity, and other positive health outcomes (e.g., reduction in blood pressure) [99, 100]. However, the impact of bariatric surgery on glycemic control is mixed [99, 101]. Most T1D bariatric surgery studies are case series or case reports with very small sample sizes ranging from 1 to 10 individuals per study, with only one larger study consisting of 22 patients [102]. Notably, existing studies of bariatric surgery in patients with T1D are heterogeneous and study design of poor quality; therefore, well-designed, randomized control trials are needed to better understand metabolic health outcomes [99] and conclusively determine if bariatric surgery may be an option for obese individuals with T1D.

Pharmacotherapy

The only other medication besides insulin that is approved by the US Food and Drug Administration for the treatment of T1D is pramlintide, an amylin analog that delays gastric emptying and increases satiety, which promotes weight loss [103]. It is not commonly prescribed because it requires an additional injection and increases risk of hypoglycemia, and it is costly [104]. While glucagon-like peptide-1 (GLP-1) receptor agonists are increasingly used to promote weight loss in T2D [105], there is also increasing attention to how individuals with T1D may benefit from their use. A recent review of published studies that used GLP-1 receptor agonists adjunctively in the treatment of T1D found that both exenatide and liraglutide are effective at reducing A1C, fasting and postprandial plasma glucose concentrations, insulin doses, and body weight without increasing risk of hypoglycemia in adults with T1D [103]. One pediatric study has been conducted, but it only evaluated exenatide in adolescents and young adults, but its impact on weight loss was not reported as the duration of the study was 3 weeks. The use of GLP-1 receptor agonists to promote weight loss in overweight/obese adults with T1D appear promising; however, more research is needed, especially on their use in children and adolescents.

Summary

Although the ADA Medical Standards of Care makes recommendations about lifestyle management in general and obesity management for the treatment of T2D specifically, there are no specific weight management recommendations for T1D [44]. Similarly, weight management is absent from the International Society for Pediatric and Adolescent Diabetes Clinical Practice Guidelines [106]. More research is needed to determine the best practice guidelines for overweight/obesity in individuals with T1D including the roles of healthy eating, physical activity, and sleep [107].

Moreover, it may be that multilevel approaches that involve family members, peers, school personnel, and modification of the home environment, in addition to individual-level approaches (e.g., individual therapy to address depression, low self-esteem, body image dissatisfaction, pharmacotherapy), are needed for overweight/obesity prevention and/or intervention programs [108]. Thus, interventions that focus solely on food consumption or physical activity are not likely to be effective. In addition, diabetes education about weight management and obesity prevention will need to occur as part of routine T1D clinic visits. To be maximally effective, these educational strategies need to be culturally tailored and gender specific, with interventions prioritized to those who are at higher risk for overweight/obesity (e.g., African Americans, Latinos, and girls). Finally, more work is needed to characterize the natural history and best treatment approach for individuals with T1D who also show clinical characteristics of T2D and metabolic syndrome, in order to avoid accelerated adverse cardiometabolic outcomes.

Conclusion

Individuals with T1D are fighting two distinct and opposing battles: achieving glycemic control via exogenous insulin delivery and maintaining a healthy body weight status. This poses unique challenges for weight maintenance, including biopsychosocial adaptations that

can further influence whether an individual can prevent or ameliorate obesity. There is a need for focused research programs that employ a combination of mechanistic, clinical, and population-based research, coupled with the most advanced technologies and study designs, to understand barriers to weight loss. In addition, the biological parameters that influence both behaviors and health outcomes need to be determined so that weight management recommendations that are specific to individuals with T1D can be developed. Efforts are currently underway through the National Institute of Diabetes and Digestive and Kidney Diseases-funded *Advancing Care for Type 1 Diabetes and Obesity Network (ACTION)* to further elucidate the biological aspects of weight gain in T1D and develop interventions to prevent and treat overweight and obesity with the overall goal of informing comprehensive clinical practice guidelines for the T1D community.

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Advancing Care for Type 1 Diabetes and Obesity Network (ACTION) is a consortium of clinical, behavioral, and basic scientists comprising expertise in endocrinology, epidemiology, nutrition, exercise physiology, clinical psychology, and biostatistics from multiple institutions led by the University of North Carolina, Stanford, University of Colorado and the Florida Hospital Translational Medicine Research Institute. ACTION aims to elucidate drivers of overweight and obesity in youth and adults with type 1 diabetes. The overarching goal of ACTION is to develop evidence-based guidelines for individuals with type 1 diabetes and their diabetes care team regarding weight management and weight loss.

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