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Overweight and Obesity in Youth With Type 1 Diabetes

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Abstract

Overweight and obesity in youth with type 1 diabetes (T1D) is now prevalent and accounts for significant health consequences, including cardiovascular complications and dual diagnosis of type 2 diabetes. Physical activity and lifestyle are modifiable and play an important role in the prevention and management of excessive weight, but it is unclear how these factors relate to overweight and obese youth with T1D. Thus, a systematic review was conducted to examine how physical activity, sedentary behavior, sleep, and diet are related to overweight/obesity in youth with T1D. Seven observational and intervention studies published between 1990 and 2013 were included in the review. Prevalence of overweight ranged from 12.5% to 33.3%. Overweight in youth with T1D was associated with infrequent napping, increased screen time, and skipping breakfast and dinner but was not related to time engaged in physical activity. Weight-related interventions indicated modest weight loss along with improved glycemic control. In light of this review, there is a need for high quality research that examines all levels of activity in youth with T1D to identify lifestyle modification targets for weight prevention and management.

INTRODUCTION

Globally, the incidence of type 1 diabetes (T1D) is increasing among youth, at an annual rate of 3%–4% per year, thus posing a significant public health problem (Bell et al., 2009; Lipman et al., 2013; Patterson et al., 2012). At the same time, the prevalence of overweight and obesity among all youth has increased precipitously over the past few decades (Wild, Roglic, Green, Sicree, & King, 2004) and has been deemed the major public health challenge facing youth in the 21st century (Jack, 2007). Surprisingly, overweight and obesity are now prevalent among youth with T1D, and a recent study demonstrated that youth with T1D are more likely to be overweight than their peers without the condition (Liu et al., 2010). Others have noted more than a twofold increase of overweight and obesity in youth with T1D since the 1990s when the Diabetes Control and Complications Trial (DCCT) availed the benefits of tight glucose control to reduce the complications of T1D (Libman, Pietropaolo, Arslanian, LaPorte, & Becker, 2003; Purnell et al., 1998). In the DCCT, a complication of intensive insulin therapy and tight glucose control was untoward weight gain, which was threefold higher in the intensive treatment group and was associated with more moderate to severe hypoglycemic events and better glucose control (American Diabetes Association, 1993; DCCT Research Group, 1988, 1993).

Because excess weight is associated with increased risk for cardiovascular disease in youth without diabetes, excess weight in youth with T1D may contribute to a higher risk of cardiometabolic complications in these youth (Purnell et al., 2013; Van Vliet et al., 2012). Indeed, youth with T1D are predisposed to such complications by having diabetes,

regardless of weight status (Krishnan & Short, 2009). Furthermore, and perhaps most alarming, several case studies have been reported in which several overweight and obese youth with T1D developed type 2 diabetes (T2D) as well, or “double diabetes,” whereby these youth became resistant to their exogenous insulin, insulin resistance being the hallmark of T2D (Pozzilli, Guglielmi, Caprio, & Buzzetti, 2011). Such a scenario may predispose youth to additional long-term cardiovascular complications.

Prevention of weight gain and long-term weight management can be effective measures to prevent or reduce overweight and obesity in youth with T1D, although until recently, this has not been a focus of treatment. Physical activity and lifestyle play a key role in overweight and obesity in the general population, but the contributing factors related to weight gain that are specific to youth with T1D have not been studied. Thus, the purpose of this systematic review is to explore the associations among physical activity, lifestyle (sedentary behavior, sleep, diet), and overweight/obesity in youth with T1D by synthesizing the findings for clinical application and direction of future research.

BACKGROUND

Epidemiology of Diabetes in Youth

T1D is an inflammatory autoimmune disorder that disrupts the functioning of the pancreas by destroying the insulin-producing beta cells. Most cases of T1D are diagnosed during childhood and young adulthood. Treatment of T1D involves replacement of insulin by injection and regular monitoring of blood glucose, which requires balancing of carbohydrate intake with physical activity. Although the tendency toward autoimmune disease is inheritable, multiple environmental factors are involved in presentation of the phenotype (Knip et al., 2005). On the other hand, T2D is a metabolic condition distinguished by insulin resistance and high blood glucose that presents typically during adulthood. The etiology of T2D is better understood and most likely related to lifestyle and genetic factors. Obesity is the predominant risk factor in those who are genetically susceptible (Patrick et al., 2004).

Diabetes is among the most common pediatric chronic conditions. Estimates vary widely in terms of how many youth are affected with T1D and T2D, and the incidence varies as a function of gender, seasonality, race, and geographical factors (Lipman et al., 2013; Soltesz, Patterson, Dahlquist, & Eurodiab Study Group, 2007). In the United States, the SEARCH for Diabetes in Youth Study Group reported that more than 150,000 youth had physician-diagnosed T1D and/or T2D in 2001 (SEARCH for Diabetes in Youth Study Group, 2006), and that the overall incidence was 24.3 per 100,000 person-years (SEARCH for Diabetes in Youth Study Group, 2007).

The prevalence of both T1D and T2D in youth is increasing. T1D has been rising at an average rate of 3%–4% per year in children and adolescents (Bell et al., 2009; Lipman et al., 2013; Onkamo, Vaananen, Karvonen, & Tuomilehto, 1999; Patterson et al., 2012), and although only accounting for about 6% of cases (SEARCH for Diabetes in Youth Study Group, 2006), the number of youth with T2D is also increasing, particularly among adolescents from minority populations (SEARCH for Diabetes in Youth Study Group, 2007). In fact, in one study the authors concluded that given current incidence estimates, the

number of youth with T1D and T2D will increase by 23% and 49%, respectively, by 2050 (Imperatore et al., 2012). The predominant factor associated with this rise of T2D in youth is excessive weight gain (Patrick et al., 2004). As described by the “accelerator hypothesis,” overweight may also partly explain the increasing incidence of T1D because of the interplay of beta-cell apoptosis and insulin resistance (Wilkin, 2001), but other environmental factors such as maternal age and birth weight may also be attributed to the rising incidence of T1D (Cardwell, Stene, Joner, Bulsara, et al., 2010; Cardwell, Stene, Joner, Davis, et al., 2010).

Recent data from the United States show that a substantial proportion of youth are overweight or obese, 16% and 12% respectively (Eaton et al., 2010). Indeed, this prevalence of overweight and obesity has maintained a nearly linear trend for decades (Han, Lawlor, & Kimm, 2010), and projections indicate that by 2050, up to 42% of the U.S. population will be obese (Hill, Rand, Nowak, & Christakis, 2010). Overweight and obese youth may develop a myriad of physical, psychological, quality of life, and psychosocial sequelae as a consequence of excess weight, and this translates to a dramatic decrease in life expectancy (Daniels, 2006; Olshansky et al., 2005). Given these adverse health outcomes and the economic impact, childhood obesity has been cited as the major public health problem for this century (Jack, 2007).

Prior to the release of the findings of the DCCT and the concomitant increase in the use of intensive insulin regimens, youth with T1D tended to be lean, mostly as a result of a loss of calories in the urine. However, corresponding to the increase of overweight and obesity in the general population, youth with T1D are also experiencing overweight and obesity (Liu et al., 2010). Trends of weight gain were found by the Pittsburgh Epidemiology of Diabetes Complications Study that showed an increase in overweight in adults with T1D, from 29% in 1986–1988 to 42% in 2004–2007, and obesity from 3% to 23% for the same period (Conway et al., 2010). There are limited epidemiologic data on youth with T1D. Recent research has demonstrated, however, that youth with T1D have a higher prevalence of overweight (22% vs. 16%) but are less likely to be obese (13% vs. 17%) than their peers without diabetes (Liu et al., 2010). Because youth with T1D, regardless of weight status, are already at greater risk of cardiovascular complications than those without T1D (Krishnan & Short, 2009; Laing et al., 2003; Soedamah-Muthu et al., 2006), the possibility of additional complications attributable to excess body weight is concerning.

Of particular concern is the emergence of double diabetes, a condition in which overweight and obese adolescents have the clinical manifestations of both T1D and T2D (Libman & Becker, 2003). This rare dual diagnosis occurs when overweight or obese youth with T1D develop insulin resistance that is characteristic of T2D. Alternatively, youth with T2D may present with autoantibodies to pancreatic beta cells, and thus develop T1D, but this scenario is less common. As the accelerator hypothesis argues, those with T1D who also have a genetic susceptibility to T2D are more likely to acquire insulin resistance, and consequently double diabetes, if they become overweight (Pozzilli et al., 2011). The manifestation of double diabetes may place overweight and obese youth at risk for high blood pressure, abnormal lipid profile, and polycystic ovary syndrome for adolescent females (Pozzilli et al., 2011). Thus, overweight or obese youth with T1D may represent an extremely at risk population. Furthermore, because insulin therapy is associated with weight gain (Purnell et

al., 1998; Russell-Jones & Khan, 2007), effective physical activity and lifestyle habits must be promoted in all youth to prevent complications of overweight and obesity.

Role of Physical Activity and Lifestyle Factors in Youth

Observational and experimental studies have revealed the beneficial effects of physical activity in youth. Regular physical activity has been shown to improve health by reducing the risk of cardiovascular disease, high blood pressure, the metabolic syndrome, obesity, and depression (Warburton, Nicol, & Bredin, 2006). Importantly, even moderate participation in physical activities, such as aerobic and strength training exercise may have beneficial effects in preventing and reducing excess body weight (Janssen & Leblanc, 2010).

Pediatric organizations recommend that youth engage in moderate to vigorous physical activity for a duration of at least 60 min per day (Strong et al., 2005; World Health Organization, 2010); however, fewer than 1 in 10 U.S. youth meet this recommendation (Troiano et al., 2008). Physical activity is also recommended for youth with T1D, providing that there are no complications at the time of exercise and blood glucose levels are within target before, during, and after exercise (American Diabetes Association, 2002; Robertson, Adolfsson, Scheiner, Hanas, & Riddell, 2009). Nevertheless, epidemiologic data suggest that few youth with T1D, as low as 4.7%, meet the recommended 60 min per day of moderate to vigorous physical activity (Liese, Ma, Maahs, & Trilk, 2013; Schweiger, Klingensmith, & Snell-Bergeon, 2010). Despite the recommendations that youth with T1D participate in physical activity, youth may have fear of hypoglycemic events and may wish to delay activity until glucose levels are in the appropriate range (American Diabetes Association, 2002). This fear of hypoglycemia during exercise may lead to decreased frequency, duration, and intensity of exercise (Brazeau, Rabasa-Lhoret, Strychar, & Mircescu, 2008; Di Battista, Hart, Greco, & Gloizer, 2009; Nordfeldt & Ludvigsson, 2005).

Although the data on the role of physical activity in youth with T1D are limited, two recently published reviews have examined this topic in detail (Chimen et al., 2012; Liese et al., 2013). The authors observed that physical activity improves fitness in youth with T1D, but youth still have a low level of cardiorespiratory fitness, suggesting that aerobic power, strength, balance, and flexibility might be compromised in youth with T1D (Blair & Connelly, 1996). Regular participation in physical activities also improves lipid levels, endothelial function, and insulin resistance, but not blood pressure in youth with T1D (Chimen et al., 2012; Liese et al., 2013). Interestingly, these authors observed that although physical activity improves insulin dosage regimens in youth with T1D, the effect of physical activity on glycemic control is limited. Others have promoted the use of family-based intervention strategies to engage youth in moderate to vigorous physical activity in order to enhance fitness levels and minimize future cardiovascular risk in youth with T1D (Faulkner, 2010; Faulkner et al., 2006; Faulkner, Michaliszyn, & Hepworth, 2010).

Overweight and obesity are complex and multifactorial conditions that are associated with many risk factors. Thus, in addition to physical activity, other lifestyle behavioral factors are important to consider for youth with T1D, including sedentary behavior, sleep, and diet.

Sedentary behaviors are activities that do not increase energy expenditure substantially higher than the resting level of 1.0–1.5 metabolic equivalents (METs; Pate, O'Neill, & Lobelo, 2008) and include such activities as sitting, reading, and watching television (screen time). In a recent review and meta-analysis of sedentary behavior and health outcomes in youth, the authors found a relationship between increased sedentary behavior and unfavorable health outcomes, such as increased body mass index (BMI) and poorer psychosocial and physical health, including the metabolic syndrome (Mark & Janssen, 2008; Tremblay et al., 2011). Youth with T1D have reported a high duration of screen time per day, the typical proxy for sedentary behavior, ranging between 110 and 140 min per day of television watching, and between 40 and 255 min per day of computer use (Liese et al., 2013). In fact, in one study of youth with T1D, the average amount of accumulated screen time was 2.9 hr per day (Galler, Lindau, Ernert, Thalemann, & Raile, 2011), which exceeds the recommendation of less than 2 hr of screen time per day (American Academy of Pediatrics, 2001). Accelerometry was used in another study to assess intensity of activity in youth with T1D and it was found that 84% of recorded daily activity was in sedentary pursuits, thus potentially posing increased cardiovascular risks and poorer glucose control (Michaliszyn & Faulkner, 2010).

Lack of sleep has also been found to be associated with overweight and obesity in adults, and sleep problems, especially insomnia and sleep apnea, are prevalent in adults with T2D (Einhorn et al., 2007; Spiegel, Knutson, Leproult, Tasali, & Cauter, 2005; Vgontzas et al., 2009). Research exploring the impact of sleep in youth with T1D is beginning to emerge. Sleep restriction was associated with reduced insulin sensitivity (Donga et al., 2010); disrupted sleep was related to glucose variability (Matyka, Crawford, Wiggs, Dunger, & Stores, 2000); and, youth with T1D and those with poorer metabolic control had more bouts of sleep apnea compared to those without T1D or those whose diabetes was in good metabolic control (Villa et al., 2000). Poorer sleep behaviors were also associated with reduced quality of life, educational attainment, and psychological problems (Perfect et al., 2012). Sleep behaviors may have unique implications for overweight and obese youth with T1D because not achieving an adequate amount of sleep is associated with weight gain (Padez, Mourao, Moreira, & Rosado, 2009; Touchette et al., 2008).

Diet and nutrition are critical elements of diabetes management. Prior to the recommendations for intensive insulin therapy and better metabolic control, dietary recommendations focused on consuming sufficient calories for growth and a balanced nutrition to be distributed throughout the day. The advent of intensive therapy, with reliance on multiple daily injections or the use of an insulin pump, led to a new approach to dietary recommendations that focused on covering carbohydrates in a meal with less emphasis on balanced nutrition (Gillespie, Kulkarni, & Daly, 1998). Although this approach makes life easier for youth with T1D, because there are no restricted foods, it has opened the door to the poor dietary habits characteristic of youth in today's society. Clearly, overconsumption of calories and fat will translate to weight gain in youth (Patrick et al., 2004), which is detrimental to youth with T1D since high saturated fats adversely impacts metabolic control (Michaliszyn, Shaibi, Quinn, Fritschi, & Faulkner, 2009). Furthermore, the SEARCH for Diabetes in Youth Study group reported that most youth with T1D do not meet American Diabetes Association recommendations for total fat, vitamin E, fiber, fruits, vegetables, and

grains, and fewer (6.5%) met recommendations of less than 10% of energy from saturated fat (Mayer-Davis et al., 2006).

Thus, as the incidence of T1D and weight gain are increasing, physical activity and other lifestyle behaviors need to be addressed. The purpose of this review is to identify the evidence related to physical activity, sedentary behavior, sleep, and diet, and overweight/obesity in youth with T1D. We hope to identify factors and strategies related to obesity and overweight prevention and management in youth with T1D. This work is necessary given that health behaviors are modifiable and may prevent the complications of overweight and obesity in youth with T1D, including those at risk for double diabetes.

METHODS

A systematic review using the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines (Moher, Liberati, Tetzlaff, & Altman, 2009) was conducted by searching the following electronic bibliographic databases with the assistance of a medical librarian: Medline, EMBASE, Cochrane Library, and CINAHL. The following keywords with various logical connections were used: Obesity (overweight, body composition, BMI, waist circumference), T1D, exercise (physical activity, motor activity), and lifestyle (sleep, sedentary behavior, diet, nutrition, self-care, health behavior, health promotion). The studies included in this review were limited to full-text articles published between 1990 and February 2013. The search strategy began in 1990 because of the early evidence that intensive insulin therapy was associated with weight gain (DCCT Research Group, 1988). To identify any studies that may have been missed during the search, relevant references were also retrieved from reference lists of selected articles. The review was restricted to publications written in the English language.

The titles and abstracts of all citations identified by the literature search were reviewed. The inclusion criteria were (a) observational or intervention studies in which overweight/obesity in the context of youth with T1D was examined; (b) physical activity or lifestyle factors were reported; and (c) participants were aged ≥ 18 years. We focused this review on youth because childhood and adolescence is a time when diabetes self-management skills are learned and lifelong behavioral habits are formed (Bandura, 2004; Schilling, Grey, & Knafl, 2002), and overweight youth are much more likely to be overweight adults (Field, Cook, & Gillman, 2005).

Exclusion criteria were (a) studies of drug therapies or surgical interventions; (b) reviews or research that did not present original findings; (c) youth with secondary causes of obesity, such as steroid use; (d) weight not calculated using an objective measure; and (e) studies focused on celiac disease or eating disorders. We excluded studies that identified eating disorders as the outcome or explanatory variable because disordered eating is a compensatory behavior for weight control, which is not relevant given the purpose of this review, but it is not uncommon in patients with T1D (Lawrence et al., 2008).

Data extraction was facilitated by the use of a data display matrix to ascertain reliable and consistent data from the sample of studies. Study and location, sample size, participant

characteristics (age, gender, race/ethnicity, diabetes duration, glycosylated hemoglobin [HbA1c]), weight status, study design, type of health behavior/outcome variables (physical activity, sedentary behavior, sleep, diet), and main findings pertinent to physical activity or lifestyle and overweight/obesity were abstracted by the first author.

RESULTS

There were 685 articles identified during the literature review and imported into Endnote software. Duplicate studies were removed via the Endnote duplicate function and any remaining duplicates were manually removed ($n = 143$). Thorough review of all 542 article titles and abstracts was conducted by two reviewers (KEM and RW); disagreement was resolved by discussion. Most studies were deemed ineligible for full-text review because of lack of an explicit focus on body weight and/or physical activity or lifestyle factors. Several manuscripts on eating disorders or celiac disease were also considered ineligible.

In total, 21 observational and intervention studies underwent complete review. After employing inclusion and exclusion criteria to the full manuscripts, 13 studies were excluded because of lack of findings related to overweight or obesity and/or physical activity or lifestyle, and one was excluded because the study focused on eating disorders. In total, seven manuscripts met inclusion criteria for our review, including the one publication from a nursing journal (Estrada, Danielson, Drum, & Lipton, 2012). No additional manuscripts were identified from reviewing the reference lists of the articles included in this review.

Study sample sizes ranged from 19 to 723 participants, and about half of the studies (4/7) had a sample size fewer than 50 participants. Two studies were conducted in the United States, and the remainder in European countries. There were five studies that employed observational methodology, and two tested an intervention. The intervention studies were also the oldest, having been conducted before the year 2000. In terms of participant characteristics, girls were the primary subjects in two studies, whereas four studies had an equal representation of boys and girls, and in one study gender was not reported (Semiz, Bilgin, Bundak, & Bircan, 2000). The age range varied from 4 to 18 years, but for those studies that reported the mean age, most focused on the preadolescent to adolescent years of 11–16 years. In only one study was a diverse sample in terms of race/ethnicity reported (Estrada et al., 2012). Diabetes duration ranged from an average of 3.7 to 7.4 years, and mean HbA1c levels ranged from 7.5% to 13.1%, whereas the American Diabetes Association recommends levels <8.0% in this age group (Silverstein et al., 2005). The prevalence of overweight/obesity ranged from 12.5% to 33.3%, and in all but one study (Galli-Tsinopoulou, Grammatikopoulou, Stylianou, Kokka, & Emmanouilidou, 2009), more than 20% of participants were overweight or obese. One of the intervention studies recruited only obese participants (Thomas-Dobersen, Butler-Simon, & Fleshner, 1993). Participant and study characteristics are identified in Table 3.1.

Physical activity ($n = 1$) and lifestyle behaviors including sedentary behavior ($n = 2$), sleep ($n = 1$), and diet ($n = 3$) were explored in the observational studies. In one study, three of these health behaviors were examined (Overby et al., 2009). Physical activity and overweight/obesity in youth with T1D was considered only in one study in which moderate

to vigorous activity was assessed with a self-report questionnaire followed by the allocation of metabolic equivalent values to activities (Overby et al., 2009). No association was found with time spent on physical activity and overweight; however, the study is limited by the use of a self-report questionnaire that had not been validated across the entire age span of the sample.

The relationship between sedentary behavior and overweight/obesity was reported in two of the observational studies. In both studies, self-report questionnaires were used to estimate the duration and frequency of screen time in youth with T1D. More time watching television and videos was correlated with a higher BMI, higher percentage of body fat, lower levels of protective lipoproteins and apolipoproteins, and higher risk of insulin resistance in a sample of girls (Heyman et al., 2012). Similarly, in another study of boys and girls, youth who watched more than 1 hr of television per day had higher odds of being overweight than those who watched television less than 1 hr per day, even after adjustment for age, gender, physical activity, and having breakfast and dinner (Overby et al., 2009).

Sleep behavior was examined in one study to determine its relationship with obesity, diabetes, and insulin resistance. More than one-third of the participants in this study were found to be overweight or obese, the highest prevalence found across the studies in this review. Using a self-report questionnaire, the authors established that regular napping was significantly and inversely associated with characteristics of overweight, including high BMI, high percentage of body fat, and high waist circumference (Estrada et al., 2012).

Dietary intake was the most often studied obesity-related lifestyle behavior. In all three studies that investigated diet, a self-report measure was used to obtain dietary intake estimates. Two of these studies resulted in the finding that youth who skipped breakfast had higher odds of being overweight compared to those who had breakfast almost every day (Overby et al., 2009; Overby et al., 2008). Similarly, those who had a regular meal pattern of eating dinner 6–7 times per week had lower odds of being overweight than those who ate dinner 0–5 times per week (Overby et al., 2009), and some show that regular meals are also related to metabolic control (Overby, Margeirsdottir, Brunborg, Andersen, & Dahl-Jorgensen, 2007). In another study, it was found that when dietary fat intake was plotted against BMI, overweight youth had a dietary fat range from approximately 100 to 138 g, which is higher than the recommended daily intake (Bantle et al., 2006; Galli-Tsinopoulou et al., 2009).

Two intervention studies were included in this review, and the outcomes of both studies included physical activity and dietary intake. In one study, a 14-week family-based behavior modification program adapted for obese adolescents with T1D was evaluated (Thomas-Dobersen et al., 1993). The intervention employed cognitive, behavioral, and affective techniques to promote modifications in diet, exercise, communication, and affect among obese youth (95% girls) and their parents with T1D (Mellin, Slinkard, & Irwin, 1987). Participants were recruited from a diabetes clinic, with 11 participants enrolled in the intervention arm and nine controls were matched from those who received routine care from the clinic. All participants were obese at baseline and data were collected at baseline, 3 months and 15 months. At the 3- and 15-month intervals, the intervention group reported

improved weight management knowledge ($p<.01$) and obesity-related behavior changes, including better dietary intake and physical activity ($p<.05$); the comparison group indicated improved obesity-related behaviors at both time points ($p<.05$). Although there was no difference between groups on weight loss at 3 months, there was a mean 3% relative weight loss at the 15-month time point in the intervention group, whereas the comparison group gained 0.9% relative weight (Thomas-Dobersen et al., 1993). Although this weight loss outcome appears promising, the small number of participants, retention issues, high variability of total weight loss, and the lack of a randomized design limit the applicability of findings.

The effectiveness of a Turkish diabetes camp for youth with T1D aimed to balance insulin dosage with activity levels and food intake was evaluated in the other intervention study reviewed. Using a pretest–posttest design without a comparison group, the intervention delivered during a 10-day camp used social physical activities and food educational programs. There were 28 adolescents enrolled, 8 of whom were overweight or obese. The mean weight loss was 0.9 kg after the first 10 days of camp (Semiz et al., 2000). Gender and statistical significance of the weight loss or sustainability was not reported.

SUMMARY AND IMPLICATIONS

Although based on a small number of observational and intervention studies included in this review, the data indicate that both overweight and obesity are rising in the population of youth with T1D and that the rates now mirror that of the general population (Liu et al., 2010). Indeed, the more recent studies included in this review demonstrated a high prevalence of overweight/obesity among youth with T1D, ranging from 12.5% to 33.3%. However, the prevalence may be less variable than this range suggests because all but one study had a mean overweight rate of 20.0% or more, although an epidemiologic review is needed to confirm this observation. Nevertheless, the high prevalence of overweight is concerning in that overweight/obesity in combination with T1D might contribute to development of double diabetes, in addition to other obesity-related complications.

Despite the limited number of studies, this review has identified what is known about obesity-related risk factors, including physical activity, sedentary behavior, sleep, and diet in youth with T1D. In brief, the observational studies yielded findings that overweight in youth with T1D was associated with infrequent napping (Estrada et al., 2012), increased screen time (Heyman et al., 2012; Overby et al., 2009), and skipping breakfast (Overby et al., 2009; Overby et al., 2008) and dinner (Overby et al., 2009) but was surprisingly not related to time spent engaging in physical activities (Overby et al., 2008). With the exception of the latter finding, these observations are largely congruent with youth in general, but must be interpreted with caution because objective measures were not used to assess behavior, sample sizes were generally small, and important participant characteristics were not reported. Nevertheless, the identification of these obesity-related behaviors in the real-world setting points to potential lifestyle modification targets for weight prevention and management in youth with T1D.

Two intervention studies were also identified in which physical activity and dietary change were used to improve weight and glycemic control in youth with T1D (Semiz et al., 2000; Thomas-Dobersen et al., 1993). In both studies, a modest weight loss of 0.9 kg after 10 days and 3% of relative weight after 15 months were reported (Semiz et al., 2000; Thomas-Dobersen et al., 1993). Again, however, the studies were limited by small sample sizes, retention issues, and missing participant characteristics that challenge the applicability of the results to a larger population. Nonetheless, these two studies suggest that weight-related interventions can have a positive impact on health behaviors and weight loss, along with other diabetes-specific health outcomes, such as improved glycemic control.

As is inherent with any review, several limitations exist. Although we believe we have conducted an exhaustive search, it is possible that some studies were not included either because of publication or selection bias. However, this may be mitigated since no additional manuscripts were identified from searching the reference lists. As mentioned before, one should take caution in the generalizability of many of these findings because they may have been compromised because of poor study quality.

Implications for Future Research and Practice

In light of this review, it is clear that more research is needed to address the role of the entire “activity spectrum,” including physical activity, sedentary behavior, and sleep on youth with T1D who are overweight or obese. For instance, although it is known that fear of hypoglycemia is a common barrier to participation in physical activity (Brazeau et al., 2008; Di Battista et al., 2009; Nordfeldt & Ludvigsson, 2005), its effects may be compounded for youth who are overweight or obese and already have a less positive attitude toward physical activity (Deforche, De Bourdeaudhuij, & Tanghe, 2006). Furthermore, youth with T1D may actually be predisposed to excess weight gain by merit of supplementing carbohydrates before, during, and after engagement with physical activities in order to avoid a hypoglycemic event. Understanding the role of sedentary behaviors, and decreasing screen time in particular, may be one intervention pathway that leads to expending calories without compromising variability in blood glucose levels. Overweight and obesity may also have unique implications for sleep in youth with T1D as well. Studies of children and adolescents have found that sleep duration is inversely associated with overweight in youth (Eisenmann, Ekkekakis, & Holmes, 2006), and excessive weight is related to an increased risk of sleep problems (Beebe et al., 2007). Youth with T1D frequently report altered sleep patterns because of nocturnal hypoglycemia (Beregszaszi et al., 1997) and variation in blood glucose (Pillar et al., 2003), and thus they may be at higher risk for overweight than those without diabetes, or alternatively may experience poor sleep quality because of both excessive weight and having T1D.

In the future, studies in the field need to assure adequate representation of boys and girls from geographically diverse locations. Furthermore, use of objective measures of health behaviors in addition to self-report measures is highly recommended. Although T1D is less common in Black and Latino populations, compared to T2D, it will be important to study these questions in youth from various backgrounds because insulin resistance tends to be worse at higher BMI in obese Latino and Black youth compared to White youth, and they

have among the highest prevalence of overweight (Holl, Jaser, Womack, Jefferson, & Grey, 2011; Ogden, Flegal, Carroll, & Johnson, 2002). Indeed, only one study in our sample reported an ethnically diverse sample (Estrada et al., 2012). To build the foundation for robust and efficacious interventions, various study designs should be considered, including qualitative, descriptive, correlational, and longitudinal designs.

Nurses and diabetes educators play a critical role in helping youth develop positive lifestyle behaviors to address the prevalent problem of overweight and obesity in youth with T1D. Because the problem of overweight in these youth is relatively new, clinical care has focused more on assuring good metabolic control and accurate carbohydrate counting than weight control. Less attention has been paid to issues related to physical activity, sedentary behavior, and sleep. For preventive efforts to avoid the deleterious effects of overweight and obesity in youth with T1D, health professionals should incorporate health-promoting guidelines that are recommended for all youth, while being especially attentive to the specific concerns of already overweight and obese youth and with T1D treatment. These recommendations include 60 min or more of moderate to vigorous physical activity per day (Strong et al., 2005; World Health Organization, 2010), fewer than 2 hr of screen time per day (American Academy of Pediatrics, 2001), and more than 9 hr of sleep per night (National Sleep Foundation, 2013). Furthermore, assessment of such health behaviors should be conducted regularly using standardized assessment tools so that youth and parents can be helped to promote and integrate health behaviors into their lives. Nurse scientists are also poised to conduct this type of research, yet only 1.5% of the 542 abstracts were published in nursing journals.

In summary, given the high prevalence of overweight and obesity in youth with T1D, there is a need for further research to explore the antecedents and consequences of excessive weight gain in youth with T1D. Although this review has identified potential lifestyle modification targets for weight prevention and management—including physical activity, sedentary behavior, and sleep—additional studies are needed to inform effective interventions for this vulnerable population.

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TABLE 3.1
Articles Meeting Inclusion Criteria for Overweight/Obesity in Youth With Type 1 Diabetes

Authors, Country	Primary Aim	Study Design	Participant Characteristics ^a	Health Behavior, Measurement	Results ^d
Observational Studies					
Estrada et al., 2012 USA	To examine sleep in families of individuals with T1D and the relationship of sleep with obesity, diabetes, and insulin resistance	Cohort/Cross-sectional	N: 78 Girls (%): 53 Age (mean, yr): 14.4±6.3 Race/Ethnicity: 36% Non-Hispanic White; 24% Non-Hispanic Black; 13% Hispanic; 5% Other Diabetes Duration (yr): NR HbA1c (mean %): NR BMI (mean): 21.2 Overweight (%): 33.3%	Sleep; self-report of previous day's sleep and wake times and frequency of daytime naps	Irregular napping was associated with overweight/obese BMI (vs. normal BMI, $OR=0.19$, $p<0.01$), higher body fat (per 10 unit increase, $OR=0.39$, $p<0.01$), and 85th percentile WC (vs. <85th percentile WC, $OR=0.20$, $p=0.05$)
Galli-Tsinopoulou et al., 2009 Greece	To assess body composition, nutritional status, and diabetes control in youth with T1D	Case-control	N: 24 Girls (%): 50 Age (mean, yr): 4–18 Race/Ethnicity: NR Diabetes Duration (yr): 3.7±2.0 HbA1c (mean %): 7.6±1.5 BMI (mean): 20.0±3.3 Overweight (%): 12.5	Diet; self-report 3-day food diary	3 overweight participants had dietary fat that ranged from ~100g to ~138g
Heyman et al., 2012 France	To examine the relationship of both physical activity and dietary composition with body composition, and markers of lipid and apolipoprotein profiles and insulin resistance in T1D adolescent girls	Case-control	N: 19 Girls (%): 100 Age (mean, yr): 15.9±1.3 Race/Ethnicity: 100% Caucasian Diabetes Duration (yr): 7.4±4.5 HbA1c (mean %): 8.1±1.3 BMI (mean): 24.6±3.9 Overweight (%): NR	Sedentary behavior; self-report questionnaire	Girls who watched more TV/videos had higher BMI ($r=0.61$, $p<0.01$), higher body fat ($r=0.60$, $p<0.01$), lower levels of protective lipoproteins (HDL-C, $r=-0.68$, $p<0.001$) and apolipoproteins (ApoA1, $r=-0.74$, $p<0.001$), and higher risk of insulin resistance (leptin, $r=0.46$, $p<0.05$; adiponectin, $r=-0.53$, $p<0.05$).
Overby et al., 2008 Norway	To describe characteristics related to skipping meals and snacking events in youth with T1D after the general introduction of insulin pumps and multiple injection treatments	Case-control	N: 665 Girls (%): 50 Age (mean, yr): 11.4±3.5 Race/Ethnicity: NR Diabetes Duration (yr): 3.8±3.1 HbA1c (mean %): 7.9±1.1 BMI (mean): 19.8±3.8 Overweight (%): 26.0	Diet; self-report questionnaire of the number of meals per day, TV viewing, personal computer use, and parents' education	Youth who skipped breakfast had higher odds of overweight compared with those who had breakfast almost every day (Adj. $OR=2.8$, 95% CI 1.1–7.2, $p<0.05$)
Overby et al., 2009 Norway	To describe the physical activity and inactivity parameters associated with overweight in T1D	Cohort/cross-sectional	N: 723 Girls (%): 48 Age (mean, yr): 12.0 Race/Ethnicity: NR Diabetes Duration (yr): 4.6 HbA1c (mean %): 7.5–8.2	Physical activity, sedentary behavior, and diet; self-report questionnaires of the number of meals per day, frequency and intensity of activity, and transportation time. The questionnaire could estimate total amount of time	More than 1 hour of TV was associated with higher odds of overweight than TV less than 1 hour per day (Adj. $OR=2.52$, 95% CI 1.40–4.54, $p<0.01$); the same was observed for

Authors, Country	Primary Aim	Study Design	Participant Characteristics ^a	Health Behavior, Measurement	Results ^a
Intervention Studies					
Semiz et al., 2000 Turkey	To evaluate the effectiveness of diabetes camp on diabetic children	Pretest–post-test evaluation without a comparison group. Intervention: 10-day camp with educational and social activity programs	N: 28 Girls (%): NR Age (mean, yr): 13.6±2.9 Race/Ethnicity: NR Diabetes Duration (yr): 5.1±3.3 HbA1c (mean %): 10.2±2.3 BMI (mean): NR Overweight (%): 28.6	Physical activity and diet: 10-day camp protocol aimed to balance insulin dosage with activity level (facilitated by social exercise programs) and food intake (facilitated by education program)	more than 2 hours of TV per day (<i>OR</i> =2.30, 95% CI 1.25–4.24, <i>p</i> =0.01). Eating breakfast 6–7 times a week had lower odds of overweight than eating breakfast 0–5 times per week (<i>OR</i> =0.48, 95% CI 0.23–0.99, <i>p</i> <0.05); the same was observed for eating dinner 6–7 times a week relative to eating dinner 0–5 times per week (<i>OR</i> =0.50, 95% CI 0.30–0.85, <i>p</i> =0.01). Physical activity was not associated with overweight
Thomas-Dobersen et al., 1993 USA	To apply a family-based behavior-modification program (SHAPEDOWN) adapted for T1D to a group of obese adolescents with T1D	Two-group repeated measures design. Intervention: Adapted 14-session behavior-modification program focusing on diet, exercise, and metabolic control Comparison: Standard nutrition care from diabetes clinic	N: 19 Girls (%): 95 Age (mean, yr): 13.9 (intervention), 15.2 (comparison) Race/Ethnicity: NR Diabetes Duration (yr): 4.6 (intervention), 6.5 (comparison) HbA1c (mean %): 12.2 (intervention), 13.1 (comparison) Overweight (%): 100.0	Physical activity and diet; self-report questionnaire of weight-related behaviors and nutrition knowledge	Intervention group increased weight management knowledge compared to comparison group (<i>p</i> <0.01). No change in relative weight at 3 months between groups; at 15 months the intervention group lost 3.0% and comparison group gained 0.9% of relative weight (<i>p</i> =NS)

Abbreviations: *N* = sample size; NR = not reported; BMI = body mass index; WC = waist circumference; T1D = type 1 diabetes; *OR* = odds ratio; CI = confidence interval; NS = not significant

^a Only characteristics and results tangential to the chapter's purpose were included.