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PSYCHOSOCIAL ASPECTS (SS JASER, SECTION EDITOR)

Medical and Psychological Considerations for Carbohydrate-Restricted Diets in Youth With Type 1 Diabetes

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Abstract

Purpose of Review Given the challenges achieving recommended glycemic targets in youth with type 1 diabetes (T1D), providers may consider recommending carbohydrate-restricted diets (CRDs) to optimize glycemic control. The goal of the present review is to describe relevant literature on the potential medical and psychosocial benefits and risks of CRDs in youth with T1D.

Recent Findings Limited data exist on the effects of CRDs in pediatric populations. Findings from studies with youth and adults are mixed; some indicate that CRDs may be associated with desirable medical outcomes, such as improved glycemic control and reduced HbA1c, which may contribute to positive psychological outcomes such as reduced diabetes distress and depressive symptoms. Others suggest that CRDs may also be associated with detrimental outcomes, including mineral deficiencies and suboptimal growth, and dietary restriction has been linked to greater diabetes distress, disordered eating, and diabetes management.

Summary More research is needed to evaluate benefits and risks of CRDs in youth. Providers should exercise caution when discussing CRDs with youth and families, particularly when considering CRDs for youth at elevated risk for eating disordered behavior.

Keywords Type 1 diabetes · Nutrition · Psychosocial · Glycemic control · Pediatric

Introduction

For people with type 1 diabetes (T1D), eating and nutrition are important aspects of diabetes management. While food is necessary for survival, optimizing dietary intake introduces additional challenges in the treatment of diabetes. In addition to encountering the cognitive burdens of calculating carbohydrates consumed for corresponding insulin needs, people with type 1 diabetes may compare their own eating with the eating habits of their peers without diabetes. Additionally, the increased risk for obesity and overweight among people with T1D [1, 2] may introduce additional food-related concerns.

From the seventeenth century through the discovery of insulin in 1921, severe restriction of calories and carbohydrates was standard of care for people with diabetes [3]. After the introduction of insulin therapy, "split-mixed" insulin regimens still required patients to eat fixed amounts of carbohydrates at set times for meals and snacks. The advent of modern insulin analogues facilitated the use of more flexible basal-bolus insulin regimens allowing patients to administer insulin in proportion to carbohydrates consumed. As a result, recommendations for carbohydrate consumption in T1D

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became less rigid. Qualitative research has demonstrated that youth with T1D, their parents, and adults with T1D appreciate the flexibility of modern insulin therapy, particularly the greater dietary choice permitted [4, 5]. However, loosening guidance for carbohydrate consumption may have contributed to weight gain and diminished the newer insulin analogs' ability to optimize glycemic control.

Currently, most dietary recommendations for people with T1D from national and international diabetes organizations are similar to guidelines for the general population [6] in endorsing a balanced diet from a variety of foods for optimal growth and development in children with T1D [7–9]. For example, the American Diabetes Association (ADA) and the International Society for Pediatric and Adolescent Diabetes (ISPAD) recommend obtaining carbohydrates from fruits, vegetables, legumes, dairy, and whole grains; consuming recommended daily amount of fiber; and limiting intake of sugar-sweetened beverages and trans fats [9, 10]. The most recent ADA nutrition guidelines state that there is no established "ideal" macronutrient mix of percent calories from carbohydrates, protein, and fat for all people with diabetes [7, 8]. The most recent ISPAD recommendations contend that carbohydrate intake should comprise 45 to 50% of total nutritional intake, with fat meeting < 35% of energy needs (saturated fat < 10%) and protein constituting 15 to 20% of caloric consumption [9]. Thus, as energy requirements increase as a child grows, the absolute amount of carbohydrates consumed in meals and snacks also increases. The consistent recommendation across organizations is to individually assess each child and family in tailoring nutritional goals and macronutrient requirements [7–9]. These organizations have not endorsed carbohydrate restriction in T1D.

Despite major medical and technological advances in diabetes management, achieving target glycemic control remains challenging, with less than 20% of youth achieving ADA glycemic target of HbA1c below 7.5% [11]. Thus, interventions to optimize glycemic control in T1D, particularly during adolescence, remain an area of high clinical importance. One area of investigation is the potential impact of diet on HbA1c. In a sample of 257 early adolescents with T1D, Mackey and colleagues [12•] reported that less than one-half met the ADA and ISPAD nutritional guidelines around energy intake from carbohydrates, proteins, and fats. Participants tended to consume a smaller portion of their daily energy intake from carbohydrates and protein than recommended and a greater portion from fats. Higher energy intake from fats was associated with higher HbA1c, and participants on flexible insulin regimens were more likely to meet HbA1c targets than those on conventional, fixed insulin dose regimens. Similarly, based on a sample of 119 pre-adolescents with T1D, Mehta and colleagues [13] described parent and youth self-reports of lower adherence to diabetes-specific diet recommendations directly correlated with higher HbA1c. Given the association of food intake with glycemic and weight outcomes [1], interventions targeting nutrition may have an important impact on health during childhood and adolescence.

Acknowledging the importance of nutritional counseling as part of multidisciplinary diabetes care, the *Diabetes Care and Education Dietetic Practice Group* [14] studied the impact of nutrition practice guidelines on patients' glycemic outcomes in a small national sample of dieticians. Participants were randomly assigned to either deliver usual care or incorporate contemporary nutrition practice guidelines into their clinical encounters. Dieticians in the Nutrition Practice Guidelines group reported spending more time with patients and focusing more on glycemic and weight-related goals than dieticians instructed to provide their usual care without additional instruction in incorporating nutritional guidelines. Adolescents and adults with T1D treated by the dieticians in the guidelines group had greater improvement in HbA1c than those with dieticians in the usual care group over 3 months. These findings suggest that nutritional guidelines have the potential to improve diabetes outcomes, particularly when dieticians have specific knowledge about the guidelines.

Within the study of nutrition on T1D outcomes, the potential impact of carbohydrate restriction is an active and controversial topic of research. Given the importance of nutritional approaches in diabetes management, the clinical and research implications of this topic are vast. With increased media attention on low-carbohydrate/high-fat diets (e.g., paleo, ketogenic diets) [15], clinicians and patients/families may be interested in considering such approaches as part of T1D management. Therefore, the purpose of this paper is to review the literature surrounding the psychological, behavioral, and medical implications of carbohydrate-restricting dietary approaches for youth with type 1 diabetes. When available, research from youth with T1D will be presented and reviewed. Additionally, data from adults with T1D will be presented and the implications for youth will be considered.

Carbohydrate Restriction in Type 1 Diabetes

Definitions of low carbohydrate diets vary greatly. The ADA previously defined low carbohydrate diets as those less than 130 g per day or 26% total energy intake from carbohydrate [16]. Feinman and colleagues [17] defined three categories of reduced-carbohydrate diets more specifically: (a) very low-carbohydrate ketogenic, in which carbohydrates are limited to 20–50 g per day or < 10% of total energy intake; (b) low-carbohydrate, in which carbohydrates are limited to < 130 g per day or < 26% of total energy intake; and (c) moderate-carbohydrate, in which carbohydrates are limited to 130–225 g per day or 26–45% of total energy intake. Some diabetes providers and dieticians recommend restricting carbohydrates to approximately 30 g/day by following structured meal

plans with low carbohydrate limits per meal (e.g., 6 g at breakfast, 12 g at lunch and dinner).

Potential Benefits of Carbohydrate-Restricted Diets

Medical Markers

Advocates of carbohydrate-restricted diets (CRDs) propose that carbohydrate restriction in T1D minimizes hyperglycemia and glycemic variability, and that reduced insulin requirements with low carbohydrate consumption mitigate the risk of hypoglycemia [18]. However, few studies evaluating the safety and effectiveness of carbohydrate-restricted diets in T1D management have been published. The EURODIAB cross-sectional study examined 3-day dietary records of 2079 individuals with T1D randomly enrolled from diabetes clinics, within defined strata for age, sex, and duration of diabetes. The investigators reported that a lower daily intake of carbohydrate was associated with lower HbA1c [19].

Most other studies have used small samples and are considered preliminary. In an observational study of 48 adults with T1D who attended an educational course on carbohydrate restriction, those who adhered to the program (about half of total participants) had lower HbA1c values over 4 years than did those who did not adhere (7.4% vs. 6.4%) [20]. In a cross-sectional study of 33 Japanese adults with T1D using continuous glucose monitors over 48 h, lower carbohydrate intake was associated with more time spent in euglycemia (70–180 mg/dL). Carbohydrate intake was not associated with time spent in hypoglycemia (< 70 mg/dL), but less time spent in hyperglycemia (> 180 mg/dL) was observed with lower carbohydrate intake [21]. Similarly, in a sample of ten Danish adults with T1D following low-carbohydrate (< 50 g/day) versus high-carbohydrate (≥ 250 g/day) diets for 1 week each in a random-order crossover study, participants spent 11% more time in euglycemia and had less glycemic variability during the low-carbohydrate week [22]. Mean glucose levels and cardiovascular markers did not differ across conditions. In a small randomized trial, ten free-living adults with T1D in New Zealand were randomly assigned to either a standard carbohydrate-counting course (no carbohydrate restriction) or to one that included instructions to follow a reduced carbohydrate diet. Participants counseled to eat a low-carbohydrate diet showed significantly reduced HbA1c levels and lower daily insulin requirements [23]. However, dietary recalls suggested that participants who consumed fewer carbohydrates did not alter fat or protein intake, resulting in an estimated 30% decrease in total daily calorie consumption from baseline. In contrast, there was a 4% reduction in calories among participants taught only to count carbohydrates. Therefore, it was impossible to determine whether the reduced HbA1c and insulin requirements were due to a change in carbohydrate or overall calorie intake [23]. Collectively, these investigations suggest potential glycemic benefit of CRDs, but the broader translation of these findings is limited by small sample sizes, short study durations, and suboptimal adherence to dietary plans. Further, most studies have been conducted with adults, which limits the degree to which these conclusions may apply to youth, a population with special challenges towards reaching target glycemia.

One large study included data about youth with T1D following a CRD approach. Lennerz and colleagues [24••] described information gathered from 316 youth and adults with self-reported T1D who participated in an online social media forum (called "TypeOneGrit") for individuals following a very low carbohydrate diet (mean self-reported daily carbohydrate intake of 36 ± 15 g). The authors corroborated participants' self-report of T1D from review with diabetes care providers and/or medical records, and reported 273 (86%) participants had suggestive evidence of T1D (e.g., insulin requirement, body weight, medical test results, and/or physician documentation of T1D diagnosis). HbA1c levels reported by participants who were parents of children with T1D were well below ADA glycemic target (5.71% ± 0.58%). Very low rates of adverse diabetes-related medical events were reported, with only two participants (1%) reporting a severe hypoglycemic event in the past year [24••]. In response to this study, Mayer-Davis and colleagues [25] published a commentary calling for caution in interpreting the results, largely due to the self-selected sample composed of people who were active on the online forum and the self-reported assessment of carbohydrate intake and HbA1c data. The commentary illustrates the preliminary nature of the research in this area and the important considerations around research rigor that are needed to draw conclusions about the impact of carbohydrate restriction nutritional approaches.

Psychological and Behavioral Markers

Limited published data exist about the potential psychological and behavioral benefits of CRDs in children with T1D. However, the medical benefits associated with CRDs described previously (e.g., stabilization of blood glucose levels, lower HbA1c) could have an indirect impact on mood, as glucose variability is associated with changes in mood, energy, and concentration [26]. For instance, data from continuous glucose monitors and momentary mood ratings in adults with T1D demonstrated decreases in positive mood ratings and increases in negative mood ratings when glucose values were higher [27]. Similarly, greater depression and anxiety symptoms have been independently positively associated with higher HbA1c, and when HbA1c decreased, depressive symptoms tended to improve even in the absence of behavioral health treatment [28].

CRDs may also be inherently satisfactory for some, leading to positive effects in other parts of everyday life. Youth with T1D may have positive perceptions about their diabetes care when following a CRD: in the online survey from the TypeOneGrit social media forum, participants (adults and parents of youth with T1D) reported high levels of overall health and satisfaction with diabetes management [24••]. In a study of adults with type 2 diabetes who followed a very low-carbohydrate ketogenic diet, participants reported reduced diabetes distress and less negative mood between meals after initiating the diet, as well as decreased carbohydrate and sweets craving, hunger, emotional eating, and eating disinhibition [29]. Although satisfaction with CRDs was not directly assessed, decreases in carbohydrate and sweets cravings when following this type of diet may suggest CRDs are satisfying for some individuals. Other "trickle down" effects may include greater ease of daily management if blood glucose levels are more consistent and predictable when following a CRD, such as needing to engage in fewer treatments for elevated or low glucose levels. Carbohydrate counting and meal flexibility using intensive insulin management (e.g., via insulin-to-carb ratio) for "normal eating" is associated with improved quality of life and satisfaction with diabetes care [30]; however, this has not been studied yet among youth with T1D following CRDs.

Potential Risks of CRDs

Medical Markers

Low-carbohydrate diets are not without controversy, and those skeptical of CRDs cite multiple concerns [25, 31]. In part due to the long-held belief that low-fat diets are most healthful, experts raise concerns that CRDs with a higher total fat content may lead to weight gain, hypertension, dyslipidemia, and cardiovascular disease or that carbohydrate restriction in T1D may cause increased risk of severe hypoglycemia due to depletion of glycogen stores impairing glucose counter-regulation [32]. An additional concern is potential increased risk of diabetic ketoacidosis secondary to excessive ketogenesis from fat metabolism. Yet, published data describing such events with CRD in T1D are lacking.

CRDs in children with T1D may result in low total caloric intake and mineral deficiencies leading to suboptimal growth. In a case series of six children with T1D in Australia and New Zealand adhering to CRDs, with daily carbohydrates among the different children ranging from approximately 20 to 90 g per day, de Bock and colleagues [31] reported that carbohydrate restriction in children with T1D can lead to growth failure and a higher-risk lipid profile. In the online survey of children in the TypeOneGrit Facebook group [24••], growth data at T1D diagnosis and following very low carbohydrate diet (mean 2.3-year duration) were available for a small subset of children ($n = 34$, 26%). The height z-score had decreased from 0.4 at T1D diagnosis to 0.2 following the start of a CRD ($P = 0.05$) raising the possibility that the CRD caused attenuation in linear growth.

Psychological and Behavioral Markers

Recommendations for dietary restriction in youth should be considered in the context of increased risk for developing disordered patterns of eating and weight control among children and adolescents with T1D [33, 34]. Individuals with T1D have bulimia nervosa at three times higher rates, and eating disorders not otherwise specified or subclinical eating disorder symptoms at two times higher rates than individuals without T1D [34]. Dietary restriction may contribute to binge eating behavior [35], and for youth with diabetes, binge eating may make it difficult to properly and consistently dose insulin, and contribute to glycemic variability as well as family conflict about dietary intake. Following a CRD may also add to the stress of feeling different from peers (social comparison) at mealtimes.

Given the increased rates of overweight and obesity in people with T1D [1], youth may consider trying a CRD with the goal of limiting insulin requirements to prevent weight gain or induce weight loss. CRDs for weight loss have grown in popularity in the media in recent years, and reduced carbohydrate intake to support weight loss may be discussed by diabetes providers [36]. Disordered eating behaviors (DEB) in people with T1D include insulin misuse or omission for weight control [34]. These behaviors can contribute to dangerous diabetes-related complications, including retinopathy and nephropathy [37], and to a threefold increased risk for mortality [38]. In one population-based study [39], as many as one-third of girls with T1D reported occasionally skipping insulin after overeating and one-fourth had clinically significant DEB. In a study of DEB among 83 adults with T1D, Merwin et al. [40] reported that insulin restriction was associated with heightened negative affect generally and about diabetes, and increases in anxiety and guilt before eating increased the likelihood of insulin restriction at their next meal. Additionally, insulin restriction was more likely when people broke a food "rule" [40]. Together, these findings suggest that restrictive eating practices may have implications for DEB and significant health complications. Individuals with T1D and eating-disordered purging via insulin restriction, colloquially known as "diabulimia," tend to report high levels of diabetes distress [41], depression, and emotion dysregulation [42]. For people with T1D and DEBs, the recommended treatment focuses on promoting more flexible eating patterns as well as decreasing frequency of insulin restriction [42].

Youth with diabetes whose parents and care providers enforce or advise a restrictive diet may also experience a

behavioral response to restriction that we call "treat insecurity," similar to the concept of food insecurity. Food insecurity is a well-documented phenomenon in which individuals with chronically unpredictable access to food are at greater risk of binge-eating and obesity, as well as weight self-stigma and compensatory behaviors [43]. If individuals do not know when their next meal is going to come, it may be adaptive to eat past the point of satiety when food is available. This has implications for health outcomes in children. For example, the imposition of restrictive feeding practices on children by parents has been associated with child overeating, eating in the absence of hunger, and higher child weight [44]. It may be particularly hard for youth if "off-limits" treats are kept in the home: restrictive feeding and home access to unhealthy foods has been associated with higher snacking among young children [45]. Similarly, "treat insecurity" for youth with T1D may also have implications for health. Children with T1D who do not know when they will again get access to sweets, high carbohydrate foods, or other "treat" foods due to restrictions on their intake may be prone to "sneaking" or hiding these foods. Given the covert nature of this food intake, they may not take insulin for these carbohydrate-rich items and thereby increase their risk for hyperglycemia.

Clinical situations related to restrictive diets in youth with T1D have not received much research attention, but may play a role in other behaviors or outcomes that could be problematic for T1D management. That is, some youth who are on CRDs may engage in maladaptive diabetes management behaviors in order to have access to carbohydrates or sugary foods. For instance, youth may purposely over-administer insulin in order to create a situation that will allow them to treat the resulting low blood glucose with candy or another sugary treat. Children might manipulate blood glucose checks, such as insufficiently wiping alcohol from their finger to produce a falsely low number, either to hide a high blood glucose value or to justify eating fast-acting glucose to "treat" the low value. Youth who worry about parental reactions to high glucose values might avoid telling their parent the correct number or avoid checking their glucose altogether. In the long term, youth who grow up with environmental limitations on their dietary intake may lack opportunities for problem-solving when encountering high-carbohydrate or other treat foods in social situations, contributing to future difficulties in moderating or managing a wide range of foods. Growing up with consistent labeling of "good" and "bad" foods may contribute to eating disordered cognitions and potentially even contribute to insulin restriction, which tends to be more likely in adults who believe themselves to have broken food "rules" [40]. In addition to the potential for DEB, youth who follow CRDs may experience emotional distress: higher dietary restraint has been linked to high diabetes distress, elevated depressive symptoms, body and weight concerns, lower self-esteem, and poorer self-efficacy [46•].

Adherence to treatment recommendations for T1D is very challenging, especially in adolescence [47, 48]. As noted earlier, Mackey et al. [12•] reported low adherence rates to ADA and ISPAD nutritional guidelines among early adolescents with T1D: around 50% of parents reported their adolescents followed the recommended nutrition plan < 75% of the time and < 50% of adolescents reported meeting ADA and ISPAD recommendations for calories from macronutrients. There are no data on adherence to CRDs, but adherence rates may be lower with more restrictive diets. Indeed, qualitative data from youth age 8 to 21 and their parents indicate that some families make efforts to restrict foods that raise blood glucose (i.e., those higher in carbohydrates including fruits, grains, and legumes), which may result in less balanced nutritional patterns [4].

Debate about dietary intake and youth adherence to CRDs could also contribute to diabetes-related family conflict, which is an important predictor of HbA1c [49]. For instance, caregivers may attribute hyperglycemia to dietary causes (e.g., "Why is your blood glucose high? What did you eat?"), leading to youth with T1D feeling blamed or ashamed for having an elevated blood glucose level or for their eating practices. Youth with diabetes may also perceive unfairness or social isolation if other family members or friends have access to foods and are told they cannot eat these items. Of note, youth with and without T1D have remarkably similar reported quality of life, except when there is high diabetes-related family conflict [50], underlining the importance of positive communication in the context of diabetes management. More research is needed to determine the degree to which diet restrictiveness and individual factors (e.g., age, food-related motivations) are related to nutritional adherence and psychosocial or family outcomes.

Conclusions

Given the rising popularity of CRDs for optimizing glucose control in T1D, providers should be aware of the potential associated medical and psychosocial benefits and risks and should consider asking directly about their patients' use of CRDs during clinical encounters. Preliminary data from adults suggests that CRDs may result in near normal HbA1c without increased risk for severe hypoglycemia, and limited data suggest the same for children and adolescents. However, no research has evaluated the potential mental health or behavioral outcomes—positive or negative—associated with using CRDs in youth with T1D. Youth with T1D adhering to CRDs should be carefully monitored for adverse effects in growth, cardiovascular metabolism, and emotional/behavioral health. Further, given the increased risk for DEB in youth with T1D, any diet that is perceived as restrictive should be recommended with caution and monitored carefully. A CRD should be stopped, modified, or relaxed if the child is

experiencing clear signs of growth failure, worsening dyslipidemia, or emotional distress or burnout from the restrictive diet.

As per ADA and ISPAD recommendations, the proportion of macronutrients should be individualized for youth with T1D. Diabetes care teams are advised to provide a supportive and flexible tone in educating families on benefits and risks of various approaches to diet, including CRDs. In addition to the potential medical benefit of lower HbA1c with CRDs, for some there may be a psychological benefit of improved mood and less diabetes management burden. However, given the elevated risk for DEB in youth with T1D and the potential for CRDs to exacerbate maladaptive focus on restrictive eating, providers should exercise caution in how they discuss carbohydrate intake and restriction. For instance, among individuals with overweight or obesity, weight-related stigma from healthcare providers is well-documented [51] and associated with a range of maladaptive outcomes, including DEB [52]. Among people with T1D in the Lennerz et al. [24••] study, only half agreed their diabetes care providers were supportive of their CRDs. Together, this highlights the importance of providers using thoughtful language and tone when discussing dietary choices with patients and their families. Asking directly about concerns related to diet and any approaches they have tried, including CRDs, may encourage an open discussion in which providers can help patients and families make choices about eating plans that are aligned with their goals and capabilities, and to prevent unsafe consequences.

Family interactions related to eating and glycemic outcomes should be considered clinically, by promoting parent–child collaboration around dietary choices, in order to maximize family support and minimize the risk for family conflict that could undermine optimal diabetes management. Using a collaborative approach may be helpful, in which providers elicit input from both parent and child on their interest in trying CRD and encourage all family members being in agreement on any dietary changes before implementing them. People may follow specific dietary goals or restrictions more consistently and perceive those dietary rules as less onerous if everyone in the household follows these "rules." For youth with T1D, children's diets have been linked with parent diet quality [53], suggesting that children learn from their parents how to eat. Children may find it easier to apply eating guidelines such as CRDs if they have expressed an interest in trying a CRD and if parents are following the approach as well.

In addition to broadening our knowledge of potential psychological benefits and detriments associated with CRDs in youth with T1D, more investigation is needed to understand (1) individual and family factors that cause some to thrive or suffer while following a CRD, (2) what amount of reduction in carbohydrates may be most appropriate to consider for youth with T1D, and (3) acceptability of CRDs among youth who are encouraged to follow them.

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Compliance with Ethical Standards

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References

Papers of particular interest, published recently, have been highlighted as:
- • Of importance
- •• Of major importance

1. Driscoll KA, Corbin KD, Maahs DM, Pratley R, Bishop FK, Kahkoska A, et al. Biopsychosocial aspects of weight management in type 1 diabetes: a review and next steps. Curr Diab Rep. 2017;17(8):58.
2. Foster NC, Beck RW, Miller KM, Clements MA, Rickels MR, LA DM, et al. State of type 1 diabetes management and outcomes from the T1D Exchange in 2016-2018. Diabetes Technol Ther. 2019;21(2):66–72.
3. King KM, Rubin G. A history of diabetes: from antiquity to discovering insulin. Br J Nurs. 2003;12(18):1091–5.
4. Mehta SN, Haynie DL, Higgins LA, Bucey NN, Rovner AJ, Volkening LK, et al. Emphasis on carbohydrates may negatively influence dietary patterns in youth with type 1 diabetes. Diabetes Care. 2009;32(12):2174–6.
5. Rankin D, Cooke DD, Clark M, Heller S, Elliott J, Lawton J, et al. How and why do patients with type 1 diabetes sustain their use of flexible intensive insulin therapy? A qualitative longitudinal investigation of patients' self-management practices following attendance at a Dose Adjustment for Normal Eating (DAFNE) course. Diabet Med. 2011;28(5):532–8.
6. U.S. Department of Health and Human Services and U.S. Department of Agriculture. 2015–2020 dietary guidelines for Americans. 8th ed. 2015. Available from: http://health.gov/dietaryguidelines/2015/guidelines. Accessed 9 Jan 2019.
7. American Diabetes Association. (5) Lifestyle management: standards of medical care–2019. Diabetes Care. 2019;42(Suppl 1):S46–60.
8. American Diabetes Association. (13)Children and adolescents: standards of medical care in diabetes—2019. Diabetes Care. 2019;42(Suppl 1):S148–S64.
9. Smart CE, Annan F, Higgins LA, Jelleryd E, Lopez M, Acerini CL. ISPAD clinical practice consensus guidelines 2018: nutritional management in children and adolescents with diabetes. Pediatr Diabetes. 2018;19(27):136–54.
10. Evert AB, Boucher JL, Cypress M, Dunbar SA, Franz MJ, Mayer-Davis EJ, et al. Nutrition therapy recommendations for the management of adults with diabetes. Diabetes Care. 2014;37(1):S120–S43.

11. Miller KM, Foster NC, Beck RW, Bergenstal RM, DuBose SN, Di Meglio LA, et al. Current state of type 1 diabetes treatment in the U.S.: updated data from the T1D Exchange clinic registry. Diabetes Care. 2015;38(6):971–8.
12.• Mackey ER, O'Brecht L, Holmes CS, Jacobs M, Streisand R. Teens with type 1 diabetes: how does their nutrition measure up? J Diabetes Res. 2018;5094569:9 **This paper describes adherence rates to macronutrients among adolescents with T1D following contemporary diabetes treatment plans and the association with glycemic outcomes. Results raise questions about the degree to which people following CRDs may adhere to the stringent guidelines.**
13. Mehta SN, Volkening LK, Anderson BJ, Nansel T, Weissberg-Benchell J, Wysocki T, et al. Dietary behaviors predict glycemic control in youth with type 1 diabetes. Diabetes Care. 2008;31(7):1318–20.
14. Kulkarni K, Castle G, Gregory R, Holmes A, Leontos C, Powers M, et al. Nutrition practice guidelines for type 1 diabetes mellitus positively affect dietician practices and patient outcomes. The Diabetes Care and Education Dietetic Practice Group. J Am Diet Assoc. 1998;98(1):62–70.
15. Ansel K. What you need to know about the ketogenic diet [Internet]. Diabetes forecast [updated Jan 2019]. Available from: http://www.diabetesforecast.org/2019/01-jan-feb/what-you-need-to-know-about.html. Accessed 9 Jan 2019.
16. American Diabetes Association. American Diabetes Association Nutrition recommendations and interventions for diabetes: a position statement of the American Diabetes Association. Diabetes Care. 2013;36(1):S12–32.
17. Feinman RD, Pogozelski WK, Astrup A, Bernstein RK, Fine EJ, Westman EC, et al. Dietary carbohydrate restriction as the first approach in diabetes management: critical review and evidence base. Nutrition. 2015;31(1):1–13.
18. Bernstein RK. Dr. Bernstein's diabetes solution: the complete guide to achieving normal blood sugars. 4th ed. Boston, MA: Little, Brown & Company; 2011.
19. Buyken AE, Toeller M, Heitkamp G, Irsigler K, Holler C, Santeusanio F, et al. Carbohydrate sources and glycaemic control in type 1 diabetes mellitus. EURODIAB IDDM Complications Study Group. Diabet Med. 2000;17(5):351–9.
20. Nielsen JV, Gando C, Joensson E, Paulsson C. Low carbohydrate diet in type 1 diabetes, long-term improvement and adherence: a clinical audit. Diabetol Metab Syndr. 2012;4(1):23.
21. Ayano-Takahara S, Ikeda K, Fujimoto S, Asai K, Oguri Y, Harashima S, et al. Carbohydrate intake is associated with time spent in the euglycemic range in patients with type 1 diabetes. J Diabetes Investig. 2015;6(6):678–86.
22. Ranjan A, Schmidt S, Damm-Frydenberg C, Holst JJ, Madsbad S, Nørgaard K. Short-term effects of a low carbohydrate diet on glycaemic variables and cardiovascular risk markers in patients with type 1 diabetes: a randomized open-label crossover trial. Diabetes Obes Metab. 2017;19(10):1479–84.
23. Krebs JD, Parry Strong A, Cresswell P, Reynolds AN, Hanna A, Haeusler S. A randomised trial of the feasibility of a low carbohydrate diet vs standard carbohydrate counting in adults with type 1 diabetes taking body weight into account. Asia Pac J Clin Nutr. 2016;25(1):78–84.
24.•• Lennerz BS, Barton A, Bernstein RK, Dikeman RD, Diulus C, Hallberg S, et al. Management of type 1 diabetes with a very low-carbohydrate diet. Pediatrics. 2018;141(6):e20173349 **Survey respondents from a community of adults and youth with T1D who followed a very low carbohydrate diet reported having low HbA1c and few adverse events. This is one of the first and largest studies in this area and has sparked controversy in the scientific community.**
25. Mayer-Davis EJ, Laffel LM, Buse JB. Management of type 1 diabetes with a very low-carbohydrate diet: a word of caution. Pediatrics. 2018;142(2):e201865007.
26. Rausch JR. Measures of glycemic variability and links with psychosocial functioning. Curr Diab Rep. 2010;10(6):415–21.
27. Hermanns N, Scheff C, Kulzer B, Weyers P, Pauli P, Kubiak T, et al. Association of glucose levels and glucose variability with mood in type 1 diabetic patients. Diabetologia. 2007;50(5):930–3.
28. Buchberger B, Huppertz H, Krabbe L, Lux B, Mattivi JT, Siafarikas A. Symptoms of depression and anxiety in youth with type 1 diabetes: a systematic review and meta-analysis. Psychoneuroendocrinology. 2016;70:70–84.
29. Saslow LR, Kim S, Daubenmier JJ, Moskowitz JT, Phinney SD, Goldman V, et al. A randomized pilot trial of a moderate carbohydrate diet compared to a very low carbohydrate diet in overweight or obese individuals with type 2 diabetes mellitus or prediabetes. PLoS One. 2014;9(4):e91027.
30. Speight J, Amiel SA, Bradley C, Heller S, Oliver L, Roberts S, et al. Long-term biomedical and psychosocial outcomes following DAFNE (Dose Adjustment For Normal Eating) structured education to promote intensive insulin therapy in adults with suboptimally controlled type 1 diabetes. Diabetes Res Clin Pract. 2010;89(1):22–9.
31. de Bock M, Lobley K, Anderson D, Davis E, Donaghue K, Pappas M, et al. Endocrine and metabolic consequences due to restrictive carbohydrate diets in children with type 1 diabetes: an illustrative case series. Pediatr Diabetes. 2018;19(1):129–37.
32. Leow ZZX, Guelfi KJ, Davis EA, Jones TW, Fournier PA. The glycaemic benefits of a very-low-carbohydrate ketogenic diet in adults with type 1 diabetes mellitus may be opposed by increased hypoglycaemia risk and dyslipidaemia. Diabet Med. 2018;35:1258–63. https://doi.org/10.1111/dme.13663.
33. Mannucci E, Rotella F, Ricca V, Moretti S, Placidi GF, Rotella CM. Eating disorders in patients with type 1 diabetes: a meta-analysis. J Endocrinol Investig. 2005;28:417–9.
34. Nielsen S. Eating disorders in females with type 1 diabetes: an update of a meta-analysis. Eur Eat Disord Rev. 2002;10:241–54.
35. De Young KP, Lavender JM, Crosby RD, Wonderlich SA, Engel SG, Mitchell JE, et al. Bidirectional associations between binge eating and restriction in anorexia nervosa. An ecological momentary assessment study. Appetite. 2014;83:69–74.
36. Ebling CB, Feldman AH, Wong JWM, Steltz SK, Ludwig DS. Effects of a low carbohydrate diet on energy expenditure during weight loss maintenance: randomized trial. BMJ. 2018;14(363):k4583.
37. Takii M, Uchigata Y, Tokunaga S, Amemiya N, Kinukawa N, Nozaki T, et al. The duration of severe insulin omission is the factor most closely associated with the microvascular complications of type 1 diabetic females with clinical eating disorders. Int J Eating Disord. 2008;41(3):259–64.
38. Goebel-Fabbri AE, Fikkan J, Franko DL, Pearson K, Anderson BJ, Weinger K. Insulin restriction and associated morbidity and mortality in women with type 1 diabetes. Diabetes Care. 2008;31(3):415–9.
39. Wisting L, Froisland DH, Skrivarhaug T, Dahl-Jorgensen K, Ro O. Disturbed eating behavior and omission of insulin in adolescents receiving intensified insulin treatment: a nationwide population-based study. Diabetes Care. 2013;36(11):3382–4.
40. Merwin RM, Dmitrieva NO, Honeycutt LK, Moskovich AA, Lane JD, Zucker NL, et al. Momentary predictors of insulin restriction among adults with type 1 diabetes and eating disorder symptomatology. Diabetes Care. 2015;38(11):2025–32.
41. Staite E, Zaremba N, Macdonald P, Allan J, Treasure J, Ismail K, et al. Diabulima' through the lens of social media: a qualitative review and analysis of online blogs by people with type 1 diabetes mellitus and eating disorders. Diabet Med. 2018;35(10):1329–36.

42. Young-Hyman DL, Peterson CM, Fischer S, Markowitz JT, Muir AB, Laffel LM. Depressive symptoms, emotion dysregulation, and bulimic symptoms in youth with type 1 diabetes: varying interactions at diagnosis and during transition to insulin pump therapy. J Diabetes Sci Technol. 2016;10(4):845–51.
43. Becker CB, Middlemass K, Taylor B, Johnson C, Gomez F. Food insecurity and eating disorder pathology. Int J Eat Disord. 2017;50(9):1031–40.
44. Faith MS, Scanlon KS, Birch LL, Francis LA, Sherry B. Parent-child feeding strategies and their relationships to child eating and weight status. Obesity. 2004;12(11):1711–22.
45. Blaine RE, Kachurak A, Davison KK, Klabunde R, Fisher JO. Food parenting and child snacking: a systematic review. Int J Behav Nutr Phys Act. 2017;14(1):146.
46.• Powers MA, Richter SA, Ackard DM, Craft C. Diabetes distress among persons with type 1 diabetes: associations with disordered eating, depression, and other psychological health concerns. Diabetes Educ. 2017;43(1):105–13 **This study reported that people with T1D who had higher diabetes distress also reported higher dietary restraint and higher HbA1c, as well as other psychosocial concerns. Findings suggest possible psychosocial correlates of following CRDs.**
47. Helgeson VS, Honcharuk E, Becker D, Escobar O, Siminerio L. A focus on blood glucose monitoring: relation to glycemic control and determinants of frequency. Pediatr Diabetes. 2011;12(1):25–30.
48. Hilliard ME, Mann KA, Peugh JL, Hood KK. How poorer quality of life in adolescence predicts subsequent type 1 diabetes management and control. Patient Educ Couns. 2013;91(1):120–5.
49. Hilliard ME, Guilfoyle SM, Dolan LM, Hood KK. Prediction of adolescents' glycemic control 1 year after diabetes-specific family conflict: the mediating role of blood glucose monitoring adherence. Arch Pediatr Adolesc Med. 2011;165(7):624–9.
50. Laffel LM, Connel A, Vangsness L, Goebel-Fabbri A, Mansfield A, Anderson BJ. General quality of life in youth with type 1 diabetes: relationship to patient management and diabetes-specific family conflict. Diabetes Care. 2003;26(11):3067–73.
51. Alberga AS, Pickering BJ, Alix Hayden K, Ball GD, Edwards AL, Jelinski S, et al. Weight bias reduction in health professionals: a systematic review. Clin Obes. 2016;6(3):175–88.
52. Puhl R, Suh Y. Health consequences of weight stigma: implications for obesity prevention and treatment. Curr Obes Rep. 2015;4(2):182–90.
53. Lipsky LM, Haynie DL, Liu A, Nansel TR. Resemblance of diet quality in families of youth with type 1 diabetes participating in a randomized controlled behavioral nutrition intervention trial in in Boston, MA (2010-2013): a secondary data analysis. J Acad Nutr Diet. 2019;119(1):98–105.