Disordered Eating Behaviors in Adolescents with Type 1 Diabetes

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Doctoral thesis dissertation

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to apply for the degree of doctor at the University of Barcelona

DISORDERED EATING BEHAVIORS IN ADOLESCENTS WITH TYPE 1 DIABETES

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1 TABLE OF CONTENTS

2 LIST OF ABBREVIATIONS

ADA	American Diabetes Association
BE	Binge Eating
BGM	Blood Glucose Monitoring
BMI	Body Mass Index
BRI	Behavioral Regulation Index
BRIEF	Behavior Rating Inventory of Executive Function
CRT	Cognitive Remediation Therapy
CREST	Cognitive Remediation and Emotion Skills Training
DEB	Disordered Eating Behaviors
DEPS-R	Diabetes Eating Problem Survey Revised
ED	Eating Disorders
EF	Executive functions
GEC	General Executive Composite
HbA1c	Glycated hemoglobin
MI	Metacognition Index
QoL	Quality of life
T1D	Type 1 diabetes

3 LIST OF ARTICLES IN THE THESIS

Thesis in compendium of publications format.

This thesis, submitted to obtain the degree of Doctor by the University of Barcelona, contains two published articles. In both, the candidate is the first author, as she contributed to conducting the studies, analyzing, and interpreting the data, and writing the manuscripts. The articles were both published in the same peer-reviewed international journal: Diabetic Medicine, ISSN: 7423071, Editorial: Wiley.

The thesis consists of 16 objectives and 2 articles:

- Study 1: **Cecilia-Costa, R**; Volkening, LK; Laffel, LM. Factors associated with disordered eating behaviors in adolescents with type 1 diabetes. Diabet. Med. 2019; 36(8): 1020-1027.
  DOI: 10.1111/dme.13890
  JCR: IF 3.083, Q3 Endocrinology and Metabolism

- Study 2: **Cecilia-Costa, R**; Hansmann, M; McGill, DE; Volkening, LK; Laffel, LM. Association of executive function problems and disordered eating behaviors in teens with type 1 diabetes. Diabet. Med. 2021; 38(11): e14652.
  DOI: 10.1111/dme.14652
  JCR: IF 4.213, Q2 Endocrinology and Metabolism

4 FRAMEWORK

The PhD candidate is a Child-Adolescent Psychiatrist who works at the Eating Disorders Unit (Mental Health Department) and Diabetes Unit (Endocrinology Department) at Hospital Sant Joan de Déu (Barcelona) since 2014. Her main clinical interest is the prevention of eating disorders (ED) in adolescents, especially among those with type 1 diabetes (T1D). Therefore, the candidate focused her research work on describing and detecting factors associated with disordered eating behaviors (DEB) in adolescents with T1D. The candidate was awarded two Alicia Koplowitz Foundation fellowships (2016-2017), and a grant from Hospital Sant Joan de Déu (2017), which give her the opportunity to do research in this field at an international research center.

The main research work of this thesis was conducted in Boston (USA), at the Joslin Diabetes Center, affiliated with Harvard University. The candidate joined the research team led by Dr Laffel and carried out the research for the thesis on DEB in adolescents with T1D under the direction of Dr Laffel. Dr Laffel is senior investigator, the Chief of Pediatric, Adolescent and Young Adult Section at Joslin Diabetes Center and Professor of Pediatrics at Harvard Medical School. The articles included in this thesis are the result of this research.

Since the very beginning of the thesis project and throughout the candidate's stay in Boston, she has also been guided by Dr. Serrano-Troncoso, Chief of Eating Disorders Unit of Hospital Sant Joan de Déu (HSJD, Barcelona). Once in Barcelona, the candidate continued her research into DEB in adolescents with T1D in HSJD under the leadership of Dr. Serrano-Troncoso and with the collaboration of the hospital's Diabetes Unit. The results of this more recent research have been presented at conferences, but as they have yet to be published, they are not included in this thesis.

During the course of PhD period, the candidate shared the most important findings of her work related with DEB in adolescents with T1D with the scientific community.

The PhD experience has prepared the candidate to meet the demands and responsibilities of the tasks of research and has stimulated her interest in continuing to study the topic. The candidate is pleased to report that she is continuing the research on this field and planning further publications.

5 SUMMARY IN CATALAN

ALTERACIONS DE LA CONDUCTA ALIMENTÀRIA

EN ADOLESCENTS AMB DIABETIS TIPUS 1

Introducció

Les alteracions de la conducta alimentària (ACA) són freqüents en persones amb diabetis tipus 1 (DT1) presentant una prevalença d'entre un 8 i un 55%. Les ACA en DT1, com a la població general, són més freqüents en dones que en homes i estan relacionades amb símptomes depressius i conflicte familiar. Les ACA en DT1 s'associen a menor automaneig de la diabetis i a un pobre control metabòlic. El maneig de la diabetis requereix planificació de les ingestes, recompte dels carbohidrats, monitoratge regular de la glicèmia i una correcta administració d'insulina, pel què és necessari una apropiada funció executiva. En persones amb DT1, els problemes en les funciones executives (FE) s'associen a un pobre maneig de la diabetis i també a ACA.

Hipòtesis

Estudi 1: les ACA oscil·laran entre un 15 i un 30% en una mostra d'adolescents amb DT1. Les ACA estaran associades al sexe femení, a major edat, a menor nivell d'estudis parental, a sobrepès/obesitat, a menor freqüència de monitoratge de les glicèmies, a major nivell sanguini d'hemoglobina glicada (HbA1c), a menor ús de la bomba d'insulina, a una pobra adherència al tractament de la diabetis, a major malestar emocional amb relació als valors de glicèmia, a major conflicte familiar relacionat amb el maneig de la diabetis, a més símptomes depressius, i a menor qualitat de vida.

Estudi 2: en una mostra d'adolescents amb DT1, un major nivell d'ACA estarà associat a problemes en les FE, informats tant pels adolescents com pels progenitors. Un major nivell d'ACA es relacionarà amb una major desregulació conductual, concretament amb problemes en el control emocional i en la flexibilitat.

Objectius

Estudi 1: avaluar la prevalença d'ACA en una mostra d'adolescents amb DT1, i comparar característiques sociodemogràfiques, biomèdiques, i psicosocials d'acord al nombre d'ACA.

Estudi 2: examinar l'associació entre problemes en les FE, informats per adolescents i progenitors, i el nombre d'ACA en una mostra d'adolescents amb DT1. Avaluar la relació del nombre d'ACA amb la desregulació conductual, concretament amb problemes en la flexibilitat i el control emocional.

Mètodes

Els estudis són transversals en adolescents (13-17 anys) amb DT1. La mostra de l'estudi 1 estava composta per 178 adolescents (48% dones) i la mostra de l'estudi 2 per 169 adolescents (46% dones) i 168 progenitors.

Estudi 1: les dades demogràfiques i del maneig de la diabetis van ser recollides en una entrevista als pares i a l'adolescent, i revisant la història clínica. A més es va obtenir el pes i la talla, i una mostra de sang. Els adolescents van respondre la *Diabetes Eating Problem Survey-Revised* (DEPS-R), que és una eina específica per explorar ACA en diabetis. Els adolescents també van respondre altres qüestionaris psicosocials incloent el *Diabetes Management Questionnaire*, el *Glucose Monitoring Communication Questionnaire*, la *Diabetes Family Conflict Scale*, el *Pediatric Quality of Life Inventory*, i la *Center for Epidemiologic Studies Depression Scale*.

Estudi 2: les ACA van ser examinades mitjançant la DEPS-R i les FE a través de la *Behavior Rating Inventory of Executive Function* (BRIEF): els progenitors van completar la versió per famílies i els adolescents la versió autoaplicada. La BRIEF té una puntuació general *(Global Executive Componsite*), dos índexs (*Behavioral Regulation Index* i *Metacognition Index*) i diverses subescales (*emotional control, inhibit, monitor, shift, organization of materials, plan/organize, task completion, iniciate, and working memory*).

En els dos estudis, els adolescents es classificaven en nivells d'ACA en funció de la puntuació de la DEPS-R: baix si <10, moderat si 10-19, i alt si ≥20. En l'estudi 2, els adolescents es van classificar en funció de la presència (puntuació de la BRIEF ≥60) o no (puntuació de la BRIEF <60) de problemes en les FE.

Per les anàlisis estadístiques, en l'estudi 1 es van utilitzar l'ANOVA, la Khi quadrat i la Khi quadrat Mantel-Haenszel, i van ser considerats estadísticament significatius els valors p≤0.01. En l'estudi 2, es va utilitzar la Khi quadrat Mantel-Haenszel i els valors p<0.01 van ser considerats estadísticament significatius.

Resultats

Estudi 1: un 26% presentaven un nivell moderat i un 15% un nivell alt d'ACA. Hi havia de forma significativa (p=0.003) una major proporció de dones en els nivells d'ACA moderat (62%) i alt (65%) que en el nivell baix (37%). També hi havia més adolescents amb obesitat en el grups moderat (13%) i alt (27%) que en el grup de baix nivell d'ACA (4%) (p=0.0003). Respecte el nivell d'estudis parental, hi havia una menor proporció d'adolescents amb progenitors amb estudis universitaris o superiors en el grup d'alt nivell d'ACA (50%) que en el grup moderat (62%) i que en el grup baix (83%) (p=0.0001). Uns majors nivells d'ACA estaven associats amb una menor freqüència diària de monitoratge de glucosa (p=0.0006), a alts nivells d'HbA1c (p=0.01), a pobra adherència al tractament (p<0.0001), a major malestar emocional en relació al monitoratge de glicèmies (p<0.0001), a pobra qualitat de vida (p<0.0001), a més símptomes depressius (p<0.0001), i a més conflicte familiar relacionat amb la diabetis (p<0.01). No es van trobar diferències entre els nivells d'ACA respecte l'edat ni en l'ús de bomba.

Estudi 2: segons la versió informada pels adolescents, hi havia una major proporció d'adolescents amb problemes en les FE en els nivells alt (19%) i moderat (18%) d'ACA que el nivell baix (2%) (p<0.001). A més, hi havia significativament (p<0.001) un major percentatge d'adolescents amb desregulació conductual en el grups moderat i alt d'ACA que en el grup de baix nivell d'ACA. No es van trobar diferències significatives

entre els tres grups en la versió per progenitors. Tenint en compte els dominis de les FE, d'acord amb la versió autoaplicada, un major nivell d'ACA es va associar amb les subescales de control emocional ($p<0.001$) i de flexibilitat ($p<0.001$), mentre que segons la versió per a progenitors, un major nivell d'ACA estava associat amb la subescala de la iniciativa ($p=0.008$).

Conclusions

Les ACA en adolescents amb DT1 són prevalents i estan associades amb diversos factors sociodemogràfics, biomèdics i psicosocials. Les ACA també estan associades amb una disfunció executiva, especialment amb problemes en el control emocional, en la flexibilitat i en la iniciativa. Els professionals que atenen a les persones amb DT1 haurien de tenir en compte els factors associats a les ACA, ja que podrien ajudar a una detecció precoç. A més, aquests factors poden també ser útils per dissenyar mesures preventives i de tractament específics per les ACA en persones amb DT1.

6 ABSTRACT

Introduction

Disordered eating behaviors (DEB) are frequent in people with type 1 diabetes (T1D), presenting a prevalence of 8-55%. As in people without T1D, DEB are more frequent in females than in males and these behaviors are related with depressive symptoms and family conflict. Among people with T1D, DEB are associated with poor diabetes self-management and lesser metabolic control. Diabetes management requires meal planning, carbohydrate counting, regular blood glucose monitoring (BGM) and insulin administration all of which require proper executive functioning. Among people with T1D, executive function (EF) problems are associated with poor metabolic control and DEB.

Aims

Study 1: To assess the prevalence of DEB in a sample of adolescents with T1D, and to describe and compare demographic, biomedical, and psychosocial characteristics according to the number of DEB.

Study 2: To examine the association between EF problems, informed by teens and parents, and the number of DEB in a sample of teens with T1D. To assess the relationship between the number of DEB and the behavioral dysregulation, specially related to flexibility and emotional control.

Methods

Both are cross-sectional studies in adolescents (13-17 years old) with T1D. Study 1 was composed of 178 teens (48% girls) and Study 2 of 169 adolescents (46% girls) and 168 parents.

Study 1: Demographic and diabetes management data on the teen participants was collected through an interview with the adolescents and their parents and a review of their clinical history. Teens' weight and height were collected as well as, a blood

sample. Youth completed the Diabetes Eating Problem Survey-Revised (DEPS-R), which is a diabetes-specific tool designed to explore DEB. Teens also completed other psychosocial surveys including the Diabetes Management Questionnaire, the Glucose Monitoring Communication Questionnaire, the Diabetes Family Conflict, the Pediatric Quality of Life Inventory, and the Center for Epidemiologic Studies Depression Scale.

Study 2: DEB were assessed using the DEPS-R. EF was examined by the Behavior Rating Inventory of Executive Function (BRIEF). Parents completed the parent proxy-report version and teens the self-report version. The BRIEF has a general score (Global Executive Composite), two indices (Behavioral Regulation Index and Metacognition Index), and several clinical scales (emotional control, inhibit, monitor, shift, organization of materials, plan/organize, task completion, initiate, and working memory).

In both studies teens were classified in different levels of DEB according the DEPS-R score: low level if score <10, moderate level if score 10-19, and high level if score ≥20. In study 2, the adolescents were classified by the presence (BRIEF score ≥60) or not (BRIEF scores <60) of problems in EF.

In study 1, the categorical variable of levels of DEB was used on bivariate analyses (ANOVA, chi square tests, and Mantel-Haenszel chi-squared tests) and p values ≤0.01 were considered statistically significant. In study 2, the Mantel-Haenszel chi-square tests were used to compare percentage of teens with EF problems by level of DEB. Values $p<0.01$ were considered statistically significant.

Results

Study 1: 26% of teens had moderate level and 15% had high level of DEB. There were more females in moderate (62%) and high (65%) level DEB groups than in low level DEB group (37%) ($p=0.003$), and there were more obese adolescents in moderate (13%) and high (27%) level groups than in low level group (4%) ($p=0.0003$). Regarding the level of parent studies, there was lower proportion of teens with parents with

college degree or higher in high level of DEB (50%), than in moderate (62%), and than in low level of DEB (83%), ($p=0.0001$). Greater levels of DEB were associated with lower frequency of daily BGM ($p=0.0006$), higher levels of glycated hemoglobin (HbA1c) ($p=0.01$), poor treatment adherence ($p<0.0001$), greater negative affect regarding BGM ($p<0.0001$), poorer quality of life ($p<0.0001$), more depressive symptoms ($p<0.0001$), and more diabetes-specific family conflict ($p<0.01$). There were not significant differences between the three levels of DEB and age or the use of insulin pump.

Study 2: According teens' self-report, there were higher proportion of teens with EF problems in high (19%) and moderate (18%) level of DEB than in low (2%) level ($p<0.001$). Also, according to the teens' self-report, there was a significantly ($p<0.001$) greater percentage of teens with behavioral regulation problems in the groups with moderate and high levels of DEB than in the group with low level of DEB. No differences were found by parental report. Regarding EF domains, by teen self-report, higher levels of DEB were associated with emotional control ($p<0.001$) and with shift ($p<0.001$) clinical scales, and by parent proxy-report greater DEB levels were related with initiate ($p=0.008$) clinical scale.

Conclusions

DEB are prevalent among adolescents with T1D and are associated with several sociodemographic, biomedical, and psychosocial factors. DEB are also associated with executive dysfunction, especially problems with emotional control, flexibility, and initiate. A greater awareness of the factors associated with DEB could contribute to early detection of DEB and may also inform efforts to design tailored preventive measures and specific treatments.

7 INTRODUCTION

7.1 DISORDERED EATING BEHAVIOR IN THE GENERAL POPULATION

7.1.1 Definition

Eating behavior can be understood as a continuum, ranging from healthy eating/diet at one extreme to an opposite extreme of eating disorders (ED). Between these two poles, there are disordered eating behaviors (DEB) [1]. DEB are eating-related problems, for weight control, that do not meet the severity criteria to be considered an eating disorder [2].

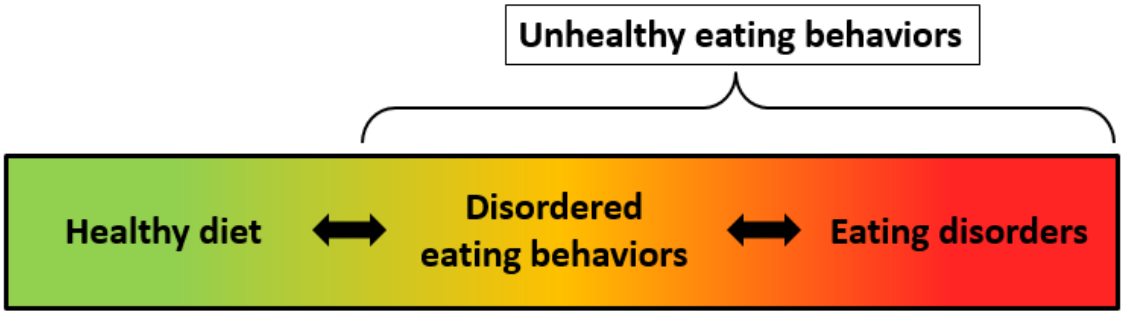

Figure 1. Continuum of eating behavior.

Note: figure created by Cecilia-Costa R, Volkening L and Laffel L.

DEB may include dieting, food selection and/or restriction, meal skipping, fasting, binge-eating, hyperactivity or intense exercise, and purging behaviors such as abuse of diuretics or laxatives and self-induced vomiting [2].

7.1.2 Prevalence

The prevalence of DEB in adolescents is around 31%-32% [3,4]. These behaviors are more frequent in females (15-57%) than in males (11-34%)[3–10] and they are more common in older than in younger adolescents [4,9]. Table 1 shows the prevalence of different types of DEB by sex [3,5,9,11,12].

Table 1. Prevalence of different types of DEB by sex.

Type of DEB prevalence	% Female	% Male	References
Binge eating	8-37	6-25	Croll, 2002; Harrison, 2019; Streigel-Moor, 2009; Forbush, 2007
Fasting	6-37	4-14	Streigel-Moor, 2009; Jankauskiene, 2019; Forbush, 2007
Skipping meals	52	20	Jankauskiene, 2019
Self-induced vomiting	4-10	2-8	Croll, 2002; Harrison, 2019; Streigel-Moor, 2009; Forbush, 2007
Laxative use	2-7	0-6	Croll, 2002; Streigel-Moor, 2009; Forbush, 2007
Diuretics use	3-7	1-6	Jankauskiene, 2019; Forbush, 2007
Diet pills use	9	2-6	Croll, 2002; Jankauskiene, 2019
Excessive exercise	6-11	6-15	Streigel-Moor, 2009; Jankauskiene, 2019
Smoking cigarettes to control hunger	14-18	10-16	Croll, 2002; Jankauskiene, 2019

Note: table created by Cecilia-Costa R.

7.1.3 Factors associated with Disordered Eating Behaviors: Sociodemographic factors

7.1.3.1 Adolescence

Adolescence is a developmental stage marked by physical, psychological, and social changes [13]. During this period, adolescents tend to engage in risky behaviors such as drug use, unsafe sexual behaviors and unhealthy eating behaviors [14]. Concerns about body weight and shape are frequent in this period of life, and this can lead to ED symptoms [15]. In the literature, body dissatisfaction during adolescence has been shown to be predictive of DEB [16–18] and adult onset of ED [19,20]. Pressure to be thin, body dissatisfaction, low self-esteem and poor social support have been identified as predictors of binge eating (BE) onset in adolescent females [21].

7.1.3.2 Socioeconomic status

There are discrepant findings in literature on the association between socioeconomic status (SES) and DEB. While some authors did not find significant differences [22,23], others found that higher SES was associated with more DEB [24,25] or even the opposite, that DEB were associated with lower SES [26,27].

7.1.4 Factors associated with Disordered Eating Behaviors: Biomedical factors

7.1.4.1 Weight status

DEB are more frequent among teens with overweight and obesity than adolescents with normal weight [4,6,28–30] or underweight [4,29,30]. Among a sample of adolescents, DEB were present in 50% of teens with obesity and 46% of teens with overweight, compared to 35% of teens with normal weight and 35% with underweight [4]. Regarding the types of DEB, self-induced vomiting is more prevalent in overweight (12%) than in the normal-weight group (5%) [6]. In addition, the tendency to lose control over food was more common in girls (61%) and boys (39%) with obesity than among females (33%) and males (12%) with normal-weight or among females (12%) and males (9%) with underweight [6]. Lipson et al. [31] observed that youth with overweight or obesity were more likely to have elevated ED risk than those with normal weight. In this adolescent sample, weight status was the most important predictor of ED risk. A longitudinal correlation has also been reported between body mass index (BMI) and DEB prevalence from childhood to adolescence, suggesting that premorbid high BMI may be a risk factor for subsequent ED symptoms [32]. Another longitudinal study assessing BMI and DEB showed that those who have never been overweight have the lowest rates of DEB, while those who gradually gained weight tended to present higher rates of DEB [33].

People with DEB have elevated BMI and a higher risk to develop overweight or obesity [34,35]. In a recent study, BMI was graded by the number of DEB reported: mean BMI in females at baseline were 21,22,23 kg/m² with 0, 1, ≥2 DEB, respectively, and

mean BMI in males were 22, 23, 26 kg/m² with 0, 1, ≥2 DEB [10]. In the same study, but upon a 15-years follow-up measurement, youth with DEB at baseline scored higher for BMI at each measurement point than those who had not reported DEB at baseline [10]. In another longitudinal study, young adults with DEB had higher weight and BMI upon a seven-year follow-up assessment than those without DEB [36]. Neumark-Sztainer [35] et al. found that dieting predicted subsequent weight gain and BMI status in a follow-up assessment after five years.

7.1.5 Factors associated with Disordered Eating Behaviors: Psychosocial and neuropsychological factors

7.1.5.1 Family environment

Weight-related conversations are frequent among families. 45% of girls report that their mothers have encouraged them to diet, and 58% say that they have been subjected to weight-related teasing by family members [37]. Family weight talk, particularly by mothers, has been associated with DEB, and weight-teasing was associated with body dissatisfaction and DEB in a sample of adolescent females [37]. Weight-teasing by the family was associated with BE and overweight in both females and males [38] and predicts this behavior after five years [37]. Dieting among mothers is associated with unhealthy weight control behaviors in adolescent females [34]. Additionally, maternal ED has been identified as a predictor of concerns about weight and body dissatisfaction in adolescent females and of dieting in adolescent males [39]. Females with DEB were less satisfied with their family relationships than their peers without weight control behaviors [29].

7.1.5.2 Depressive symptoms

The prevalence of depressive symptoms in a sample of adolescents was 23%, and these symptoms are strongly and positively correlated with DEB. Specifically, the comorbidity of depressive symptoms and DEB is 10-12% [40]. In one study, depressive

symptoms, body dissatisfaction, pressure to be thin, appearance overvaluation, and low self-esteem were all found to predict BE two years later [21]. In another study, depressive symptoms, body dissatisfaction and weight concerns during adolescence all predicted the development of DEB ten years later [17].

DEB have been significantly associated with low self-esteem and depression [41]. DEB was also tied to depressive symptoms reported in a follow-up assessment five years later [42].

7.1.5.3 Executive function

Executive functions (EF) are a set of cognitive processes involved in reasoning, decision-making and other complex behaviors [43]. Working memory, emotional control, and inhibition are examples of EF [44].

EF problems have been associated with DEB, especially those related to behavioral regulation, such as emotional control, set-shifting, inhibition, and monitoring [45]. Youth with BE or overeating habits had more EF problems than youth without these behaviors [46]. Bulimic symptoms were associated with problems with inhibition in a non-clinical sample [45]. Among a sample of adolescent females, difficulties with planning and impulsivity predicted weight gain from middle childhood to adolescence, and this effect was possibly explained by BE in early adolescence [47].

ED were also associated with executive dysfunction. In a sample of participants with BE disorder, those with poorer set-shifting abilities tended toward greater loss of control over eating than those without EF problems [48]. In another sample of people with anorexia and bulimia nervosa, poorer set-shifting was associated with ED symptoms, especially in binge and purging subtypes, and with a longer duration of illness [49].

One tool to assess executive function is the Behavior Rating Inventory of Executive Function (BRIEF) [44,50]. There are different versions of the BRIEF depending on who is to complete the test. For example, there is a teen repot version and a parent report version. The total BRIEF score is the Global Executive Composite (GEC), which

is the sum of two indices; the Behavioral Regulation Index (BRI) and Metacognition Index (MI), both which are made up of several subscales or clinical scales assessing different EF domains. The BRI includes the emotional control, inhibition, monitoring (teens version) and shift subscales, and the MI contains the monitoring (parents version), organization of materials, planning/organizing, task completion (teen version), initiate (parent version) and working memory subscales [50]. All these components are outlined in figure 2.

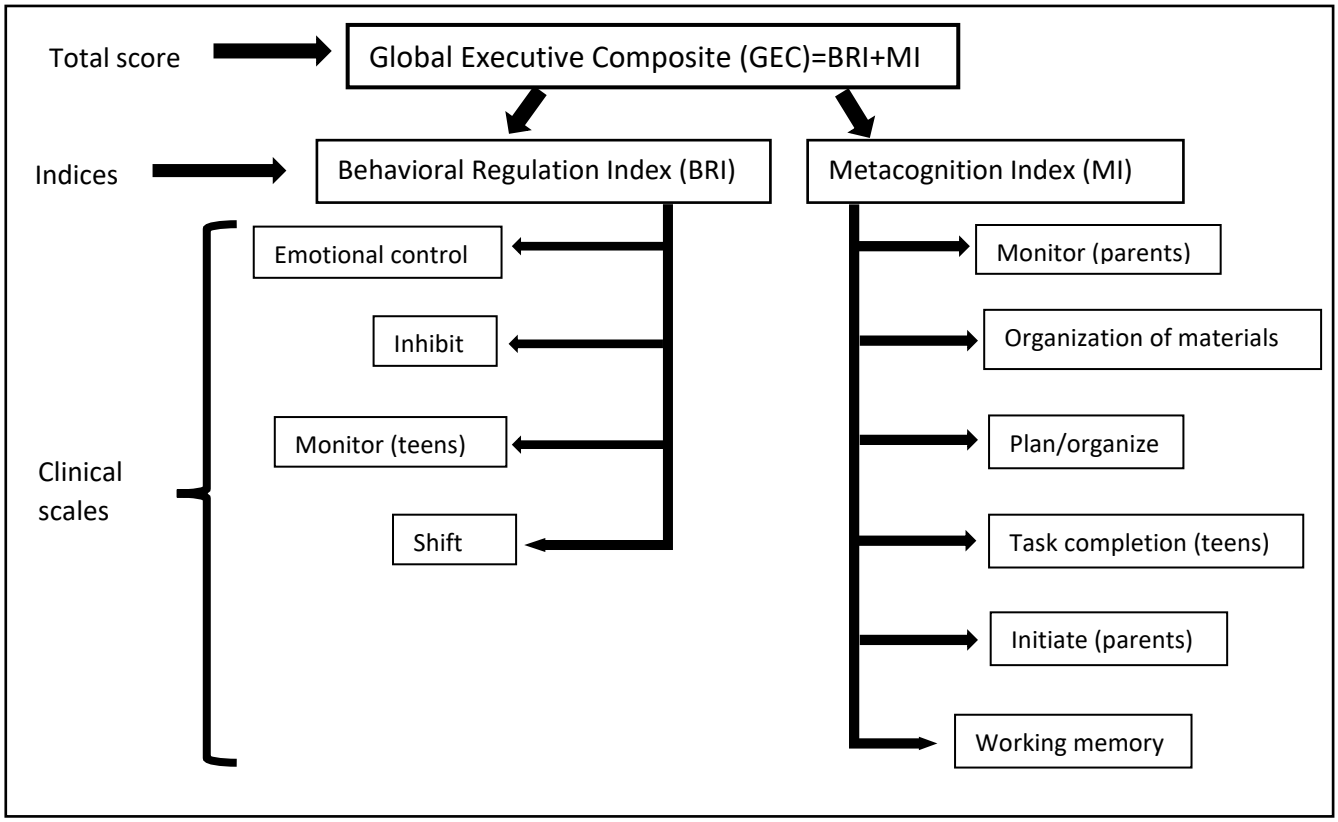

Figure 2. Behavior Rating Inventory of Executive Function (BRIEF) components.

Note: figure created by Cecilia-Costa R, Hansmann M, Volkening L and Laffel L.

7.1.5.4 Quality of life

Adolescents with DEB had poor quality of life (QoL) as measured in the physical, psychological, and social dimensions of well-being [51]. A systematic review showed a link between DEB and lower health-related QoL in children and adolescents [52]. ED risk among adolescents was also found associated with low health-related QoL [6]. ED

symptoms such as loss of control over food, food thoughts, body dissatisfaction, and self-induced vomiting were predictive factors of poor QoL [6].

In addition, poor physical well-being has been associated with DEB[53]. Poor psychosocial QoL predicted an increase of DEB six months later [54].

7.1.6 Disordered eating behaviors evolution

DEB prevalence tends to remain high or increased over time from adolescence to adulthood [55]. Adolescents with unhealthy weight-control behaviors (fasting, skipping meals, food restriction, using food substitute, smoking cigarettes to control hunger) have an increased risk of BE and extreme weight-control behaviors (self-induced vomiting, taking diet pills, laxatives or diuretics) five years later [35].

Neumark-Sztainer et al. [55] and Haynos et al. [56] conducted a 10-year follow-up study of DEB evolution by gender, and Haynos et al. looked at the same sample in a 15-year follow-up. The results showed that dieting remained constant in females but had increased in males after ten years. The additional measurement fifteen years after the initial assessment showed an increase in dieting among participants of both genders. High frequency dieting (≥5 times/year) had decreased among females but remained stable among males at the time of the 15-year follow-up. Unhealthy weight control behaviors decreased slightly in females after ten years and remained stable after fifteen years, while among males these behaviors remained stable after ten years, but increased after fifteen years. BE and extreme unhealthy weight control behaviors increased in both genders at both follow-up assessments.

7.1.7 Development of Eating Disorders

DEB are tied to the development of ED. The presence of DEB in childhood and adolescence tends to lead to an increased risk of developing an ED in young adulthood. For example, eating too little or too slowly, struggles with food, and unpleasant meals in early childhood can all lead to an ED in adolescence and young adulthood [57]. Overeating during childhood is associated with an increased risk of BE disorder in

adolescence, and undereating during childhood is associated with an increased risk of anorexia nervosa in adolescent females [58]. A study by Neumark-Sztainer et al. [35] showed that females who reported dieting at baseline assessment were more likely to report ED five years later than those who were not dieting at baseline.

7.2 TYPE 1 DIABETES

7.2.1 Definition and incidence

Type 1 diabetes (T1D) is a chronic disease characterized by the reduction or non-production of insulin due to a functional impairment of pancreatic β cells. The etiopathogenesis of T1D is multifactorial: genetic, autoimmune, and environmental [59].

T1D has an incidence of 15/100.000 inhabitants/year worldwide [60]. The incidence varies among countries; it is highest in Scandinavian countries (>25 cases/100.000 inhabitants/year), followed by other countries in Europe, the United States of America, and Australia (10-25 cases/100.000 inhabitants/year), and lowest in Asian countries (<5 cases/100.000 inhabitants/year) [61]. Data from large epidemiological studies show that the incidence of T1D has increased by 2-5% worldwide, with the exception of Central American and the Caribbean, where the trend was a 4% decrease [62].

In terms of the appearance of T1D throughout people's lifespan, the incidence rate of the disease increases from birth to puberty [62,63]. The incidence is greatest in youth aged 10-14 years and decreased after the age of 14 [63,64].

7.2.2 Diabetes treatment and metabolic control

T1D is treated with insulin and it must be administrated many times throughout the day. The goal of the treatment is to keep glycemia close to normal ranges (70-180mg/dL) [65]. Intensive treatment with insulin to achieve blood glucose levels close to those of general population is associated with a reduction in diabetes complications [66–68]. In addition to intensive insulin administration and blood glucose level monitoring,

proper diet and regular exercise are important to maintain blood glucose levels in normal ranges [69].

Long-term blood glucose levels can be assessed by measuring glycated hemoglobin (HbA1c). Measurements of HbA1c quantifies glucose attached to the hemoglobin (erythrocytes protein) and give information about the average blood glucose level over the preceding 2-3 months (erythrocyte life) [70,71]. The American Diabetes Association (ADA) described the goal of HbA1c of <7.5% (<58mmol/mol) for youths and <7% (<53mmol/mol) for adults [70]. Among a sample of people with T1D, the ADA goal was achieved by the 17% of children and adolescents and by the 21% of adults [72]. Data from the literature show that mean HbA1c increases from the ages of 5 to 15-18 and then begins to decrease at age 28 and keeps decreasing beyond the age of 30 [72].

7.2.3 Diabetes complications

Insulin is the hormone that helps keep blood glucose at normal levels, thus a lack of insulin leads to an increased blood glucose level which is hyperglycemia. Hyperglycemia affects organ cells, especially in the retina (retinopathy), peripheral nerves (neuropathy), and renal glomerular cells (nephropathy) which all are microvascular complications that are specific to diabetes [73]. Due to hyperglycemia, cardiac autoimmunity, and other associated risk factors (dyslipidemia, high blood pressure, and high body mass index [BMI]), people with T1D are also at increased risk of macrovascular complications such as coronary heart disease, peripheral vascular disease, and cerebrovascular disease [74,75]. Diabetic ketoacidosis is an acute diabetes complication that emerges due to severe hyperglycemia. It is most common in adolescents and young adults [72]. It has been suggested that poor adherence to insulin treatment is the most important factor contributing to long-term poor glycemic control and diabetes ketoacidosis in youth [76].

7.2.4 Diabetes treatment adherence and factors associated

Self-management of T1D is challenging, as it involves frequent blood glucose monitoring (BGM), proper insulin dose administration, meal planning and carbohydrate counting. These activities require appropriate diabetes self-management education, good cognitive functioning and psychosocial well-being [69,77]. Diabetes treatment adherence could be assessed by the Diabetes Management Questionnaire which is a tool with 20 items related with the treatment diabetes tasks [78].

7.2.4.1 Adolescence

The epidemiological, pathophysiological, therapy response, and developmental stage characteristics of child and adolescent diabetes should be considered when making decisions about diabetes care [79].

Adolescence is a developmental stage when youth acquire maturity and competencies for self-care and independence from their parents. When diabetes responsibility is transferred from parents to youth without sufficient teen autonomy, the result can be worsened HbA1c levels [80]. Teenagers with T1D tend to present poor treatment adherence and deteriorated metabolic control [81]. Parental support for diabetes management in adolescents has been linked to better adherence to treatment [81]. Family-based psychoeducational interventions are an effective way to encourage better parent involvement in diabetes management and attain improved HbA1c levels in youth [82].

Among adolescents, there is a high prevalence of anxiety, mood symptoms and disordered eating behaviors (DEB), all of which can affect diabetes treatment adherence [81]. Psychosocial support [69] and positive motivational interviews [83] have the potential to promote diabetes treatment adherence in adolescents and young adults.

7.2.4.2 Socioeconomic status

Among children and adolescents with T1D, lower socioeconomic status (SES) was related to poorer diabetes outcomes such as a lesser frequency of glucose monitoring and higher blood HbA1c levels [84]. Children and teens who live in social deprived areas have higher HbA1c than those who do not live in such areas [85]. Higher levels of SES or of parental education are both associated with a greater tendency to meet HbA1c targets [86].

7.2.4.3 Family environment

The term diabetes family conflict refers to parent-teen divergences around diabetes-specific tasks such as BGM, insulin administration and medical appointments [87]. The level of this conflict could be measured through the Diabetes Family Conflict Scale which contains items exploring family conflict related with diabetes-specific tasks [87]. Higher levels of family conflict are associated with poorer glycemic control as assessed using HbA1c [88] and with higher levels of psychological distress in parents and youth [89].

Diabetes family conflict has also been tied to negative youth and family affect with regard to BGM [90]. Affect regarding BGM refers to emotions experienced in connection with glycemic levels when checking blood glucose levels, such as feeling frustrated or scared when levels of glycemia are high or low. This negative affect could be assessed by the Blood Glucose Monitoring Communication Questionnaire. The negative affect related with BGM is associated with poor glycemic control and poor quality of life [90].

7.2.4.4 Executive function

Neurological development is essential for health care [91]. Diabetes self-management requires problem-solving abilities, planning, and self-control, and all of them require proper executive functioning. During adolescence, a time when diabetes treatment adherence and management generally worsen [72], executive function (EF)

continues to mature [91]. The prevalence of EF problems, as reported by parents, in adolescents with T1D ranges from 11% to 19% [92].

Among people with T1D, EF problems are associated with lower levels of treatment adherence [92–94], poorer glycemic control [93–96], poorer quality of life [92] and somatic problems [97].

7.2.4.5 Psychological symptoms and psychiatric disorders

Adolescents with T1D are more likely to present psychological symptoms than those without diabetes [98]. In a study comparing a sample of young adults with childhood onset T1D with a matched cohort without diabetes, Cooper et al. [99] found that 14% of people with diabetes met the criteria for a psychiatric disorder, compared to only 6% of those without diabetes. Anxiety, eating, mood, personality, and behavior disorders were more frequent among people with diabetes than in people without diabetes [99]. In two systematic reviews, the prevalence of clinical depression among individuals with T1D was 12%, while in individuals without diabetes was 3% [100,101].

Adolescents with depressive symptoms have been shown to display infrequent BGM [102–104], high levels of HbA1c [103,104], and a high risk of hospitalization for diabetes complications [105]. Internalizing disorders, such as depressive and anxiety disorders, are associated with repeated hospitalizations for diabetes in adolescents [106].

Psychiatric disorders are frequent in teens with chronically poor glycemic control, especially among those who have experienced at least one serious hypoglycemic episode [107].

7.3 DISORDERED EATING BEHAVIORS IN TYPE 1 DIABETES

Disordered eating behaviors (DEB) and eating disorders (ED) are more prevalent among people with type 1 diabetes (T1D) than among those without diabetes. In a sample of female teens, 14% of those with T1D had DEB and 10% had ED, while in a control group, 8% and 4% presented these behaviors respectively [108]. In a longitudinal study, people who had been diagnosed with T1D in childhood had a greater cumulative

incidence of ED (1.3%) than those without diabetes (0.3%) [99]. Adolescents with T1D tend to have more bulimic symptoms and a greater drive for thinness and body dissatisfaction than those without diabetes [109]. For the majority (94%) of people with T1D and ED, diabetes was diagnosticated before ED [110]. In a study detecting ED in people with diabetes, the distribution of types of ED among people with T1D was: 30% bulimia nervosa, 25% binge eating disorder, 17% anorexia nervosa and 28% ED not otherwise specified [111].

7.3.1 Screening for Disordered Eating Behaviors in people with type 1 diabetes

Identifying DEB in people with T1D is challenging, as there are potential confounders that must be considered. These confounders include attitudes as part of the treatment (carbohydrate counting), phenomena as part of the disease (dysregulation of satiety), and adverse effects of the treatment (excessive hunger) [112]. The etiology and motivation of the behavior should be considered. For example, missing insulin injection due to suboptimal self-management differs from intentional insulin omission for the purposes of weight control [113].

There are questionnaires designed to screen for DEB and ED in the general population, but these tools may not be appropriate for assessing DEB or ED in people with T1D due to the latter characteristics. Using general questionnaires in people with T1D could result in false positives, as many questions touch on food and diet practices that are in fact appropriate behaviors in people with T1D. Symptoms related to high blood glucose levels due to poor diabetes management, like weight loss, frequent water intake, and poor energy could be misidentified as DEB using these general questionnaires. In addition, using general scales among people with T1D can sometimes also result in false negatives, because they could restrict or omit insulin as a purging behavior, a behavior which is not assessed by general population screening questionnaires [114,115].

The Diabetes Eating Problem Survey Revised (DEPS-R) is a specially designed questionnaire to screen for DEB in people with T1D and recommended for the

American Diabetes Association (ADA) [77]. The DEPS-R is made up of 16 items. It features both general and diabetes-specific questions to assess DEB, and it includes items on insulin restriction and omission (Table 2) [116]. DEPS-R is the main tool used in the present thesis and the questions included are listed below:

1. Losing weight is an important goal to me
2. I skip meals and/or snacks
3. Other people have told me that my eating is out of control
4. When I overeat, I don't take enough insulin to cover the food
5. I eat more when I am alone than when I am with others
6. I feel that it's difficult to lose weight and control my diabetes at the same time
7. I avoid checking my blood sugar when I feel like it is out of range
8. I make myself vomit
9. I try to keep my blood sugar high so that I will lose weight
10. I try to eat to the point of spilling ketones in my urine
11. I feel fat when I take all of my insulin
12. Other people tell me to take better care of my diabetes
13. After I overeat, I skip my next insulin dose
14. I feel that my eating is out of control
15. I alternate between eating very little and eating huge amounts
16. I would rather be thin than have good control of my diabetes

Table 2. Disordered Eating Behavior Revised (DEPS-R) items [116].

DEPS-R questions are answered on a six-point Likert scale (0 = never, 1 = rarely, 2 = sometimes, 3 = often, 4 = usually, 5 = always,) and the total score is the sum of all responses. Total scores range from 0 to 80 where higher scores indicate a greater presence of DEB. The validated cut-off score of ≥20 indicates a high level of DEB and the need for additional evaluation [116].

7.3.2 Prevalence of Disordered Eating Behaviors in people with type 1 diabetes

The prevalence of DEB in people with T1D has been found to range from 8% to 55%, depending on the definition adopted and the method used to assess DEB [108,109,125,117–124]. In samples of adolescents and young adults, where DEB were assessed using the DEPS-R, 18-38% scored above the cut-off of ≥20 [109,119–121,124–127] (Table 3).

As is the case in people without T1D, DEB in people with this disease occurs more often in females than in males. DEB among people with T1D has been seen to range from 13% to 50% in females and from 9% to 27% in males [114,117,119–121,125,126]. DEB are also more common in older than in younger adolescents [119,128,129]. The prevalence of DEB range from 8% at 11-13 years old group to 38% at 17-19 years old group [119].

As mentioned above, DEB in people with insulin-treated diabetes, mainly T1D, have the potential for a unique purging behavior, namely, insulin omission or restriction. The prevalence of insulin manipulation for weight control in people with insulin-treated diabetes is 17-18% [129,130]. In adolescents with T1D, the prevalence of insulin restriction is 32%, and the prevalence of insulin omission after overeating is 7% [119]. Insulin manipulation for weight control is also more frequent in females than in males [114,117] ; while 10% of females referred skipping insulin and 7% of females referred to taking less insulin for weight control, only 1% of males reported these behaviors [117]. Findings as to the prevalence of insulin misuse among females with T1D range from 7 to 36% [108,117,119,131–133]. In study of people in treatment for ED, 90% of those with T1D presented insulin manipulation for weight control [134].

7.3.3 Factors associated with Disordered Eating Behaviors: Sociodemographic factors

7.3.3.1 Adolescence

As in the general population, for people with T1D adolescence is a developmental stage associated with worsened self-care, risky behaviors such as unhealthy eating and an increased risk of developing psychological disorders [135].

Among people with T1D, DEB have been shown to be more prevalent in teens than in preteens [129] and in older adolescents than younger ones [119,124]. Literature put DEB prevalence at 16% in those aged 10-14 and 25% in youth aged 15-19 [124]. Self-induced vomiting is more frequent from the ages of 14 to 21 and insulin restriction from 18 to 27 [123].

7.3.3.2 Socioeconomic status

In studies of adolescents with T1D, DEB have been associated with lower socioeconomic status (SES) [126,136]. For example, binge eating is more frequent among adolescents with a lower social level [137]. The authors of one such study suggest that lower levels of parental education and/or occupation could be a sign of risk for DEB [126].

7.3.4 Factors associated with Disordered Eating Behaviors: Biomedical factors

7.3.4.1 Weight status

DEB prevalence, assessed by the DEPS-R, has been shown to increase with body mass index (BMI) [119,138]. Wisting et al. [119] found a DEB prevalence among females of 9% in underweight, 23% for normal weight, 42% in overweight, and 53% in obese; and among males 6-7% in underweight and normal weight, 15% for both overweight and obese. Another author found a DEB prevalence of 21% in healthy weight group while the prevalence increased to 37% in an overweight/obesity group [138]. In a prospective

study by Markowitz et al. [139], people with overweight/obesity scored higher on the DEPS-R than those with normal weight in all study assessments (Table 3). Binge eating (BE) is more prevalent in youth with obesity (61%) than in youth with normal or underweight (47%) [124] . In addition, an elevated BMI has been found to be associated with the onset [140] and the persistence and worsening of DEB [141]. In study among adolescent females who reported having been overweight at least once in their lives presented more DEB than those who reported never having been overweight [142] .

Individuals with T1D and DEB are more likely to have a higher BMI than those without DEB [124,125,143]. Among a sample of adolescents with T1D those at risk for disordered eating presented a prevalence of overweight/obesity of 59%, versus 41% in those at low risk for disordered eating group [144]. In a longitudinal study, those with DEB have higher BMI five years later [145].

7.3.5 Factors associated with Disordered Eating Behaviors: Type 1 Diabetes

Chronic illnesses have been associated with DEB [146]. Living with a chronic disease may lead to distress. Diabetes distress is an emotional condition that arises from living with and managing diabetes. People with diabetes often feel angry, scared, guilty, depressed, overwhelmed, rejected, burdened by diabetes and the self-management responsibilities that come with it, and concerned about diabetes complications [147]. Individuals with diabetes distress present more depressive and eating-related symptoms, and more shape and weight concerns, than those without diabetes distress [148] . Diabetes distress is associated with overeating [149] .

DEB have also been associated with diabetes distress [149]. Females who have stopped engaging in insulin restriction have reported some relief of diabetes distress [150].

Moreover, a disease like T1D that requires a consistent focus on the diet may increase susceptibility to developing DEB [151,152] . Diabetes management demands a focus on food, diet, and carbohydrate counting [70]. A model by Goebel-Fabbri et al. [153,154], suggests that main goals of diabetes treatment, for example glycemia near to

normal levels, could be associated with perfectionism and frustration related to blood glucose ranges and also feeling deprived of food choices, which may lead to disordered eating (Figure 3).

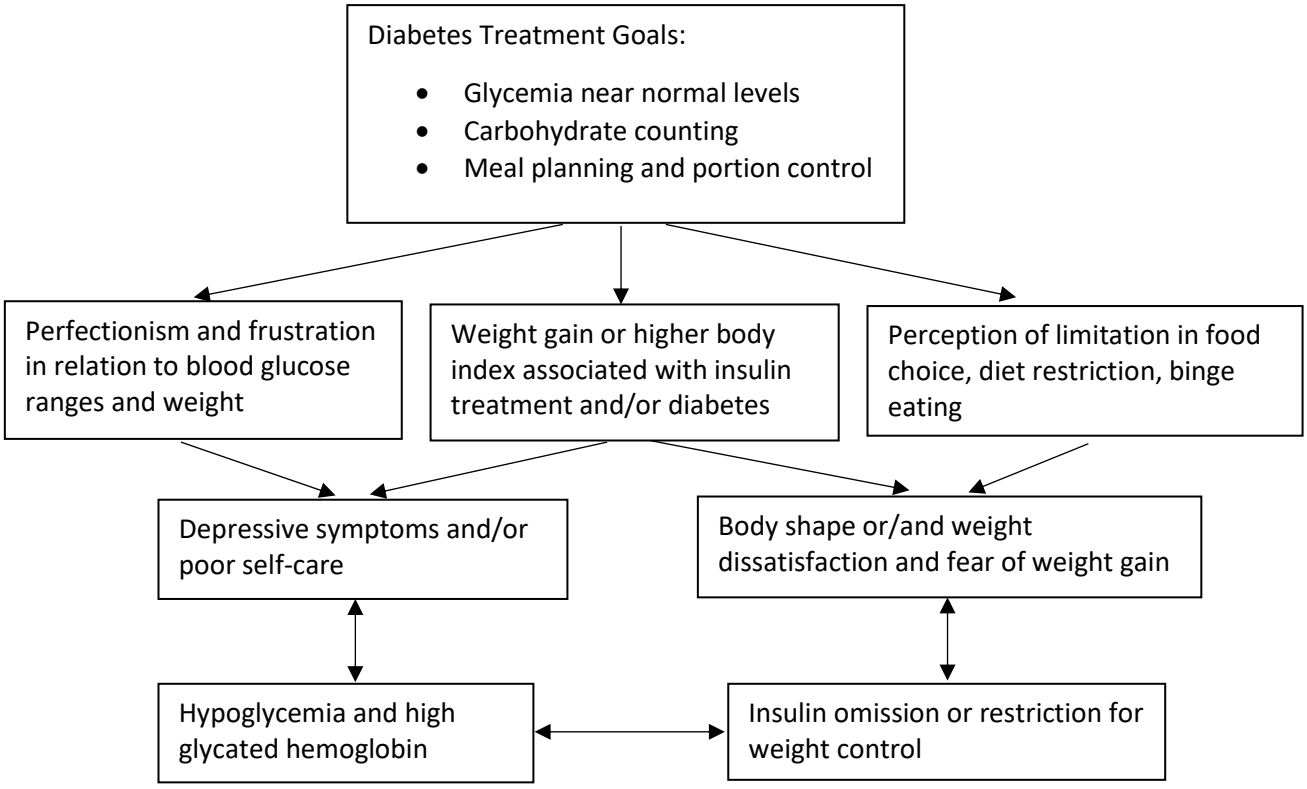

Figure 3. Model of disordered eating in type 1 diabetes by Goebel-Fabbri el al., [153] .

Note: figure adapted from Goebel-Fabbri et al., 2009.

In addition, the introduction of insulin treatment and the improvement of metabolic control have been associated with weight gain [155]. Fear of further weight gain related to T1D treatment can lead to insulin manipulation or other DEB for weight control [153–155]. In a sample of females with T1D, insulin restriction has been associated with fear that improving glycemic levels would lead to a weight gain [150]. In another study, a sample of adults with T1D reported body image concerns due to the difficulties to control and/or lose weight implied with the insulin treatment [156]. A model created by Daneman et al. [155] suggest that insulin-related weight gain, as well

as diabetes-specific nutritional attention and feeling different due to the disease, are all specific vulnerabilities of disordered eating among people with T1D (Figure 4).

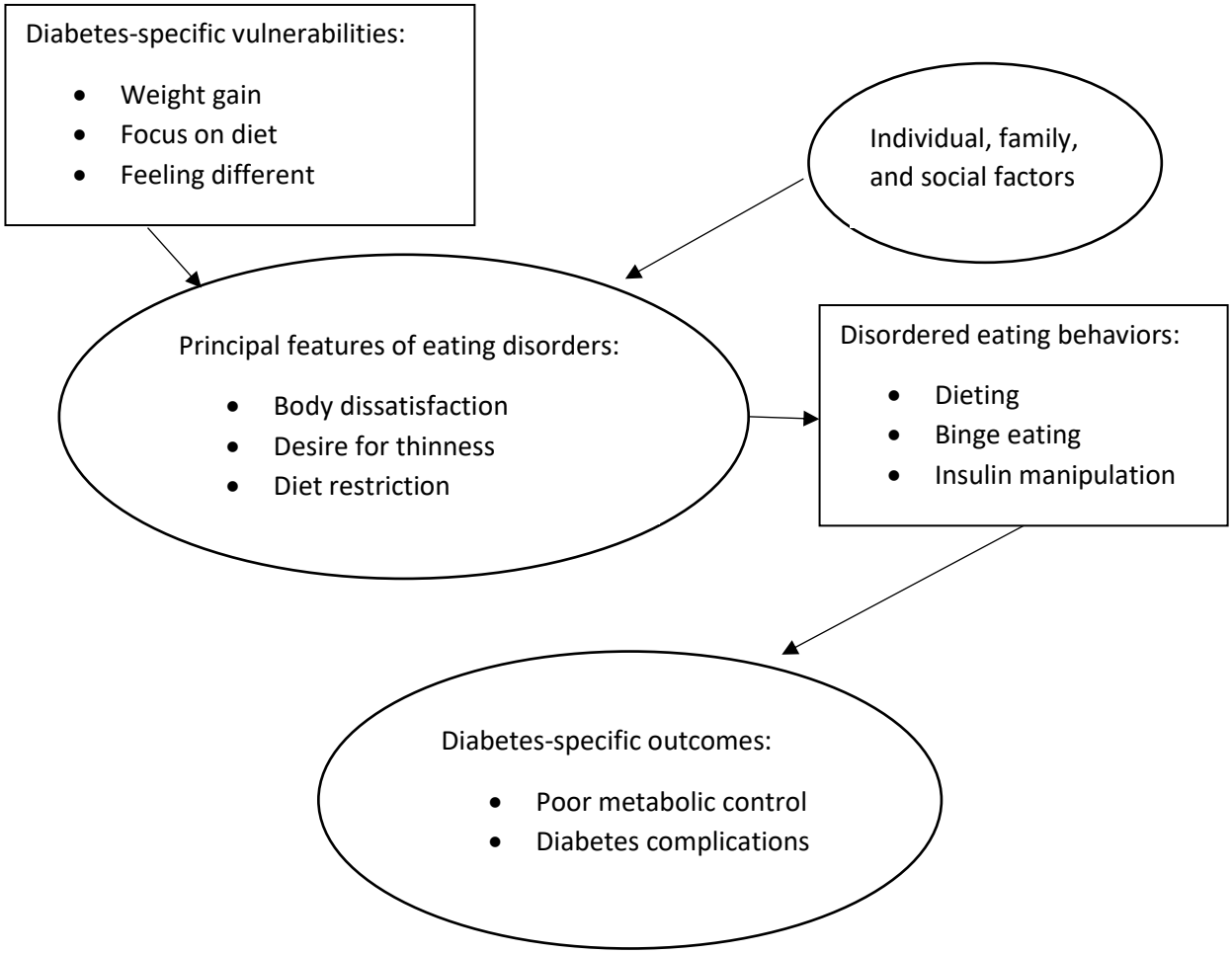

Figure 4. Model of disordered eating in type 1 diabetes by Daneman et al., [155].

Note: figure adapted from Daneman et al., 2002.

Regarding technology use in T1D, insulin pump initiation was found to decrease the number of DEB six month later [139]. In addition, a recent review concluded that the use of the continuous glucose monitor can help to detect insulin restriction and that the use of the insulin pump could provide benefits with regard to disordered eating [157].

DEB are associated with high levels of glycated hemoglobin (HbA1c) [117,119,120,125,131,138,144,150,158], less frequent blood glucose monitoring [144], and poor diabetes treatment adherence[144,150,158]. Colman et al. [158] found that high levels of DEB, as assessed by DEPS-R, were associated with poor diabetes adherence assessed by the Diabetes Management Questionnaire (Table 3). In longitudinal study among women with T1D was found that those who stopped engaging in insulin restriction reported fewer problems with diabetes management and better diabetes self-care [150]. In case-control study among women with T1D, the researchers found that the group with DEB were more time in hyperglycemia than the group without DEB [159] (Taula 3). Among people with T1D, DEB have also been linked to diabetes complications such as diabetic ketoacidosis, hypoglycemia episodes, neuropathy, and nephropathy [124,128,131–133], as well as with early mortality [132].

7.3.6 Factors associated with Disordered Eating Behaviors: Psychosocial and neuropsychological factors

7.3.6.1 Family environment

Family conflict related to diabetes tasks had been found to be associated with DEB [160,161] (Table 3). Also, negative family eating environment have been linked to DEB among teens with T1D [160] (Table 3). Markowitz et al. [116] found that DEPS-R scores were positively correlated with scores for Diabetes Family Conflict and Glucose Monitoring Communication Questionnaire. Families of adolescent females with T1D and DEB are more likely to have poor meal structure, infrequent family meals and to make negative comments about eating and weight than those without DEB [162]. A correlation was found between maternal weight and body shape concerns and unhealthy eating attitudes on adolescents [163]. Family cohesion is inversely associated with DEB [117].

7.3.6.2 Depressive symptoms

Depressive symptoms tend to be highly prevalent among people with T1D, and these psychological comorbidities have been associated with DEB. In a sample of adults with T1D, the prevalence of depression was 6% and it was associated with high presence of DEB [122] (Table 3). In a recent study of adolescents with T1D, 61% presented negative affect (depressive and anxiety symptoms), and the presence of these symptoms was associated with higher level of DEB [127] (Table 3). In a sample of youth with T1D, 15% screened positive for at least two instruments assessing anxiety, depression, or/and eating behavior [164]. Depressive symptoms and low self-esteem have been shown to increase the risk of DEB onset [140] and the persistence and worsening of DEB [141] in females with T1D.

Among adolescents with T1D, those with DEB present fewer positive attitudes towards life, less joy in life, and greater tendency for depressive mood than those without DEB [143]. In study of women with T1D it was found that those with DEB had higher frequency of negative emotions than those without DEB [159] (Taula 3).

7.3.6.3 Executive function

There is limited research on the association between executive function (EF) problems and DEB in people with T1D. However, there is one study with a sample of young adults with T1D, where the score of EF measure (BRIEF) was the most important factor related to the DEB measure (DEPS-R), while in the comparative sample of young adults without diabetes, mood symptoms were the most important variable associated with DEB. The same study showed that the problems with shifting and planning/organizing were the executive function domains associated with DEB [165] (Table 3). In another study, Young-Hyman et al. [166] found that a lack of emotional regulation was related to bulimic symptoms.

7.3.6.4 Quality of life

Adults, youth, and adolescents with T1D and DEB have a poorer physical and psychosocial quality of life (QoL) than those without DEB [124,143]. Among adolescents with T1D, those with a desire to lose weight were more likely to present DEB and displayed poorer QoL than those without the desire to lose weight [167]. People with T1D and DEB have more depressive symptoms and a poorer QoL comping to those without DEB [124,143].

7.3.7 Levels of Disordered Eating Behaviors in type 1 diabetes

Certain authors who have assessed DEB in people with T1D have defined three levels of DEB [131,163,168]. For example, Rydall et al. [131], described three categories depending on the frequency and the number of DEB; highly disordered eating behavior (≥1 DEB, twice/week), moderately disordered eating behavior (≥1 DEB, twice/month), and nondisordered eating behavior (<1 DEB, <twice/month). The assessment of these three levels allowed the researchers to define the characteristics of the moderate group[131,163,168]. At baseline in the Rydall et al. longitudinal study, HbA1c levels in the moderately disordered eating behavior group (8.9±1.7%) were between the highly disordered eating behavior group (11.1±1.2%) and the nondisordered eating behavior group (8.7±1.6%). At five-year follow-up, 43% of the moderately disordered eating behavior group had retinopathy, while 86% of the people in highly disordered group and 24% of people in nondisordered eating behavior group presented this diabetes complication [131].

7.3.8 Disordered Eating Behaviors Progression

DEB tends to persist, worsen or progress to clinical ED [123,128,131,133,145,150] and when remissions happen, DEB tend to be followed by relapses [128]. Females are more likely to have persistent DEB than males. In a study with a follow-up after three years, 29% of females and 14% of males with T1D were found to maintain DEB [123]. In a sample of girls with T1D, 92% of those who reported DEB at the beginning of the study

continued to present these behaviors after five years [145], and in another study of women with T1D 67% persisted in misusing insulin after eleven years [150]. In study among girls and women with T1D, in those who presented DEB remission, presented a recurrence rate of 71% [128].

7.3.9 Development of Eating disorders

As mentioned previously, DEB are associated with the development of ED and, as DEB, ED are also associated with recurrences when remission happen. In a longitudinal study assessing the incidence, remission, and recurrence rate of ED among females with T1D over 14-years of follow-up, Colton et al. [128] observed an incidence of 39%, and although 70% of DEB remitted, 60% recurred.

ED in T1D are associated with poor metabolic control, diabetes complications and poor ED treatment adherence. Individuals with T1D and ED presented higher levels of HbA1c [108,169] and higher rates of hypoglycemia and hospitalization than those without ED [169]. People with T1D and bulimia nervosa presented a higher risk of retinopathy than those without ED [169]. Among people in treatment for ED, those with T1D presented higher dropout rates from therapy and lower rates of remission compared with those without T1D [134].

Due to the high prevalence of DEB among adolescents with T1D and the associations with diabetes complications and the development of ED it is important to study the factors related to DEB in this population. More information about the factors associated with DEB among adolescents with T1D could be useful in terms of early detection and could help in the design of preventive measures and treatment tailored to this specific risk population.

The following table (Table 3) summarizes the literature detailed in this introduction about the prevalence and associated factors of DEB, measured through DEPS-R, among individuals with T1D.

Table 3: Summary of prior studies on the prevalence of DEB, assessed by Diabetes Eating Problem Survey Revised (DEPS-R), and associated factors among people with type 1 diabetes.

Study	Type 1 diabetes (T1D) sample	Comparison group	Study design	The main purpose of the study	Main tools	Main results
Araia et al., 2017 [121]	477 adolescents (mean age 16 years old)	No	Cross-sectional	To examine the prevalence of DEB and gender differences	-DEPS-R	38% of the sample (50% of females and 18% of males) had DEB (DEPS-R scores ≥20)
Broadley et al., 2018 [165]	74 young adults (mean age 25 years old)	201 controls without diabetes	Case-control study	To examine the association between EF and DEB in young adults with T1D, and to compare with a group without T1D	-DEPS-R -Eating Disorders Examination Questionnaire -Behavior Rating Inventory of Executive Function (BRIEF)	-Poor executive function, assessed by BRIEF, was associated with significantly more DEB in the T1D group -The most important factor associated with DEB was BRIEF score among T1D group while for the group without diabetes was the negative mood
Caccavale et al., 2015 [160]	151 teens (mean age 15.6 years old) with T1D and their parents	No	Cross-sectional	To study associations of DEB with factors associated with family eating environment and diabetes management behaviors	-DEPS-R -Diabetes Family Responsibility Questionnaire -Diabetes family conflict scale	-Both parents and teens reported that family conflict was associated with DEB -Teens reported that family eating environment was associated with DEB
Cherubini et al., 2018 [126]	163 youth (11-20 years old)	No	Cross-sectional	To examine the association of metabolic, clinical, and socioeconomic factors with DEB in adolescents with T1D	-DEPS-R	-The prevalence of DEB, assessed by DEPS-R (scores ≥20), was 34,4%. By sex: 41.7% in females and 26.6% in males -DEPS-R ≥ 20 was associated with overweight, low socioeconomic status, high HbA1c, avoidance of insulin administration

Study	Type 1 diabetes (T1D) sample	Comparison group	Study design	The main purpose of the study	Main tools	Main results
Colman et al., 2018 [158]	136 youth (mean age 13.8)	No	Longitudinal	To study the association of DEB with glycemic control measures	-DEPS-R -Diabetes Management Questionnaire	-DEB was associated with higher HbA1c (P = 0.001) and with poor diabetes adherence (P = 0.03)
Doyle et al., 2017 [120]	27 women and 33 men (age range 21±2.5 years)	No	Cross-sectional	To assess the prevalence of DEB in both men and women with T1D	DEPS-R	-23% of the whole sample; 27% of women and 18% of men presented DEB (DEPS-R scores of ≥20) -DEPS-R scores were significantly correlated with HbA1c level (r=0.55, p=.001) and BMI (r=0.27, p<.05)
Markowitz et al., 2013 [139]	43 youth (10–17 years old)	No	Prospective	To assess DEB prevalence and associated factors after pump therapy implementation	DEPS-R	-Overweight/obese youth screened higher on the DEPS-R than those with normal weight (p<0.02) -BMI was correlated with DEPS-R scores over time (all r=0.48, p=0.003) -The initiation of insulin pump was associated with a decrease of DEB
Nip et al., 2019 [124]	2,156 youth and young adults (mean age 17.7±4.3 years) with T1D and 149 youth and young adults (mean age 21.8±3.5 years) with type 2 diabetes who were receiving insulin therapy	No	Cross-sectional	To examine the prevalence of DEB and its associations with glycemic control and psychosocial functioning	DEPS-R	-DEB (DEPS-R scores ≥20) were observed in 21.2% of participants with T1D and 50.3% of participants with type 2 diabetes -Prevalence of DEB in both T1D and type 2 diabetes was highest in the 15-19-year-old group (24.9%) than in those aged 10–14 years (16%) -Among youth with T1D, binge eating was reported by 60.9% of participants with obesity and 47.2% of participants with normal or underweight -For both types of diabetes, those with DEB had a higher BMI, more depressive symptoms, poorer quality of life, and more hypoglycemic and ketoacidosis episodes than those without DEB

Study	Type 1 diabetes (T1D) sample	Comparison group	Study design	The main purpose of the study	Main tools	Main results
Rama et al., 2021 [159]	13 women (median age 25 years) with T1D and self-declared DEB	10 women (median age 29.5 years) with T1D without DEB	Case-control study	To explore the emotional state of women with T1D and to compare those with DEB between those without DEB	-DEPS-R -Diabetes Distress Scale -Yale Food Addiction Scale	-The DEB group had a significantly higher frequency of negative emotions/week than the group without DEB (p=0.030) -The DEB group spend more time with hyperglycemia than the group without DEB (p=0.015)
Rose et al., 2020 [127]	100 teen-caregiver pairs (teen mean age 14.02±1.78 years)	No	Cross-sectional	To examine the association between DEB and negative affect	-DEPS-R - The Patient-Reported Outcome Measurement Information System	-25% of teens presented DEB (DEPS-R scores ≥20) -61% of teens reported negative affect (depression and anxiety symptoms) -Higher negative affect scores and female gender were associated with higher DEPS-R scores
Ryman et al., 2019 [161]	116 teens (12-17 years old)	No	Cross-sectional	To assess if diabetes family conflict was associated with DEB	-DEPS-R -Diabetes Family Conflict Scale	-Teens with DEB (DEPS-R scores ≥20) had high family conflict in diabetes management according to both parents and teens reports (both p <0.001)
Troncone et al., 2020 [109]	183 teens (13–18 years old)	183 controls without diabetes	Cross-sectional	To examine DEB in teens with T1D and to compare with peers without T1D	-DEPS-R -Eating Disorder Inventory 3	-37,7% of the adolescents with T1D prese5nted DEB (DEPS-R scores ≥20) and had more eating problems than peers without T1D
Troncone et al., 2022 [125]	690 teens (mean age 14.97±1.81)	No	Cross-sectional	To assess the prevalence of DEB and to demographic, clinical, and psychological differences among adolescents with and without DEB	-DEPS-R -Youth self-report	-28.1% (35% girls, 21% boys) had DEPS-R score ≥ 20 -Girls had higher DEPS-R total scores than boys (p < .0001) -Teens with DEB had higher zBMI (p < .0001) and HbA1c (p < .0001) -Adolescents with DEB presented more emotional and behavioral problems (both internalizing and externalizing) than those without DEB (all p < .0001)
Watt et al., 2021 [138]	199 adults (18–65 years old)	No	Cross-sectional	To assess the prevalence of DEB and associated factors	-DEPS-R	-The prevalence of DEB increased with BMI, from 21,3% in the normal BMI group to 37,1% in the overweight/obese group (p=0.02) -High level of DEB (DEPS-R of ≥20) was associated with high HbA1c (p<0.001)

Study	Type 1 diabetes sample	Comparison group	Study design	The main purpose of the study	Main tools	Results
Wisting et al., 2013 [119]	770 youth (11–19 years old)	No	Cross-sectional	To examine the prevalence of DEB, insulin restriction and omission among youth with T1D	-DEPS-R	-18% of the whole sample; 27.7% of the females and 8.6% of the males presented DEB (DEPS-R ≥20) -31.6% of insulin restriction, and 6.9% of insulin omission -The prevalence went from 8.1% at ages 11–13 group to 38.1% at ages 17–19. -The range was from 7.2% in the underweight group to 32.7% in the obese group -People with DEB and insulin restriction had significantly higher HbA1c than those without these behaviors (p<0.001)
Wisting et al., 2018 [122]	282 adults (18–79 years old)	No	Cross-sectional	To assess the prevalence of DEB and symptoms of depression and anxiety among adults with T1D	-DEPS-R -Hospital Anxiety and Depression Scale	-20.3% of the whole sample (24.8% of females and 13.3% of males) had DEB (DEPS-R scores ≥20) -The prevalence for anxiety was 19.0%, and for depression was 6.2% -Significant associations were found between symptoms of eating disorder, anxiety, and depression, with correlation coefficients ranging from 0.47 (p<0.001) to 0.68 (p<0.001) in females, and 0.39 (p<0.001) to 0.61 (p<0.001) in males

Abbreviations: BMI Body Mass Index, BRIEF Behavior Rating Inventory of Executive Function; DEB Disordered Eating Behaviors, DEPS-R Diabetes Eating Problems Survey Revised, HbA1c Glycated Hemoglobin, T1D Type 1 Diabetes. Note: table created by Cecilia-Costa, R.

8 HYPOTHESES

- Disordered eating behaviors (DEB) would range from 15 to 30% in a sample of adolescents with type 1 diabetes (T1D)
- Hypotheses related to sociodemographic factors:
    - There would be a higher percentage of females than males with higher levels of DEB
    - The adolescents with higher levels of DEB would be older than those with lower levels of DEB
    - There would be a higher percentage of adolescents with parents with a college degree or higher in lower levels of DEB
- Hypotheses associated with biomedical factors:
    - There would be a higher percentage of overweight/obese teens with higher levels of DEB
    - Adolescents with higher levels of DEB would monitor their blood glucose concentration less frequently than those with lower levels of DEB
    - Teens with higher levels of DEB would have higher blood glycated hemoglobin concentration than those with lower levels of DEB
    - Teenagers using insulin pump would represent a lower percentage in higher levels of DEB
- Hypotheses related to psychosocial factors:
    - Teens with higher levels of DEB would have poor diabetes treatment adherence
    - There would be higher negative affect regarding blood glucose monitoring in adolescents with higher levels of DEB than those with lower levels of DEB
    - Diabetes-specific family conflict would be more frequent among teens with higher levels of DEB

    - Depressive symptoms would be more frequent in adolescents with higher levels of DEB
    - Higher levels of DEB would be associated with poorer quality of life
- Hypotheses related to neuropsychological factors:
    - In a sample of adolescents with T1D, DEB would be associated with general executive function (EF) problems, as measured by both self and parental report
    - There would be a higher percentage of teenagers with behavioral dysregulation with higher levels of DEB
    - Teens with higher levels of DEB would have more problems in emotional control and shift than those with lower levels of DEB

9 AIMS

GENERAL AIMS

The overall aims of this thesis are to assess the prevalence of disordered eating behaviors (DEB) and to study factors associated with DEB in a sample of adolescents with type 1 diabetes (T1D). In particular, these studies have sought to investigate the association of DEB with sociodemographic, biomedical and psychosocial factors (Study 1) and with problems in general executive function (EF) and specific EF domains (Study 2).

SPECIFIC AIMS

- To assess the prevalence of DEB in a sample of adolescents with T1D
- Aims related to sociodemographic characteristics:
    - To study the sex distribution by level of DEB
    - To study the age distribution by level of DEB
    - To assess parental education distribution by level of DEB
- Aims associated with biomedical outcomes:
    - To examine the weight status distribution by DEB level
    - To study the blood glucose monitoring frequency distribution by level of DEB
    - To explore glycated hemoglobin distribution by level of DEB
    - To study the insulin pump use distribution by level of DEB
- Aims related to psychosocial factors:
    - To assess the association between diabetes treatment adherence and levels of DEB
    - To examine the association between negative affect toward BGM and levels of DEB
    - To assess the association between diabetes-related family conflict and levels of DEB

    - To examine the association between depressive symptoms and levels of DEB
    - To assess the associations between quality of life and levels of DEB
- Aims associated to neuropsychological factors:
    - To assess if DEB are associated with EF problems, according to parent and teen reports, in a sample of adolescents with T1D
    - To explore the association between behavioral dysregulation and levels of DEB
    - To identify which EF domains are associated with higher levels of DEB

10 MATERIAL, METHODS, AND RESULTS: SCIENTIFIC PUBLICATIONS

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Research: Educational and Psychological Aspects

Factors associated with disordered eating behaviours in adolescents with Type 1 diabetes

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Aims To assess the occurrence of disordered eating behaviours in teenagers with Type 1 diabetes and to compare characteristics according to level of disordered eating behaviours.

Methods In this cross-sectional study, we collected adolescents' demographic and diabetes management data by parent–youth interview and chart review. Teenagers completed psychosocial surveys, including the Diabetes Eating Problem Survey-Revised (DEPS-R), a diabetes-specific measure of disordered eating behaviours. We categorized teenagers according to level of disordered eating behaviours: low, DEPS-R score <10; moderate, DEPS-R score 10–19; and high, DEPS-R score ≥20.

Results The 178 teenagers (48% girls) were aged 14.9±1.3 years, with diabetes duration of 7.4±3.7 years. Most (59%) had low, 26% had moderate, and 15% had high levels of disordered eating behaviours. Several biomedical and psychosocial characteristics differed by level of disordered eating behaviours. There were more girls in the moderate (62%) and high (65%) than in the low level of disordered eating behaviours group (37%; P=0.003) and more obese teenagers in the moderate (13%) and high (27%) groups than in the low group (4%; P=0.0003). Frequency of daily blood glucose monitoring decreased (P=0.0006) and HbA_{1c} level increased (P=0.01) with greater level of disordered eating behaviours. A greater level of disordered eating behaviours was also associated with poorer treatment adherence, more negative affect regarding blood glucose monitoring, poorer quality of life, and more depressive symptoms (all P<0.0001), along with more diabetes-specific family conflict (P=0.01).

Conclusions Identifying teenagers with Type 1 diabetes who have moderate and high levels of disordered eating behaviours may prevent progression to eating disorders and substantial morbidity by directing support and intervention efforts to those in need.

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Introduction

Subclinical disordered eating behaviours and clinical eating disorders occur more often in people with Type 1 diabetes than in their peers without diabetes [1–3]. Disordered eating behaviours may include dieting, excessive caloric restriction, fasting, binge-eating, intense exercise for weight control, and purging behaviours, such as abuse of laxatives or diuretics and self-induced vomiting [4]. Insulin omission or restriction for weight control is a purging behaviour specific to insulin-treated diabetes, mainly Type 1 diabetes [5].

The prevalence of disordered eating behaviours in people with Type 1 diabetes ranges from 8% to 55%, depending on the definition and method of measurement [2,3,6–9]. As in young people without Type 1 diabetes, disordered eating behaviours occur more frequently in girls and young women than in boys and young men [6,8–10], more frequently in older than in younger adolescents [8,11], and in association with family conflict [7]. Insulin omission or restriction as a purging behaviour occurs in 11–30% of girls and women with Type 1 diabetes [3,5,12–15].

Among people with Type 1 diabetes, disordered eating behaviours are associated with poor diabetes self-management and worse metabolic control, contributing to increased risk of short- and long-term diabetes complications. Adverse effects include elevated HbA_{1c} levels and abnormal lipid profiles, while complications include diabetic ketoacidosis, retinopathy, neuropathy and nephropathy, as well as premature mortality [5,11,12,14,15]. In an 11-year follow-up study, women with Type 1 diabetes who reported

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What's new?

- Disordered eating behaviours are common in people with Type 1 diabetes and are associated with poor glycaemic control, diabetes complications and early mortality.
- This study used a diabetes-specific survey, the Diabetes Eating Problem Survey-Revised (DEPS-R), in teenagers with Type 1 diabetes to identify factors associated with varying levels of disordered eating behaviours.
- Female sex, overweight/obesity, infrequent blood glucose monitoring, and poor glycaemic control were associated with more disordered eating behaviours, as were poorer quality of life and presence of depressive symptoms.
- These findings may help direct support and intervention efforts to those in most need and prevent progression to clinical eating disorders.

intentionally under-dosing or omitting insulin at baseline had a threefold higher relative risk of death during the 11-year follow-up period than those who did not under-dose or omit insulin at baseline [15].

When untreated, disordered eating behaviours often worsen and progress to clinical eating disorders [11,13]; hence, early identification of young people with Type 1 diabetes who have disordered eating behaviours has important utility for early intervention in order to prevent progression to clinical eating disorders and development of diabetes complications. General screening measures for disordered eating behaviours, however, may not be appropriate in Type 1 diabetes populations because of the necessary emphasis on food and carbohydrate-counting for this group of people. General screening measures may misidentify some diabetes management behaviours as disordered eating behaviours. In addition, there is a need to assess the presence of insulin restriction or omission as a unique purging behaviour in people with Type 1 diabetes. The Diabetes Eating Problem Survey-Revised (DEPS-R) was created to overcome the deficiencies of general disordered eating behaviour screening measures as it was designed specifically for use in people with Type 1 diabetes [16,17].

The aims of the present study were to assess the occurrence of disordered eating behaviours, as measured by the DEPS-R, in a sample of teenagers (aged 13–17 years) with Type 1 diabetes, and to describe and compare the characteristics of participants according to level of disordered eating behaviours (i.e. number and frequency of behaviours). We also aimed to identify a threshold on the DEPS-R for a moderate level of disordered eating behaviours. We hypothesized that more disordered eating behaviours would be associated with older age, female sex, overweight/obesity, higher HbA_{1c}, and poorer psychosocial characteristics, with the moderate group having characteristics intermediate between those with the lowest and highest levels of disordered eating behaviours.

Participants and methods

Participants

Participants were adolescents with Type 1 diabetes receiving care in a paediatric diabetes centre. The inclusion criteria included young people aged 13–17 years, Type 1 diabetes diagnosed according to American Diabetes Association criteria, diabetes duration ≥6 months, daily insulin dose ≥0.5 units/kg, HbA_{1c} 48–97 mmol/mol (6.5–11.0%), and fluency in English to complete surveys. The exclusion criteria included any significant developmental, cognitive or medical conditions or major psychosocial/family issues that would interfere with study participation. Given the narrow participant age range of 13–17 years, a group known to be at risk for disordered eating behaviours, we estimated that at least 150 participants would provide a sufficient range of DEPS-R scores to achieve our aims. The study protocol was approved by the institutional review board. Parents/young people provided written informed consent/assent before completing any study procedures.

Data collection

Data were collected at a single study visit that occurred on the same day as a clinic appointment. Parents/teenagers self-reported diabetes management data (e.g. insulin regimen, blood glucose monitoring frequency) during a brief joint parent/teenager interview conducted by a trained research assistant. Research assistants collected additional diabetes management data from the electronic medical record. Height and weight were obtained in a standardized manner using a stadiometer and electronic scale that were appropriately calibrated. We calculated BMI percentiles using the Centers for Disease Control and Prevention growth charts [18]. We then categorized teenagers by weight status according to BMI percentile: underweight (<5th percentile), normal weight (5th to <85th percentile), overweight (85th to <95th percentile), and obese (≥95th percentile). Teenagers provided a blood sample for measurement of HbA_{1c} (reference range: 4–6%, Roche Cobas Integra; Roche Diagnostics, Indianapolis, IN, USA). Teenagers completed the following validated surveys on a tablet computer using REDCap software [19].

The Diabetes Eating Problem Survey-Revised (DEPS-R) is a 16-item survey that assesses general and diabetes-specific disordered eating behaviours in people with Type 1 diabetes [16]. Items are answered on a six-point Likert scale ('never' to 'always'). Total scores range from 0 to 80; higher scores indicate more disordered eating behaviours. The validated cut-off score of ≥20 indicates a high number and frequency of

disordered eating behaviours that may warrant additional evaluation [16].

The Diabetes Management Questionnaire [20] is a 20-item survey that measures adherence to diabetes management tasks. Items are answered on a five-point Likert scale ('almost never' to 'almost always'). Total scores range from 0 to 100; higher scores indicate greater adherence.

The Blood Glucose Monitoring Communication Questionnaire [21] is an eight-item survey that assesses negative affect related to blood glucose monitoring. Items are answered on a three-point Likert scale ('almost never' to 'almost always'). After transformation, total scores range from 0 to 100; higher scores indicate more negative affect.

The Diabetes Family Conflict Scale [22] is a 19-item survey that assesses the level of family conflict around diabetes-specific tasks, such as blood glucose monitoring. Items are answered on a three-point Likert scale ('never argue' to 'always argue'). After transformation, total scores range from 0 to 100; higher scores indicate more conflict.

The Pediatric Quality of Life Inventory (PedsQL) Generic Core Scales [23] is a 23-item survey that measures the teenager's quality of life, including both physical and psychosocial functioning. Items are answered on a five-point Likert scale ('never' to 'always'). Total scores range from 0 to 100; higher scores indicate better quality of life.

The Center for Epidemiologic Studies Depression Scale [24,25] is a 20-item survey that assesses depressive symptoms. Items are answered on a four-point Likert scale ('rarely or none of the time' to 'most or all the time'). Total scores range from 0 to 60; higher scores indicate more depressive symptoms.

Statistical analysis

Statistical analyses were performed using SAS software (version 9.4; SAS Institute, Cary, NC, USA). To assess characteristics associated with disordered eating behaviours, we categorized teenagers by level of disordered eating behaviours according to DEPS-R score: <10 = low number/frequency of disordered eating behaviours, 10–19 = moderate number/frequency of disordered eating behaviours, ≥20 = high number/frequency of disordered eating behaviours. This categorical variable for level of disordered eating behaviours (low, moderate, high) was used in bivariate analyses (ANOVA, chi-squared tests, Mantel–Haenszel chi-squared tests).

Disordered eating behaviours were assessed as a continuous variable (DEPS-R score) in unpaired *t*-tests (male vs female DEPS-R scores) and in multivariate linear regression. Multivariate analyses with DEPS-R score as the dependent variable were performed to assess multiple factors associated with disordered eating behaviours. Variables were included in the model if their association with disordered eating behaviour had a *P* value <0.1. In bivariate analyses, *P* values ≤0.01 were considered statistically significant because of the multiple comparisons. In multivariate analyses, *P* values <0.05 were considered statistically significant.

Results

Participant characteristics

Table 1 describes demographic and diabetes management characteristics among the 178 participants. The mean participant age was ~15 years and the majority of participants (70%) had diabetes for ≥5 years. Approximately half of the participants (48%) were girls and 88% were white. Most came from two-parent families (87%) and had at least one parent with a college degree or higher (72%). Two thirds of teenagers used pump therapy for both basal and bolus insulin delivery. The mean daily insulin dose was ~1 unit/kg and the majority of teenagers (63%) checked blood glucose levels ≥5 times/day. The mean HbA_{1c} concentration was 69±11 mmol/mol (8.5±1.0%); only 15% achieved HbA_{1c} goal of <58 mmol/mol (<7.5%). About two-thirds of teenagers were of normal weight, 26% were overweight, and 10% were obese. Only two teenagers were underweight; therefore, we included these two teenagers in the normal weight group for analyses.

DEPS-R scores

Figure 1 shows the distribution of DEPS-R scores by sex. Girls had a higher mean DEPS-R score than boys (12.4±10.3 vs 7.5±7.1; *P*=0.0003). Overall, most teenagers (59%) had a low level of disordered eating behaviours, with DEPS-R scores <10, 26% had a moderate level, with DEPS-R scores 10–19, and 15% had a high level, with DEPS-R scores ≥20. More girls than boys had moderate (34% vs 19%) and high (20% vs 10%) levels of disordered eating behaviours (*P*=0.003).

Disordered eating behaviours and demographic/diabetes management characteristics

Table 1 summarizes participant characteristics according to level of disordered eating behaviours. There were no significant differences among the low, moderate, and high groups with respect to age, diabetes duration, race, family structure, insulin regimen, daily insulin dose, or HbA_{1c} concentration. There was a higher percentage of girls in the moderate (62%) and high groups (65%) than in the low group (37%; *P*=0.003). Compared with teenagers in the low group, teenagers in the high group were less likely to have a parent with a college degree or higher (*P*=0.0001). Teenagers in the high group also checked blood glucose levels less often (*P*=0.0006) and had higher HbA_{1c} concentrations (*P*=0.01) than teenagers in the low group. The HbA_{1c} in the moderate group was midway between the low and high groups. There

Table 1 Participant characteristics: overall and by level of disordered eating behaviours

	All teenagers (*N*=178)	Disordered eating behaviour level			*P*
		Low: DEPS-R score <10 (*n*=105)	Moderate: DEPS-R score 10–19 (*n*=47)	High: DEPS-R score ≥20 (*n*=26)	
Age, years	14.9±1.3	14.7±1.3	15.2±1.3	15.0±1.4	0.07
Diabetes duration, years	7.4±3.7	7.0±3.6	8.6±3.9	6.4±3.0	0.02
Sex: female, %	48	37	62	65	0.003
Race/ethnicity: white, %	88	89	85	88	0.8
Family structure: from two-parent family, %	87	86	87	92	0.4
Parent education: college degree or higher, %	72	83	62	50	0.0001
Insulin regimen: pump, %	67	73	62	54	0.1
Daily insulin dose, units/kg	0.96±0.24	0.94±0.22	0.95±0.28	1.07±0.24	0.04
Blood glucose monitoring frequency, times/day	5.3±1.9	5.7±1.9	5.0±2.0	4.2±1.2	0.0006
HbA_{1c}					0.01
mmol/mol	69±11	67±10	72±13	75±13	
%	8.5±1.0	8.3±0.9	8.7±1.2	9.0±1.2	
HbA_{1c} <58 mmol/mol (<7.5%), %	15	17	15	8	0.3
Weight status, %					0.0004
Normal weight	64	70	62	42	
Overweight	26	26	26	31	
Obese	10	4	13	27	

DEPS-R, Diabetes Eating Problem Survey-Revised. Data presented are mean ± SD, unless otherwise indicated. *P* values obtained from ANOVA (age, diabetes duration, insulin dose, blood glucose monitoring frequency, HbA_{1c}), chi-squared tests (sex, race/ethnicity, insulin regimen) and Mantel–Haenszel chi-squared tests (family structure, parent education, % HbA_{1c}<58 mmol/mol, weight status).

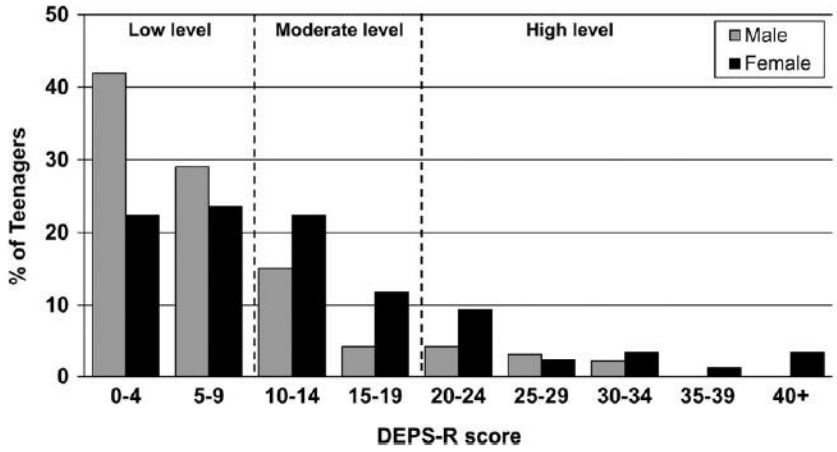

FIGURE 1 Distribution of Diabetes Eating Problem Survey-Revised (DEPS-R) scores by sex. More female than male participants had moderate (34% vs 19%) and high (20% vs 10%) levels of disordered eating behaviours (*P*=0.003).

was also a greater proportion of obese teenagers in the high compared with the lower groups (*P*=0.0003).

In a multivariate linear model (R^2=0.24, *P*<0.0001), controlling for age, diabetes duration, parent education, insulin regimen, insulin dose and blood glucose monitoring frequency, the variables of sex, weight status and HbA_{1c} were significantly associated with DEPS-R score. Female sex (*P*=0.0004), obesity (*P*=0.047) and HbA_{1c} ≥75 mmol/mol (≥9.0%) (*P*=0.046) were all associated with higher DEPS-R scores. In these adjusted analyses, girls scored 4.5 points higher on the DEPS-R than boys, those who were obese scored 5.3 points higher than those of normal weight, and those with elevated HbA_{1c} ≥75 mmol/mol (≥9.0%) scored 3.0 points higher than those with lower HbA_{1c} values (Fig. 2).

Disordered eating behaviour and psychosocial characteristics

A number of psychosocial constructs were also associated with level of disordered eating behaviour (Table 2).

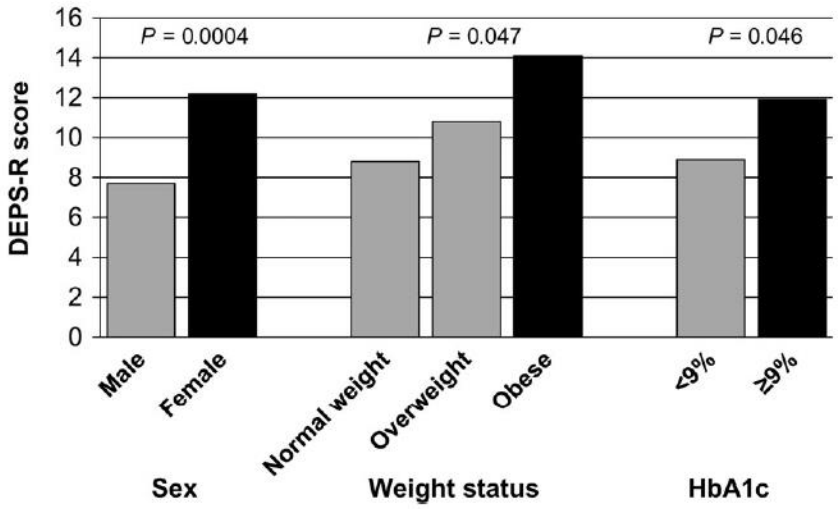

FIGURE 2 Diabetes Eating Problem Survey-Revised (DEPS-R) scores in multivariate model by sex, weight status and HbA_{1c}. In a significant multivariate model, female sex (P=0.0004), obesity (P=0.047) and HbA_{1c} ≥75 mmol/mol (≥9.0%; P=0.046) were significantly associated with higher DEPS-R scores.

Treatment adherence was significantly lower in the moderate and high groups than in the low group (P<0.0001). Negative affect regarding blood glucose monitoring differed significantly among all three groups, with more negative affect associated with higher level of disordered eating behaviours (P<0.0001). Diabetes-specific family conflict was lowest in the low group (P=0.01). Quality of life differed significantly among all three groups, with poorer quality of life associated with higher level of disordered eating behaviours (P<0.0001). Depressive symptoms differed significantly among all three groups, with more depressive symptoms associated with higher level of disordered eating behaviours (P<0.0001).

In a multivariate model (R^2=0.42, P<0.0001) with the psychosocial measures as the independent variables, poorer treatment adherence (P=0.0003), more negative affect regarding blood glucose monitoring (P=0.0008), and more depressive symptoms (P=0.003) were significantly associated with higher DEPS-R score. Diabetes-specific family conflict and quality of life were not significantly related to DEPS-R score in the model. The addition of sex, weight status, and HbA_{1c} as independent variables improved the overall model (R^2=0.50, P<0.0001) without changing the significance of the psychosocial measures. In this model, female sex (P=0.003) and obesity (P=0.0004) predicted higher DEPS-R score but HbA_{1c} did not.

Table 2 Psychosocial survey scores by level of disordered eating behaviours

	Disordered eating behaviour level			
	Low: DEPS-R score <10 (n=105)	Moderate: DEPS-R score 10–19 (n=47)	High: DEPS-R score ≥20 (n=26)	P
Treatment adherence	75±10	67±12	66±12	<0.0001*
Negative affect regarding blood glucose monitoring	27±21	40±20	54±19	<0.0001†
Diabetes-specific family conflict	15±22	26±28	23±17	.01‡
Quality of life	89±11	83±9	71±17	<0.0001†
Depressive symptoms	5±6	10±8	19±13	<0.0001†

DEPS-R, Diabetes Eating Problem Survey-Revised. Data presented are mean ± SD. P values obtained from ANOVA test.
*Low group significantly different from both moderate and high groups.
†Low, moderate and high groups all significantly different.
‡Low group significantly different from moderate group; low group vs high group, P=0.1.

Discussion

In this study of 178 teenagers with Type 1 diabetes, we found that approximately two out of every five teenagers had moderate or high levels of disordered eating behaviours; 26% had moderate levels and 15% had high levels of disordered eating behaviours. Several biomedical and psychosocial factors were associated with both moderate and high levels of disordered eating behaviours, indicating that subthreshold DEPS-R scores of 10–19, below the threshold of ≥20, may identify an opportunity for intervention to prevent progression of disordered eating behaviours.

Our findings confirm recent studies that have reported associations between more disordered eating behaviours and female sex [6,8,26], higher BMI [8,9,13,26–28] and poorer glycaemic control [6,8,9,29] in people with Type 1 diabetes. In a recent large epidemiological study of 52 215 children

and young adults with Type 1 diabetes, 467 individuals had an eating disorder according to the fourth edition of the Diagnostic and Statistical Manual of Mental Disorders criteria [29]. Those with eating disorders had higher HbA_{1c} levels as well as higher rates of diabetic ketoacidosis and risk factors for future complications compared with those without eating disorders.

In a study of 770 young people with Type 1 diabetes from the Norwegian Childhood Diabetes Registry [8], 18% scored ≥20 on the DEPS-R, similar to our rate of 15%. The Norwegian study reported that significantly more girls (28%) than boys (9%) had DEPS-R scores ≥20. Young people who scored ≥20 on the DEPS-R had higher BMI z-score (0.7 vs 0.2 standard deviation scores (SDS), $P<0.001$), higher HbA_{1c} (77 vs. 68 mmol/mol [9.2 vs. 8.4%], $P<0.001$), and were older (15.6 vs. 14.4 years, $P<0.001$) than young people who scored <20. In a study of 60 young adults with Type 1 diabetes [9], 23% scored ≥20 on the DEPS-R (30% of women vs 18% of men), a rate slightly higher than the present study (15%), which may be attributable to the difference in ages of the two samples. The young adults who scored ≥20 on the DEPS-R had higher HbA_{1c} (90 vs 62 mmol/mol [10.4 vs 7.8%]; $P<0.001$) and higher BMI (28.0 vs 25.4 kg/m^2; $P=0.06$) than those who scored <20. None of these previous studies assessed a group with a moderate level of disordered eating behaviours as in the present study.

The present study also builds on previous studies that have reported associations between more disordered eating behaviours and poorer psychosocial attributes in individuals with Type 1 diabetes [13,27,30]. In a sample of 199 adolescents with Type 1 diabetes, Grylli *et al.* [27] found that young people with disordered eating behaviours had a less positive attitude toward life, more somatic complaints, lower self-esteem, and more depressive symptoms than young people without disordered eating behaviours. In a study of 83 adults with Type 1 diabetes assessed using momentary sampling, Merwin *et al.* [30] found that more negative affect regarding diabetes was associated with a higher likelihood of insulin restriction. Olmsted *et al.* [13] followed 101 girls with Type 1 diabetes for 5 years, none of whom had disordered eating behaviours at baseline, and assessed factors related to the development of disordered eating behaviours over time. They found that more concerns about body weight/shape, lower self-esteem, and more depressive symptoms predicted the onset of disordered eating behaviours.

In addition to stratifying young people by the previously validated DEPS-R score threshold of ≥20 [16], we further divided those with DEPS-R scores <20 into those with scores <10, considered as a low level of disordered eating behaviours, and those with scores of 10–19, considered as a moderate level of disordered eating behaviours. The longitudinal study by Rydall *et al.* [12] also classified young women into three different gradations of disordered eating behaviours, those who were non-disordered, moderately disordered, and highly disordered. These authors reported that increasing severity of disordered eating behaviours was associated with greater risk of microvascular complications during follow-up. Similarly, another study by Maharaj *et al.* [7] categorized adolescent girls as non-eating disturbed, mildly disturbed, and highly disturbed. These authors also reported increasing severity of disturbances in body image and eating attitudes in association with increasing severity of disturbed eating behaviours.

We found that teenagers with a moderate level of disordered eating behaviours had many biomedical and psychosocial characteristics (parent education, blood glucose monitoring frequency, HbA_{1c}, overweight/obesity, negative affect regarding blood glucose monitoring, general quality of life, and depressive symptoms) that were different from teenagers in both the low and high groups, while for some characteristics (sex, treatment adherence and diabetes-specific family conflict), the moderate group was similar to the high group. Taken together, these data suggest that it may be possible to identify teenagers with a moderate level of disordered eating behaviours at a point in the clinical course when interventions may prevent development of more severe disordered eating behaviours and even progression to clinical eating disorders. Interventions and treatment can be tailored for those with a low or moderate level of disordered eating behaviours to prevent worsening of disordered eating behaviours.

Many of the biomedical characteristics associated with moderate and high levels of disordered eating behaviours are routinely assessed during regular diabetes clinic appointments. Clinicians should be educated on these relationships so that they can be alert to factors that may indicate elevated risk of disordered eating behaviours. For example, although low body weight is often associated with clinical eating disorders, such as anorexia nervosa, clinicians should be aware that higher BMI is associated with disordered eating behaviours in people with Type 1 diabetes [8,9,13,26–28].

A strength of the present study is the use of the validated, diabetes-specific DEPS-R screening measure [16]. When assessing disordered eating behaviours in people with Type 1 diabetes, it is important to use a diabetes-specific measure because general screening measures do not capture diabetes-specific behaviours such as intentional insulin omission or restriction. In addition, Type 1 diabetes requires attention to food and carbohydrate intake, and general screening measures may misidentify these behaviours as disordered eating behaviours. Another strength is the inclusion of both female and male participants in a study sample of adolescents, a group in which eating disorders often develop. Many studies examining disordered eating behaviours in people with Type 1 diabetes have included only female participants [5,7,11,14]. It is important, however, to include both male and female participants in order to gain a better understanding of how disordered eating behaviours may differ in boys and young men with Type 1 diabetes compared to girls and young women with Type 1 diabetes.

A limitation of the present study is its cross-sectional design; future longitudinal studies will enable a better understanding of the predictive nature of moderate levels of disordered eating behaviours for progression to high levels of disordered eating behaviours or frank eating disorders. In addition, the present study sample was relatively homogeneous and high functioning, which may limit generalizability, with 88% of participants being white, 87% being from two-parent families, and 67% receiving insulin pump therapy, although only 15% achieved target HbA_{1c} levels of <58 mmol/mol (<7.5%).

In summary, our data suggest that there may be an opportunity to identify teenagers with moderate as well as high levels of disordered eating behaviours by using the score thresholds of 10–19 and ≥20, respectively, on the DEPS-R screening measure, a tool supported for clinical use by the American Diabetes Association in their recent position statement on the psychosocial care of people with diabetes [17]. Early identification of disordered eating behaviours may allow timely intervention to prevent progression to eating disorders and the resulting poor glycaemic control, acute and chronic diabetes complications, and premature mortality. Teenagers with either moderate or high levels of disordered eating behaviours will likely benefit from additional support to improve glycaemic control and reduce the risk of progressive disordered eating behaviours.

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Competing interests

The authors have no relevant conflicts of interest to disclose related to this research.

Previous publication

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DIABETIC Medicine

RESEARCH ARTICLE

Association of executive function problems and disordered eating behaviours in teens with type 1 diabetes

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Abstract

Aim: To explore cross-sectional associations between executive function problems and disordered eating behaviours in teens with type 1 diabetes.

Methods: Executive function was assessed by the Behavior Rating Inventory of Executive Function (BRIEF), self-report and parent proxy-report versions. Scores ≥60 (on Global Executive Composite, Behavioral Regulation Index, Metacognition Index or clinical scales) indicated problems with executive function. Disordered eating behaviour was assessed by the Diabetes Eating Problem Survey Revised (DEPS-R) and categorized as follows: <10 low, 10–19 moderate and ≥20 high.

Results: In the 169 teens (46% girls, median age 16.0 years [range 13.7–18.7], median diabetes duration 8.9 years [range 1.4–16.6]), 29% had moderate and 12% had high level of disordered eating behaviours. Executive function problems were present in 9% by self report and 26% by parent proxy-report. Among teens with moderate/high level of disordered eating behaviours, 19% had executive function problems by self report (vs. 2% of teens with low level of disordered eating behaviours, $p < 0.001$) and 33% had executive function problems by parent proxy-report (vs. 20% of teens with low level of disordered eating behaviours, $p = 0.056$). A greater level of disordered eating behaviours was associated with executive function problems by teen self report on the General Executive Composite ($p < 0.001$), Behavioral Regulation Index ($p < 0.001$), emotional control clinical scale ($p < 0.001$), shift clinical scale ($p < 0.001$) and by parent proxy-report on the task initiation clinical scale ($p = 0.008$).

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Conclusions: Assessing executive function and screening for disordered eating behaviours in teens with type 1 diabetes could help identify a subset of teens at high risk for adverse outcomes and need for intervention.

KEYWORDS

adolescence, disordered eating behaviours, executive function, type 1 diabetes

1 | INTRODUCTION

Managing type 1 diabetes is challenging as it requires ongoing glucose monitoring, meal organization, carbohydrate counting and making decisions about insulin administration. These activities demand neurocognitive competencies such as executive function. Executive function is a group of cognitive processes involved in complex behaviours, reasoning and decision making.[1] Working memory, set-shifting, inhibitory control and emotional control are examples of executive functions. Executive function plays an important role in problem solving and self-control.[1] In persons with type 1 diabetes, executive function difficulties are associated with higher HbA1c levels.[2,3]

During adolescence, the challenges and burden of diabetes self care may increase, and HbA1c levels generally increase.[4] During this sensitive developmental time, executive function continues to mature,[5] and neurocognitive functioning and psychosocial status may influence diabetes management. Difficulties with cognitive and emotional self-regulation during late adolescence and emerging adulthood are associated with suboptimal diabetes management.[6,7]

Adolescence is a critical period of physical, cognitive and emotional development when certain psychological concerns may emerge. For example, worries about body image and weight may lead to disordered eating behaviours and clinical eating disorders.[8] In persons with type 1 diabetes, disordered eating behaviours are associated with higher glucose levels, diabetes complications and premature mortality.[9–11] Screening for psychosocial concerns and self-care deficits is recommended in persons with type 1 diabetes due to the potential impact on diabetes management, well-being and short- and long-term physical health, as well as to avoid progression to clinical mental health conditions, such as eating disorders.[12]

Previous research in the general population has suggested that problems with executive function are associated with disordered eating behaviours[13,14] and clinical eating disorders.[15,16] However, there is limited research about this association in persons with type 1 diabetes, especially in the vulnerable adolescent age group.[17] Problems with executive function may make it more difficult to carry out daily diabetes management tasks, which may lead to glucose levels outside of the target range. This may be compounded by disordered eating behaviours, especially those associated with insulin restriction or omission. Adolescents with type 1 diabetes may also engage in disordered eating behaviours as a way of dealing with frustrations and negative emotions about their diabetes. More knowledge about this relationship is critical to guide the design of tailored prevention and management measures.

The present study aimed to examine associations between problems with executive function and level of disordered eating behaviours in teens with type 1 diabetes, a group experiencing growth in executive function domains and at risk for emergence of disordered eating behaviours. It was hypothesized that problems with executive function would be associated with more disordered eating behaviours.

Novelty statement

- Executive function problems are associated with disordered eating behaviours in the general population, but there is limited research in persons with type 1 diabetes, especially adolescents.
- In a sample of 169 teens with type 1 diabetes, executive function problems (particularly related to emotional control, set-shifting and task initiation) were more prevalent among those with more disordered eating behaviours.
- In clinical practice, assessment of executive function and disordered eating behaviours could help identify teens with type 1 diabetes in need of intervention due to their high risk for adverse outcomes.

2 | SUBJECTS, MATERIALS AND METHODS

2.1 | Study sample

Study participants were recruited from an academic paediatric diabetes centre to participate in a

longitudinal study aimed at improving self-care and glycaemic outcomes in teens with type 1 diabetes.[18] Participants from one of the two study sites (56% of the main study sample) also completed this sub-study assessment of teen executive function. Inclusion criteria for study participation included: age 13–17 years, type 1 diabetes for at least 6 months, daily insulin dose ≥0.5 units/kg, HbA1c 6.5%–11.0% (48–97 mmol/mol) and reading/writing comprehension in English. Exclusion criteria included any other major medical or psychiatric disorder warranting active treatment changes (e.g. treated thyroid conditions or celiac disease were not exclusions). The eligibility criteria and sample size were selected to assess the primary outcomes of the longitudinal study. The study protocol was approved by the Institutional Review Board. Written informed consent was obtained from parents and written assent was obtained from teens before study participation.

2.2 | Data collection

Data were collected on the day of regularly scheduled clinical appointments. Teens and parents were interviewed by trained research assistants who collected demographic and diabetes management information. Teens and parents completed the surveys described in Section 2.3. Additional diabetes management information was obtained from electronic medical records. Teens were weighed and measured using an electronic scale and stadiometer, both appropriately calibrated, by trained personnel. Body mass index (BMI) percentiles were calculated using the Centers for Disease Control and Prevention growth charts.[19] Teens were categorized by weight status according to BMI percentile: underweight (<5th percentile), normal weight (5th to <85th percentile), overweight (85th to <95th percentile) and obese (≥95th percentile). Blood samples were obtained for measurement of HbA1c (ref. range: 4%–6%, Roche Cobas Integra, Roche Diagnostics).

2.3 | Measures

Parents completed the Behavior Rating Inventory of Executive Function (BRIEF) parent form to assess parent proxy-report of teen executive function.[20] Teens completed the Behavior Rating Inventory of Executive Function Self-Report (BRIEF-SR)[21] and the Diabetes Eating Problem Survey-Revised (DEPS-R)[22] to assess self report of executive function and disordered eating behaviours, respectively.

2.3.1 | Diabetes Eating Problem Survey-Revised

The DEPS-R is a validated screening measure that assesses self report of general and diabetes-specific disordered eating behaviours, especially in persons using insulin therapy.[22] The survey contains 16 items, which are answered on a 6-point Likert scale (0 = never, 1 = rarely, 2 = sometimes, 3 = often, 4 = usually, 5 = always). The total score is the sum of all response items; scores range from 0 to 80, with higher scores indicating more disordered eating behaviours. The validated cut-off score of ≥20 indicates a high level of disordered eating behaviours and need for additional evaluation.[22] Scores from 10 to 19 have been described as a moderate level of disordered eating behaviours at which further assessment might be considered.[23]

2.3.2 | Behavior Rating Inventory of Executive Function

The BRIEF is a validated questionnaire that assesses executive function. The youth self-report version has 80 items and the parent proxy-report version has 86 items.[20,21] Items are answered on a 3-point Likert scale (Never, Sometimes and Often). The Global Executive Composite (GEC) total score represents overall executive function and is a summary of the Behavioral Regulation Index (BRI) and the Metacognition Index (MI). The BRI and MI are each composed of several clinical scales. The BRI contains the emotional control, inhibit, monitor and shift clinical scales in the self-report version and the emotional control, inhibit and shift scales in the parent proxy-report version. The MI is composed of organization of materials, plan/organize, task completion and working memory scales in the self-report version, and the monitor, organization of materials, plan/organize, initiate and working memory scales in the parent proxy-report version. Raw scores were converted to age- and sex-adjusted T-scores, where higher scores indicate more problems with executive function. T-scores 60–64 on the GEC, BRI, MI or the clinical scales are considered mildly elevated and T-scores ≥65 are considered clinically elevated. For these analyses, we defined executive function problems as T-scores ≥60 to include both those with mild and clinically elevated executive function problems.

2.4 | Statistical analysis

Statistical analyses were performed using SAS software (version 9.4; SAS Institute). Descriptive data are

presented as mean ± SD or *n* (percentage). Teens were categorized by level of disordered eating behaviour according to DEPS-R score: <10 = low frequency of disordered eating behaviours, 10–19 = moderate frequency of disordered eating behaviours, ≥20 = high frequency of disordered eating behaviours. Teens also were categorized depending on the presence (BRIEF scores ≥60) or absence (BRIEF scores <60) of executive function problems. These categorical variables for level of disordered eating behaviours (low, moderate and high) and problems with executive function (present or not) were used in bivariate analyses. Mantel–Haenszel chi-square tests were used to compare percentages of those with executive function problems according to level of disordered eating behaviour. Due to the number of comparisons, $p < 0.01$ was considered statistically significant.

3 | RESULTS

3.1 | Participant characteristics

Demographic and diabetes management characteristics are shown in Table 1. The study sample for analyses was composed of 169 teens and 168 parents. For one parent, total scores could not be calculated for several of the BRIEF scales because there were too many missing responses and thus this parent's data were excluded. Youth (46% girls, 88% white) had a mean age of 15.9 ± 1.3 years (median 16.0, range 13.7–18.7 years), and most were from two-parent families (87%) and had at least one parent with a college degree or higher (72%). Diabetes duration was 8.4 ± 3.7 years (median 8.9, range 1.4–16.6 years) and 67% were treated with insulin pump therapy. Mean HbA1c was 8.5 ± 1.2% (69 ± 13 mmol/mol), and only 16% achieved the 2019 American Diabetes Association HbA1c target level of <7.5% (<58 mmol/mol). Normal weight was found in 56% of the teens, overweight in 31% and obesity in 14%; none of the teens were underweight.

3.2 | Disordered eating behaviours assessed by DEPS-R

DEPS-R scores are shown in Table 1. Overall, 59% of teens had a low level of disordered eating behaviours (DEPS-R <10), 29% had a moderate level of disordered eating behaviours (DEPS-R 10–19) and 12% had a high level of disordered eating behaviours (DEPS-R ≥20). Disordered eating behaviours differed significantly between girls and boys (girls: 51% low, 29% moderate, 21% high; boys: 65% low, 29% moderate, 5% high; $p = 0.009$).

3.3 | Executive function problems assessed by BRIEF: GEC, BRI and MI scores

According to the overall GEC score, 9% of teens had executive function problems (GEC ≥60) by teen self report and 26% by parent proxy-report. Problems with behavioural regulation (BRI scores ≥60) were noted in 8% of teens by self report and 18% of teens by parent proxy-report. Executive function problems related to metacognition (MI scores ≥60) were found in 10% of teens by self report and 27% by parent proxy-report. Neither self report nor parent proxy-report of executive function problems differed significantly between boys and girls.

3.4 | Associations between executive function problems and disordered eating behaviours

Figure 1 displays the percent of teens with executive function problems (scores ≥60) according to level of disordered eating behaviours. Teen self report of global executive function problems (GEC ≥60) was higher in the groups with moderate and high levels of disordered eating behaviours than in the group with a low level of disordered eating behaviours ($p < 0.001$). There were significantly greater percentages of teens with behavioural regulation problems (BRI ≥60) in the groups with moderate and high levels of disordered eating behaviour compared with those with a low level of disordered eating behaviours ($p < 0.001$). The percentage of teens with executive function problems related to metacognition (MI ≥60) was highest in the group with a moderate level of disordered eating behaviours; however, the overall Mantel–Haenszel chi-square test was not significant ($p = 0.034$). The rate of executive function problems on the GEC, BRI and MI by parent proxy-report increased with a greater level of disordered eating behaviours, but the associations were not statistically significant.

Table 2 shows the number and percent of teens with executive function problems (scores ≥60) on each of the BRI and MI clinical scales (by both teen self report and parent proxy-report) according to the level of disordered eating behaviours. By teen self report, a greater level of disordered eating behaviours was associated with executive function problems on two of the BRI clinical scales: emotional control ($p < 0.001$) and shift ($p < 0.001$). By parent proxy-report, a greater level of disordered eating behaviours was associated with executive function problems on the MI clinical scale of initiate ($p = 0.008$).

4 | DISCUSSION

Executive function problems and disordered eating behaviours are two major challenges that can emerge during

TABLE 1 Participant characteristics

	All teens ($N = 169$)	Girls ($n = 77$)	Boys ($n = 92$)
Age (years)	15.9 ± 1.3	16.0 ± 1.3	15.9 ± 1.3
Diabetes duration (years)	8.4 ± 3.7	8.8 ± 3.7	8.1 ± 3.8
Race/ethnicity (% non-Hispanic white)	149 (88)	68 (88)	81 (88)
Family structure (% two-parent family)	147 (87)	68 (88)	79 (86)
Parent education (% college degree or higher)	122 (72)	52 (68)	70 (76)
Insulin regimen (% pump)	114 (67)	54 (70)	60 (65)
Daily insulin dose (units/kg)	0.97 ± 0.28	0.92 ± 0.26	1.02 ± 0.29
Blood glucose monitoring frequency (times/day)	5.1 ± 1.8	5.1 ± 1.9	5.2 ± 1.8
Continuous glucose monitoring use (%)	36 (21)	11 (14)	25 (27)
HbA1c (%, mmol/mol)	8.5 ± 1.2	8.5 ± 1.2	8.5 ± 1.1
	69 ± 13	69 ± 13	69 ± 12
HbA1c <7.5% (<58 mmol/mol) (%)	27 (16)	11 (14)	16 (17)
Weight status (%)			
Normal weight	94 (56)	40 (52)	54 (59)
Overweight	52 (31)	27 (35)	25 (27)
Obese	23 (14)	10 (13)	13 (14)
DEPS-R total score	10 ± 10	13 ± 12	8 ± 8
Disordered eating behaviour level (%)			
Low (DEPS-R <10)	99 (59)	39 (51)	60 (65)
Moderate (DEPS-R 10–19)	49 (29)	22 (29)	27 (29)
High (DEPS-R >20)	21 (12)	16 (21)	5 (5)

Note: Data presented are mean ± SD or *n* (%).

adolescence and potentially negatively impact self-care behaviours and glycaemia.[3,6,7,23] In our sample of 169 teens with type 1 diabetes, executive function problems were more prevalent among those with moderate to high levels of disordered eating behaviours compared with those who had low level of disordered eating behaviours, suggesting important associations between executive function problems and disordered eating behaviours in teens with type 1 diabetes.

Previous research in the general population has shown that executive function problems are associated with subclinical disordered eating behaviours[13,14,24,25] and clinical eating disorders.[15,26] In particular, studies have shown that problems in the specific domains of set-shifting and emotional control are associated with disordered eating behaviours and eating disorders.[13,14,16] Set-shifting refers to a person's 'ability to move freely from one situation, activity, or aspect of a problem to another, as the circumstances demand'.[27] Difficulty with set-shifting has been associated with anorexia and bulimia nervosa, suggesting that cognitive rigidity may be a risk and maintenance factor for eating disorders.[16] Treatment for type 1 diabetes requires careful attention to food intake, activity, glucose levels, insulin doses and physical symptoms. Executive function problems may cause difficulties attending to these tasks, which may result in glucose levels outside of the target range that could be compounded by disordered eating behaviours, especially those associated with insulin restriction or omission.

In our sample, executive function problems on the emotional control and shift scales by teen self report and initiate scale by parent proxy-report were associated with moderate to high levels of disordered eating behaviours. Broadley et al. similarly found that problems in the areas of shift and planning/organizing were associated with disordered eating behaviours in young adults with type 1 diabetes.[17] In a sample of 43 youth with type 1 diabetes, Young-Hyman et al. found that high levels of emotion dysregulation were associated with more bulimic symptoms.[28] Merwin et al. used ecological momentary assessment to explore predictors of insulin restriction in adults with type 1 diabetes over a 3-day period.[29] They found that higher levels of anxiety/nervousness and guilt were associated with greater likelihood of restricting insulin at the

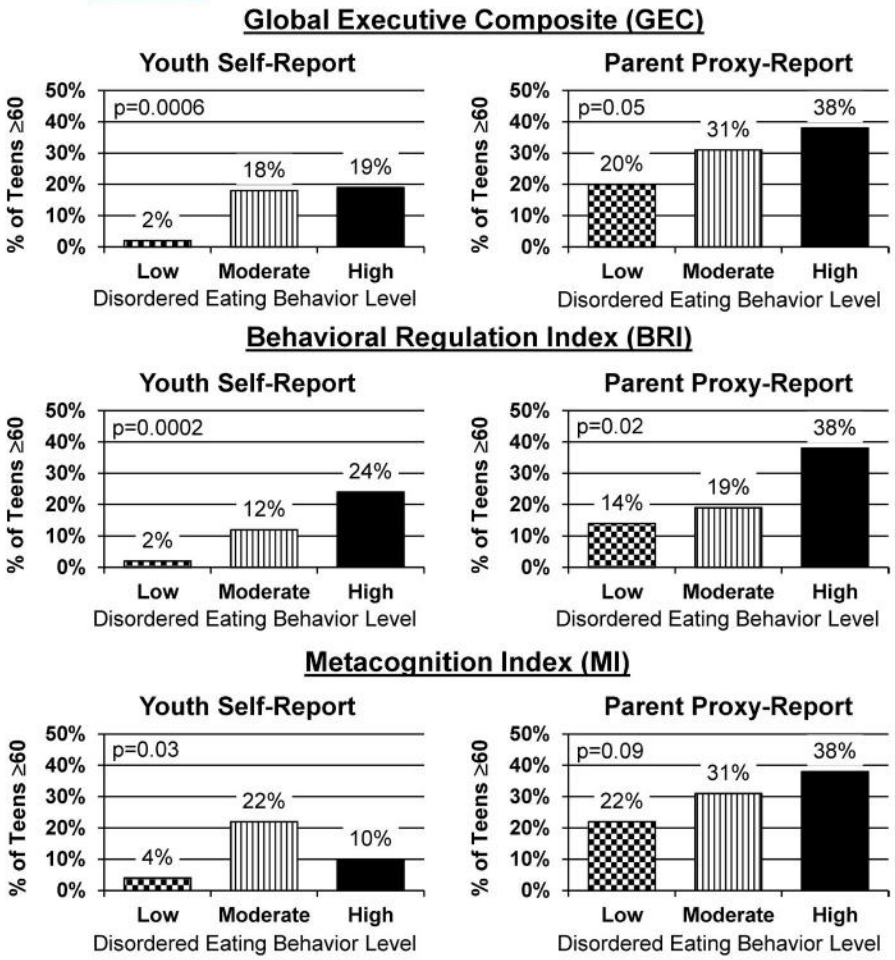

FIGURE 1 Executive function problems according to disordered eating behaviour level. There were significantly greater percentages of teens with global executive function problems (GEC ≥60) by teen self-report and behavioural regulation problems (BRI ≥60) by teen self report in the groups with moderate and high levels of disordered eating behaviours (GEC: $p < 0.001$, BRI: $p < 0.001$). Note: 99 teens had low risk for disordered eating behaviours, 49 teens had moderate risk and 21 teens had high risk.

next meal/snack (odds ratios of 1.72 and 1.84 for every 1-point increase above the person's average level of anxiety/nervousness and guilt, respectively). The authors suggest that helping people respond effectively to these emotions may decrease insulin restriction. Thus, the executive function domains of set-shifting and emotional control appear to be particularly relevant for disordered eating behaviours in both persons with and without type 1 diabetes.

Understanding the relationship between executive function and disordered eating behaviours in persons with type 1 diabetes is important. Disordered eating behaviours are difficult to treat once established and there have not been many evidence-based successful interventions for disordered eating in persons with type 1 diabetes.[30] Therefore, identification of factors that may make a person with type 1 diabetes more vulnerable to the development of disordered eating behaviours will allow clinicians to intervene before such behaviours have become established and are more difficult to treat. One recent study of adolescents with type 1 diabetes identified 'yellow flags' for disordered eating behaviours.[31] Executive function problems can similarly be viewed as a 'yellow flag'. If a clinician is aware that a teen has difficulties with executive function, from previous screening tests performed by schools or other providers or from family members' reports of behaviours suggesting difficulties with executive function (e.g. no tolerance for changes in plans), the clinician can monitor for signs of disordered eating behaviours.

Second, treatments for eating disorders in general populations often include cognitive components. For example, difficulties with set-shifting are often targeted during clinical treatment for eating disorders, such as anorexia nervosa, through the use of cognitive remediation therapy.[32] Cognitive remediation therapy involves exercises to increase awareness of one's thinking processes, encourage more adaptive thinking styles and apply these skills to everyday situations.[33] In a sample of adolescents with anorexia nervosa, treatment with cognitive remediation therapy was associated with an improvement in shift scores on the BRIEF by both self report and parent proxy-report.[34] Cognitive remediation therapy may be paired with emotion skills training, which focuses on recognizing, managing and expressing emotions.[35] Cognitive remediation and emotion skills training could be helpful tools to manage set-shifting and emotional regulation problems in persons with type 1 diabetes and disordered eating behaviours. A better understanding of the relationship between executive function and disordered eating

TABLE 2 Executive function problems on Behavioral Regulation Index and Metacognition Index clinical scales (score ≥60) according to disordered eating behaviour level

	Disordered eating behaviour level			
	Low ($N = 99$)	Moderate ($N = 49$)	High ($N = 21$)	p value
Behavioral Regulation Index clinical scales: youth self report (% of teens ≥60)				
Emotional control	2 (2)	9 (18)	6 (29)	<0.001
Inhibit	5 (5)	3 (6)	3 (14)	0.175
Monitor	2 (2)	4 (8)	2 (10)	0.059
Shift	2 (2)	12 (24)	4 (19)	<0.001
Behavioral Regulation Index clinical scales: parent proxy-report (% of teens ≥60)				
Emotional control	16 (16)	13 (27)	8 (38)	0.016
Inhibit	14 (14)	9 (19)	3 (14)	0.747
Shift	20 (20)	12 (25)	6 (29)	0.343
Metacognition Index clinical scales: youth self report (% of teens ≥60)				
Organization of materials	8 (8)	8 (16)	2 (10)	0.416
Plan/organize	3 (3)	7 (14)	2 (10)	0.055
Working memory	6 (6)	8 (16)	3 (14)	0.080
Task completion	9 (9)	16 (33)	4 (19)	0.016
Metacognition Index clinical scales: parent proxy report (% of teens ≥60)				
Organization of materials	26 (26)	23 (48)	9 (43)	0.023
Plan/organize	24 (24)	10 (21)	7 (33)	0.606
Working memory	29 (29)	15 (31)	7 (33)	0.691
Initiate	18 (18)	15 (31)	9 (43)	0.008
Monitor	21 (21)	12 (25)	8 (38)	0.126

Note: Data presented are n (%). p values obtained from Mantel–Haenszel chi-square tests. Disordered eating behaviour level: Low = DEPS-R <10, Moderate = DEPS-R 10–19, High = DEPS-R >20. The Monitor scale is part of the Behavioral Regulation Index in the BRIEF youth self-report version and part of the Metacognition Index in the BRIEF parent proxy-report version. The Task Completion scale is included in the youth self-report version but not the parent proxy-report version. The initiate scale is included in the parent proxy-report version but not the youth self-report version.

behaviours in persons with type 1 diabetes will be beneficial for efforts to develop effective treatments for disordered eating behaviours in persons with type 1 diabetes.

We assessed executive function by both teen self report and parent proxy-report, allowing for more comprehensive evaluation of teen executive function. Most prior studies evaluating executive function in teens with type 1 diabetes have included teen self report[3] or parent proxy-report of executive function,[2] but not both. The higher prevalence of teen executive function problems by parent proxy-report than teen self report observed in our sample is consistent with other data from adolescents with traumatic brain injury,[36] adolescents with specific language impairment[37] and typically developing adolescents.[36,37] It is important to recognize that when differences are observed between two raters, one rater is not necessarily better or more accurate than the other. Rather, both can provide important, complementary information. The BRIEF-SR manual states that '[The BRIEF-SR] is intended as an adjunct to parent and/or teacher observations of the same functions, such as those captured by the BRIEF Parent and Teacher Forms. Comparing all views of an individual's functioning provides a more comprehensive set of assessment data, and similarities and differences between raters can be clinically useful'.[38] Although the prevalence of executive function problems differed between teen self report and parent proxy-report, the direction of most associations between level of disordered eating behaviours and self report/parent proxy-report of executive function was similar. Differences may be due in part to the fact that there is no parent proxy version of the DEPS-R and therefore parent proxy-report of executive function was compared with teen self report of disordered eating behaviours in the analyses.

A strength of the present study is that the sample only included teens (13–17 years old), which makes the sample suitable to better understanding the association of problems with executive function and disordered eating behaviours in

teens with type 1 diabetes. Another strength is the assessment of executive function by the BRIEF, which is composed of several clinical scales assessing different executive domains; other studies evaluate only a specific domain such as set-shifting.[16,39] Although our assessments of executive function and disordered eating behaviours were based on self-report and parent proxy-report surveys, both of the measures used (DEPS-R and BRIEF) are validated and widely used measures for assessing the respective constructs of disordered eating behaviours and executive function.

Our study has a number of limitations. First, directionality or causality cannot be determined in this study given the cross-sectional nature of the analyses. Second, we were not able to assess associations of executive function problems with disordered eating behaviours using the clinically significant higher cut-point of ≥65[27] on the BRIEF, as the percent of teens exceeding this threshold was relatively small by both youth and parent report. Nonetheless, the current analyses provide exploratory observations of likely clinically important associations between mildly elevated scores on the BRIEF with moderate and high risk for disordered eating behaviours using the validated DEPS-R scale. Next, although we used a p value of <0.01, there is still a possibility of type 1 error due to multiple comparisons. In particular, there was an unusual observation of greater executive function problems for the metacognition index in teens with moderate level of disordered eating behaviours and not a high level, suggesting possible type 1 error. In addition, the sample included a relatively high percent of teens from two-parent families and high parental educational attainment, potentially limiting generalizability. However, disordered eating behaviours are relatively common in such a demographic. The study sample was also limited to teens with an HbA1c of 6.5%–11.0% (48–97 mmol/mol). The exclusion of teens with higher HbA1c levels may have excluded some teens with higher levels of disordered eating behaviours and/or executive function problems. Future studies, including longitudinal research, are needed to better understand the associations between executive function problems and disordered eating behaviours, especially in more diverse samples of teens with type 1 diabetes, to inform specific interventions to preserve physical and mental health of teens for the present and future.

In summary, executive function problems were associated with disordered eating behaviours in our sample of teens with type 1 diabetes. If clinicians are aware of potential difficulties with executive function, they can also be alert for disordered eating behaviours and intervene at the first sign before such behaviours become established and more difficult to treat. A better understanding of the relationship between executive function problems and disordered eating behaviours in persons with type 1 diabetes will help to develop effective treatments for this population. Indeed, in a special issue of Diabetic Medicine commemorating the 25th anniversary of the Psychosocial Aspects of Diabetes Study Group, Broadley et al. cited the need for additional research, stating that 'further investigation into cognitive correlates of disordered eating in diabetes could be fruitful, as cognitive interventions for disordered eating have been explored in populations without diabetes and may present an opportunity for treatment or prevention in people with diabetes'.[30] In teens with type 1 diabetes and disordered eating behaviours, a focus on executive function—and any specific domains that are impaired—may be a new target in the management of disordered eating behaviours to prevent progression to clinical eating disorders.

CONFLICT OF INTEREST

The authors report no relevant potential conflicts of interest.

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11 DISCUSSION

This thesis contributes to the knowledge of prevalence of and factors associated with disordered eating behaviors (DEB) in adolescents with type 1 diabetes (T1D). The studies included in this thesis shed light on the association of DEB with sociodemographic, biomedical, and psychosocial factors (study 1) and executive dysfunction (study 2) in adolescents with T1D.

The first study found that approximately four out of every ten adolescents had moderate or high level of DEB; 15% presented high level of DEB, and 26% presented moderated level of DEB. These prevalence rates are within the range of prevalence found by other authors assessing high levels of DEB [108,117,118,120–123] and moderate levels of DEB [131,163,168]. The prevalence of high level of DEB was close to that found in other studies (18-38%) using the cut-off score (≥20) of Diabetes Eating Problem Survey Revised (DEPS-R) to assess the high level of DEB [109,119–121,124,126,127].

This study showed that several sociodemographic and biomedical factors were associated with both moderate and high levels of DEB in teens with T1D. As described in the literature among people with T1D, in current research higher level of DEB was associated with female sex [114,117,119–121,126], higher body mass index (BMI) [119,124,138,139,143,144], less blood glucose monitoring (BGM) [144] and higher levels of glycated hemoglobin (HbA1c) [117,119,120,131,138,144,150,158]. Higher levels of DEB were found to be associated with lower levels of parental education, echoing the literature had been linked DEB to lower socioeconomic status in people with T1D [126,136].

Previous literature show higher level of DEB in older adolescents than younger ones [119,124], but these differences in age were not found in the current study. This could be explained by the fact that the age range (13-17 years old) of the sample was narrower than in other studies in the literature [124]. In addition, while the previous

research shown insulin pump use to be related with lower risk of DEB [139,157], this association was not found either in the current study, although there was a higher percentage of pump users with lower levels of DEB.

This study also confirmed the association found in previous research between more DEB and poorer psychosocial characteristics, such as depressive symptoms [122,124,127,140,143] and poorer quality of life (QoL) [124,143], and also with diabetes-specific psychosocial characteristics such as poorer diabetes treatment adherence [144,150,158] and higher diabetes-related family conflict [116,160,161]. Additionally, DEB was found to be associated with negative affect related to BGM. Although this association had not been previously assessed in the literature to date, negative emotions related with BGM had been associated with diabetes-related family conflict and poor QoL [90].

Previous research in the general population had found that executive function (EF) problems were associated with DEB [45–47] and eating disorders (ED) [48,49]. In the same way, the second study also confirms an important association between EF problems and DEB in people with T1D according to both parent and teen reports. General executive dysfunction was more prevalent in those with moderate to high levels of DEB than among those who had a low level of DEB. Even though this association was only statistically significant in the self-reported version, the direction of most associations between level of DEB by both versions assessments of EF was similar.

Specially, in this study, it was showed that DEB were associated with behavioral dysregulation, as measured by the Behavioral Regulation Index (BRI), in line with the previous studies in general population [45]. Ciszewski et al., found that behavioral regulation domains such as emotional control, shift, inhibition and self-monitoring were related with ED symtoms [45]. In present research, EF problems, as registered on the emotional control and shift, subscales of BRI, by teen self-report and on the

initiate, subscale of metacognition index, by parent proxy-report were associated with moderate to high levels of DEB. Similarly, studies in general population showed that problems with flexibility are associated with ED such as binge eating [48] and with bulimia and anorexia nervosa [49]. Among people with T1D, Broadley et al. [165] also found that DEB were associated with flexibility problems and Young-Hyman et al. [166] found that bulimic symptoms were related with emotional dysregulation. In fact, in both the general and T1D population it has been suggested that disordered eating is sometimes used to manage emotional distress [166,170]. Regarding the association between the initiate subscale and DEB according to parent report, Broadley et al. [165] also found that in a sample of adults with T1D, DEB were associated with metacognitive scales such as planning/organizing which could suggest that those with problems also in metacognition tend to misuse disordered eating in order to solve problems. To sum up, these findings advice that dysfunction in certain EF domains might act as a risk and maintenance factor for DEB in people with T1D.

11.1 Strengths and limitations

A strength of both studies included in this thesis is the utilization of the DEPS-R, which is a diabetes-specific scale, to assess DEB [116]. DEPS-R is validated to be used in adolescents and recommended by the American Diabetes Association to screen for eating problems in people with insulin treated diabetes [77,116]. Among people with T1D, it is important to use a diabetes-specific measure because general scales do not screen for diabetes-specific behaviors such as insulin omission or restriction. In addition, T1D requires carbohydrate counting and attention to food intake which on general scales could be mistakenly considered DEB.

DEPS-R has a validated cut-off (≥20) which detects people with a high level of DEB [116]. In both studies, teens were categorized into three DEB levels according to their DEPS-R scores. The high level DEB group had DEPS-R scores of ≥20. The moderate DEB level group had DEPS-R scores of 10-19. The low level DEB group had DEPS-R scores of

<10. According to previous literature, it is important not only to identify those individuals with high levels of DEB, but also those in the moderate DEB group, in terms of prevention of diabetes complications [131] and DEB severity [163,168] . Detecting adolescents with moderate levels of DEB may allow identification of teens in a clinical course point when interventions could prevent development of more severe DEB or even progression to clinical ED. It may also allow to protect teens from experiencing acute or chronic diabetes complications.

The teens in the moderate level DEB group in the first study differed from their peers in both the low and high-level DEB groups in terms of characteristics such as weight status, parent education, BGM frequency, HbA1c levels, negative affect regarding BGM, general quality of life (QoL), and depressive symptoms. While in some characteristics, including sex, treatment adherence and diabetes-specific family conflict, the moderate group was similar to the high DEB group. These are the first studies in the field to assess the moderate level DEB group using a diabetes-specific survey. As the moderate level of DEB group has different characteristics than those of the low and high level of DEB groups, it is considered important to assess the three levels when exploring DEB.

Many studies exploring DEB in people with T1D have only included females [128,133,150,163]. Therefore, the inclusion of both females and males could be considered another strength of these studies. Including both males and females could contribute new information about sex differences in eating behavior among people with T1D. Another strength could be that the studies only include teens (13-17 years old), thereby providing extensive information on a stage of life when people are particularly vulnerable to develop DEB.

A remarkable strength of the second study is that the evaluation of EF was carried out using BRIEF, which is a tool that in addition to including general

assessment, it also has different clinical scales each aimed at different EF domains. Previous studies evaluating EF in ED focused on a specific domain such as set-shifting [48,49] obtained limited assessment of EF. In addition, EF evaluation in this study included a self-report and a parent proxy-report, while previous studies included only a self-report [94] or a parent proxy-report on EF [95], but not both. Differences between raters do not necessarily imply that one rater is more accurate or give better information than another, but that both may provide complimentary data altogether contributing to a more comprehensive set of EF assessment. Getting EF information from two different sources provides a potentially useful clinically opportunity to look at similarities and differences between providers [50]. The higher prevalence of executive dysfunction according to parent proxy-report than in the teen self-report coincided with other studies of adolescents, including those with language impairment [171], traumatic brain injury [172] and neurophsychologically healthy controls [171,172]. This could be explained by the fact that EF and awareness of EF in adolescence are still in development [91]. Despite the difference in prevalence between the parent proxy-report and the self-report, the direction of the associations between level of DEB and EF problems was, as mentioned above, similar. Differences in these associations could be in part due to the lack of a parent proxy version of DEPS-R. There is no parent version of DEPS-R, thus BRIEF parent proxy-report was compared with the DEPS-R teen self-report in the analyses, which could be a limitation.

Another limitation of the second study is that the analyses were performed using mildly elevated scores of BRIEF (>60) instead of using the prescribed cut-off for clinical significance of ≥65 [173] because the percent of teens over the threshold was relatively small in both the youth and parent report.

A limitation of both studies included in this thesis is their cross-sectional design. The results provide information about association without directionality or causality. Longitudinal literature in T1D shows that DEB tends to persist or progress to severe

forms [123,128,131,133,145,150]. In a longitudinal study among 169 adolescents with T1D, the author of this thesis and colleagues found that 66% of teens stayed at the same level of DEB and 20% progressed to a higher level of DEB upon an 18 month follow-up [174].

In addition, both studies included relatively homogeneous samples. Most of the participants came from two-parent families with high levels of parental educational attainment, which could limit generalizability. Another limitation of both studies is that the participants' HbA1c was limited to 6.5%–11.0% (48–97 mmol/mol), excluding those with higher HbA1c, a factor that might have excluded some teens with DEB and/or EF problems.

11.2 CLINICAL IMPLICATIONS

The results of this thesis have several clinical implications in terms of prevention, early detection, and DEB management in adolescents with T1D. Clinicians who attend people with T1D should be aware of the associations related to DEB reported in this thesis.

The information in these studies could be useful in the design of specific preventive measures. As mentioned previously, adolescents are at increased risk of presenting risky behaviors. Therefore, health educational interventions addressed to teenagers and families and focused on general and diabetes-specific healthy eating patterns could not only improve diabetes management, but it could also help prevent the appearance of unhealthy disordered eating. Positive motivational interviews, tailored for adolescents and young adults with T1D, promote diabetes treatment adherence and could also promote healthy lifestyle among this population. Moreover, diabetes-educational programs addressed to families and youth with T1D could improve diabetes management: blood glucose monitoring, carbohydrate counting and insulin use, all them diabetes-specific behaviors that may be associated with DEB. In addition, the authors recommend regular exercise practice promotion among

adolescents with T1D since sport, in addition to improving glycemic levels, can also protect from developing overweight and obesity, which in turn could prevent unhealthy weight control behaviors.

As mentioned earlier, adolescents with T1D present high levels of negative affect such as depressive symptoms which brings out the need for appropriate psychological support to this population. Appropriate psychological support should help them manage emotional discomfort and respond effectively to negative emotions. To note, negative emotion before, during or after meals could negatively affect food intake. Thus, managing negative affect in adolescent with T1D would prevent the development of unhealthy eating behaviors and/or insulin misuse.

Another element that could help preventing the risk of DEB is family psychological support for parents with adolescents with T1D. This type of psychological support would provide parents with tools for better management of emotional distress and/or caregiver burnout, which ultimately could reduce diabetes-specific family conflict improving family environment and in turn, family mental health.

Data on many of the biomedical characteristics examined in the first study, such BMI and HbA1c, are collected during regular clinical diabetes appointments, and changes in these measurements could act as a warning to explore DEB during a routine appointment. Eilander et al. [175] describe factors associated with DEB (for example elevated HbA1c and body dissatisfaction) as clinical and psychological 'yellow flags' and recommend for screening for them in routine clinical visits. The authors of the first study recommend to add psychological screening regarding depressive symptoms, weight, and body concerns in regular diabetes visits.

If clinicians are aware of factors associated with executive dysfunction such as poor diabetes treatment adherence and/or DEB, they be better able to collect information about executive dysfunction in order to uncover any potential indicators of these risky behaviors. Specially, considering the EF problems found associated with DEB, clinicians should ask teens about problems in emotional control (overreactions, tearful, angry outbursts) and presence of rigidity (upset or disturbed when plans change), and ask parents about problems in task initiation (not a self-starter, not taking the initiative). Young-Hyman et al. [77] recommend screening for cognitive impairment in adults with T1D, and the authors of the second study underline the importance of also assessing adolescents for the presence of possible EF problems.

If we take into consideration all the information provided in this thesis, the profile most likely associated with DEB among adolescents with T1D would be: a girl with overweight/obesity, low parent education, low frequency of BGM, poor diabetes treatment adherence, negative affect associated with the results of the BGM, diabetes family conflict, depressive symptoms, poor QoL, and problems in emotional control, flexibility and in task initiation.

The identification of the factors explored in this thesis could also help clinicians to design tailored treatment plans. DEB and ED are especially difficult to treat in people with T1D, not only for the comorbidity of the diabetes per se, associated with poor metabolic control and diabetes-specific complications, but also for the peculiarities of the DEB due to the diabetes, such as the possibility of the presence of a unique weight control behavior such as insulin omission or restriction. Indeed, there is no sufficient and successful evidence-based interventions for DEB in people with T1D.

Some neuropsychological interventions, used in the general population with ED, target are specific domains of EF to improve ED symptoms. Cognitive Remediation Therapy (CRT) is an intervention which uses cognitive exercises to improve different

domains of EF including rigidity [176,177]. Cognitive Remediation and Emotion Skills Training (CREST) adds to the CRT exercises for emotional recognition, expression and management [178]. CRT was associated with the improvement of shift scores on the BRIEF, both in the self-report and the parent proxy-report, in a sample of adolescents with anorexia nervosa [179]. And the CREST was found to improve shift and the emotion task among adults with anorexia nervosa in an in-patient unit [178]. In light of these findings in the general population, the CRT and CREST could be also helpful to manage DEB in people with T1D and EF problems. Thus, treatments that have proven useful in the general population with ED could be an opportunity for treatment of DEB and ED among people with T1D.

Another aspect to consider when treating DEB or ED in people with T1D is the need to embrace a multidisciplinary approach, as associated factors affect many dimensions of the person. As biomedical, diabetes-related, psychosocial, neuropsychological, and socioeconomic factors are associated with DEB, endocrinology and mental health teams with knowledge of T1D and ED, respectively, along with social workers and social educators, all have essential roles to play in managing DEB and ED in people with T1D.

In summary, identifying factors that could make a person with T1D likely to develop DEB may facilitate early clinical detection and intervention for these behaviors and prevent the development of severe forms of DEB or clinical ED. The detection of these factors could be helpful in the design of tailored preventive measures and more effective treatments for DEB and ED symptoms in adolescents with T1D. In addition, an early identification of DEB or those more vulnerable to develop DEB among people with T1D should make diabetes clinicians more focused in improving metabolic control to prevent acute and chronic diabetes complications and premature mortality.

11.3 Research implications / Future perspectives

Future research, including longitudinal research and studies with more diverse samples of teens with T1D, is needed to expand the knowledge of factors associated with DEB in teens with T1D.

Research with more heterogenic samples, with more diverse socioeconomic status and a wider age range could help increase the generalizability of the findings. In addition, longitudinal data would give information about the direction of association and could help shed more light on the progression to both severe forms of DEB and the development of ED. Longitudinal studies could also be useful to assess the effectiveness of specific preventive and treatment interventions for DEB in people with T1D and to determine if these interventions are adequate to help adolescents with T1D preserve and recover their physical and mental health.

12 CONCLUSIONS

The aim of this thesis was to study the prevalence and the factors associated with disordered eating behaviors in teens with type 1 diabetes. The investigation was focused on the prevalence and sociodemographic, biomedical, and psychosocial factors; and executive dysfunction:

1. Disordered eating behaviors were prevalent in a sample of adolescents with type 1 diabetes.
2. Disordered eating behaviors were more prevalent among females.
3. No differences were found between the groups with high, moderate, and low levels of disordered eating behaviors in association with age.
4. Disordered eating behaviors were associated with lower socioeconomic status.
5. Disordered eating behaviors were associated with high weight status.
6. Disordered eating behaviors were associated with a lower frequency of blood glucose monitoring.
7. Disordered eating behaviors were associated with higher blood glycated hemoglobin.
8. No differences were found between high, moderate, and low levels of disordered eating behaviors and insulin pump use.
9. Disordered eating behaviors were associated with poor diabetes treatment adherence.
10. Disordered eating behaviors were associated with negative affect with regard to blood glucose levels.
11. Disordered eating behavior were associated with diabetes-related family conflict.
12. Disordered eating behaviors were associated with depressive symptoms.
13. Disordered eating behaviors were associated with poor quality of life.

14. Disordered eating behaviors were associated with general executive function problems, reported by teens, in a sample of adolescents with type 1 diabetes.
15. In a sample of adolescents with type 1 diabetes, disordered eating behaviors were associated with behavioral dysregulation reported by teens.
16. Problems in emotional control and flexibility, according to teen self-report, were associated with disordered eating behaviors.
17. Problems in task initiation, according to parent proxy report, were associated with disordered eating behaviors.

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