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SYSTEMATIC REVIEW OR META-ANALYSIS

Diabetes technologies in people with type 1 diabetes mellitus and disordered eating: A systematic review on continuous subcutaneous insulin infusion, continuous glucose monitoring and automated insulin delivery

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Abstract

Aims: In this systematic review, we aimed (1) to identify and describe research investigating the use of advanced diabetes technologies (continuous subcutaneous insulin infusion, CSII; continuous glucose monitoring, CGM; automated insulin delivery, AID) in people with type 1 diabetes (T1DM) and disordered eating and (2) to discuss potential (dis)advantages of diabetes technology use in this population, derived from previous research.

Methods: We conducted a systematic literature search in two electronic databases for English articles published between 2000 and 2020 addressing eating disorders and/or dysfunctional eating behaviours and diabetes technology use in children, adolescents and adults with T1DM (PROSPERO ID CRD42020160244).

Results: Of 70 publications initially identified, 17 were included. Overall, evidence on the use of diabetes technologies in people with T1DM and disordered eating is scarce. The majority of the studies reports findings on CSII in people with T1DM and dysfunctional eating behaviours or eating disorders. Findings predominantly stem from observational data and are, in most cases, secondary findings of the respective studies. Providing the greatest flexibility in diabetes management, CSII may have benefits in disordered eating. CGM data may complement the diagnostic process of disordered eating with a physiological indicator of insulin restriction (i.e. time spent in hyperglycaemia).

Conclusions: Results on possible (dis)advantages of diabetes technology use in people with T1DM and disordered eating are based on observational data, small pilot trials and anecdotical evidence from case reports. Prospective data from larger samples are needed to reliably determine potential effects of diabetes technology on disordered eating in T1DM.

KEYWORDS

eating disorders, disordered eating behaviours, bulimia nervosa, anorexia nervosa, continuous glucose monitoring, continuous subcutaneous insulin infusion, automated insulin delivery

Novelty Statement

What is already known?

- Dysfunctional eating behaviours and eating disorders in type 1 diabetes are related to deterioration of glycaemic control. Diabetes technologies are potent tools to improve self management outcomes.

What has this study found?

- Evidence on the use of diabetes technologies in people with type 1 diabetes and disordered eating is scarce and stems from case reports, observational data and small pilot trials.
- Providing the greatest flexibility, continuous subcutaneous insulin infusion may be beneficial in disordered eating.

What are the clinical implications of the study?

- The use of diabetes technologies may have benefits in people with type 1 diabetes and disordered eating, but prospective data from representative samples are critically needed.

1 | INTRODUCTION

Dysfunctional eating behaviours and eating disorders in type 1 diabetes mellitus (T1DM) are serious, yet understudied, conditions. For people with T1DM, diabetes management requires a lifelong and careful consideration with food choices and carbohydrate counting, which has long been discussed as a factor that drives an increased risk for the development of disordered eating in this population.[1,2] Moreover, weight gain can be a side effect of insulin therapy that can occur beyond the initial rehydration phase,[3,4] which may lead to body dissatisfaction and, in consequence, to attempts to reduce weight and restricted eating behaviour.[1,2,5] Other vulnerability factors discussed to contribute to the development and maintenance of disordered eating in T1DM include low self-esteem/feeling different due to diabetes, pressure of diabetes management[2] and co-morbid mental disorders such as depression.[6] Prevalence estimates for disordered eating range from <1% to 39%.[7-12] This wide range in prevalence may be resulting from different study designs, sample characteristics and a lack of consensus when it comes to the definition of disordered eating in people with T1DM.[13]

1.1 | Definition of disordered eating in people with type 1 diabetes mellitus

Disordered eating in T1DM includes (a) psychiatric eating disorders, which can be diagnosed by international classification systems and (b) 'disordered' or 'dysfunctional' eating behaviours that are not frequent or severe enough to warrant diagnosis for a psychiatric eating disorder.[14] We define dysfunctional eating behaviours as a variety of unhealthy weight management behaviours and eating disorder symptoms, including restricted eating, binge-eating and the diabetes-specific omission of insulin and subsequent 'purging' of calories via intentional hyperglycaemia and glucosuria ('insulin purging'[15]). This purging behaviour is exclusive to people with diabetes and often referred to as 'diabulimia' because purging behaviours are among the diagnostic criteria for bulimia nervosa. The term 'diabulimia' should be handled with caution, as it is used inconsistently to either describe diabetes-specific insulin purging as a single symptom of eating disorders or to replace the diagnosis 'bulimia nervosa' in T1DM.[16]

Insulin omission has been found to be a common feature in T1DM.[2,17] In a study on the prevalence of disordered eating in adolescents with T1DM, 18.5% of the boys and 20.5% of the girls reported to restrict insulin at least three times per week.[18] Although highly effective for weight control, restricting and underdosing insulin will almost inevitably result in a deterioration of glycaemic control and, hence, increase the risk of serious health consequences, hyperglycaemic crisis and ketoacidosis, and early-onset diabetes complications, as evidenced by a threefold increase in mortality compared with people with T1DM who have never restricted insulin.[19]

The presence of purging behaviour is among the diagnostic criteria for bulimia nervosa and also subtypes of anorexia nervosa. Bulimia nervosa seems particularly more common in people with T1DM than in the nondiabetic population,[9]

whereas other eating disorders such anorexia nervosa and binge-eating have a lower prevalence.[12]

1.2 | Advanced diabetes technologies

An increasing number of people with T1DM use advanced diabetes technologies (DTs) for facilitating their diabetes management. If properly used, DT such as continuous subcutaneous insulin infusion (CSII), continuous glucose monitoring (CGM) or a combination of both devices (automated insulin delivery, AID) are potent tools that have been amply demonstrated to improve self management outcomes in people with T1DM.

Compared with insulin regimens built on multiple daily injections (MDIs), CSII is linked to lower glycated haemoglobin (HbA1c) levels, reduced severe hypoglycaemia, higher quality of life and treatment satisfaction in people with T1DM.[20] The effective use of CSII requires people to be motivated to safely manage the device. Thus, with regard to disordered eating in T1DM, various impacts of CSII use are conceivable: using CSII may contribute to a negative body image,[20] that can in turn increase the risk for disordered eating.[1,5] Additionally, weight gain on insulin treatment might further deteriorate body dissatisfaction: although daily insulin requirements may be reduced under CSII[21,22] and, hence, significant weight gain may occur less frequently compared with injection insulin therapies,[23] a recent 10-year retrospective study found a linear increase in body weight for both CSII and MDI across the study period.[24] On the other hand, CSII allows for an even more flexible eating behaviour through constant rapid-acting insulin infusion (basal rate) complemented by variable insulin boluses[22] and thus may prevent people with T1DM from engaging into a vicious cycle of unfavourable glycaemic control, restraint eating and disordered eating behaviour.[5]

CGM has been shown to be superior to conventional self monitoring of blood glucose with regard to significant reductions in HbA1c, reduced exposure to hypoglycaemia and higher patient satisfaction.[25,26] The use of CGM may be related to improvements in disordered eating: excessive calorie intake after hypoglycaemia is discussed as a mechanism through which disordered eating is potentiated in people with T1DM.[5] Because CGM is associated with reduced exposure to hypoglycaemia, the need for compensatory, 'involuntary' calorie intake to treat hypoglycaemia may be lowered. However, evidence on this hypothetic impact of CGM on disordered eating in T1DM is scarce.

The combined use of CGM and CSII, either as sensor-augmented pump therapy or integrated in a hybrid closed-loop system, is related to several self management benefits for children, adolescents and adults with T1DM. Emerging evidence on AID suggests improved glycaemic control, higher patient satisfaction and other psychosocial benefits[27-29] that go beyond advantages of CGM and CSII alone. Further reducing the burden of daily self management with AID may as well have a positive impact on mental health. To date, little is known about potential (dis)advantages of AID use in people with T1DM and disordered eating.

As discussed above, DT use may come with specific challenges and pitfalls in people with T1DM and disordered eating but may also offer advantages for diabetes management.[30] Therefore, this systematic literature review has two aims. First is to identify and comprehensively describe findings on the use of DT in people with T1DM and dysfunctional eating behaviours or eating disorders and second is to discuss possible advantages and disadvantages of DT use in this population in the light of previous findings.

2 | METHODS

The systematic review process adheres to the PRISMA statement.[31] The protocol was registered with PROSPERO International prospective register of systematic reviews (CRD42020160244).

2.1 | Search strategy

We conducted a systematic search in PubMed and Web of Science in June 2020 for English articles published between 2000 and 2020. Keywords that were searched included 'continuous glucose monitoring', 'continuous subcutaneous insulin infusion', 'automated insulin delivery', 'eating disorder*' 'anorexia nervosa', 'bulimia nervosa' and 'disord* eating behav*' linked with Boolean operators (AND/OR). The full search strategy is included in the Appendix. We handsearched the retrieved articles for additional references.

2.2 | Inclusion and exclusion criteria

We included English articles published in scientific journals between 2000 and 2020 addressing eating disorders/disordered eating behaviours and DT use in T1DM. Duplicates were removed. To be included in this systematic review, studies must have met the following criteria: (1) publication in a scientific journal between 2000 and 2020 in English, (2) addressing disordered eating (i.e. dysfunctional eating behaviours or eating disorders) in people with T1DM and (3) further addressing CSII, CGM or AID use. Animal studies were excluded. The screening process included an initial title and abstract screening and a subsequent full text screening. Each publication was rated by two independent raters. In case of disagreement, the co-authors discussed the rating until a consensual agreement was arrived.

2.3 | Data extraction and quality assessment

We extracted relevant information using a predefined data extraction sheet. From each study, the following data were extracted: (1) study details (e.g. authors, year of publication), (2) study type and methods (e.g. study aim, design), (3) sample characteristics (e.g. sample size, age, gender), (4) type of disordered eating addressed (dysfunctional eating behaviours, clinical eating disorders), (5) type of DT addressed (CSII, CGM, AID) and (6) outcome domain and measures, if applicable.

Study quality was assessed by two independent reviewers with regard to potential bias (e.g. selection, performance, attrition, detection) using an established assessment tool for observational cohort and cross-sectional studies or controlled interventional studies, if applicable.[32] Based on 14 questions, an overall rating was assigned, indicating a low, moderate or high risk of bias. Disagreements were resolved by discussion.

3 | RESULTS

The PRISMA flow chart illustrates the inclusion and exclusion of studies (Figure 1). Our search identified a total of 70 publications across the two databases. Nine duplicates were removed. Thirty-six articles did not meet the inclusion criteria and were excluded in the title and abstract screening. Four publications were identified by hand-searching references. Interrater reliability was satisfactory for title and abstract screening (Cohen's kappa = 0.78) and excellent for full-text screening (Cohen's kappa = 0.92).[33] We examined the full texts of 29 publications in detail, and 17 studies met the inclusion criteria. Of the 17 included studies, 15 studies addressed the use of CSII in people with T1DM and disordered eating.[11,12,34-46] Three studies referred to CGM (two of which also addressed CSII),[38,39,47] and one study referred to the use of AID in people with T1DM and disordered eating[48] (Table 1).

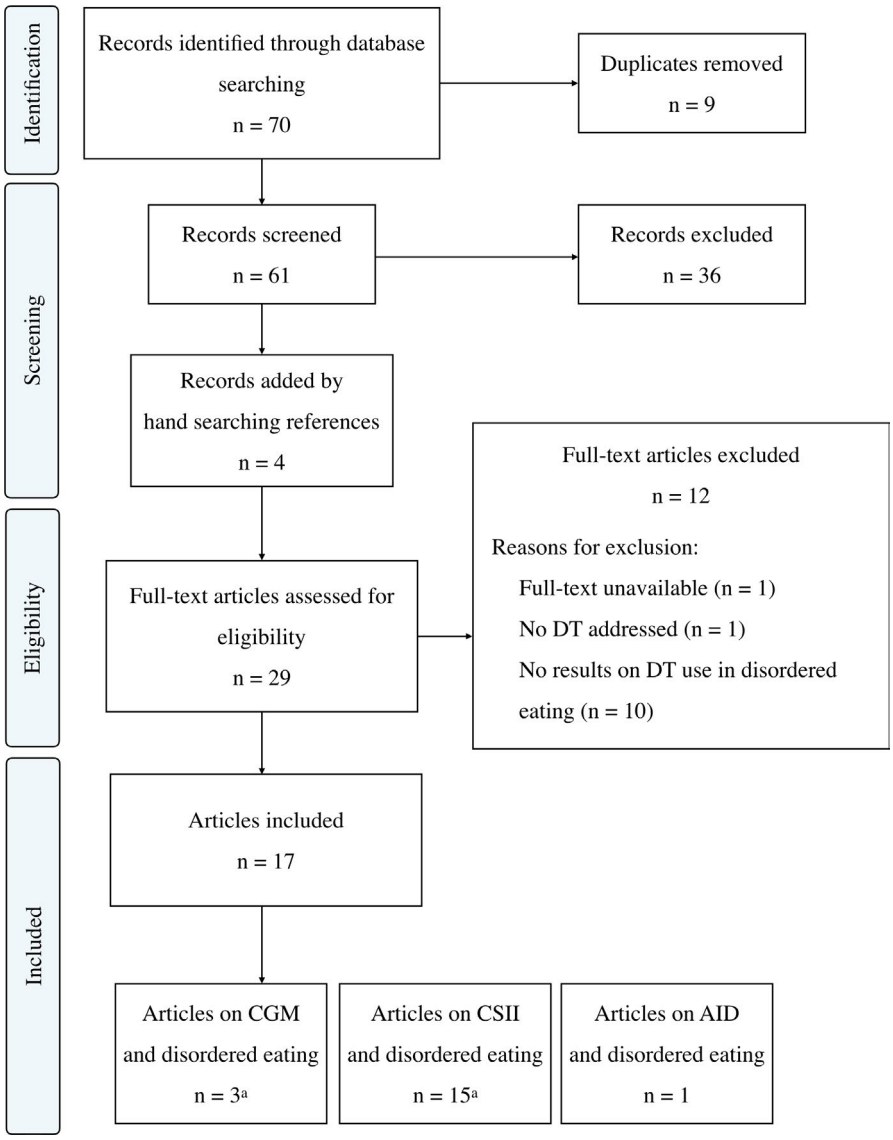

FIGURE 1 PRISMA flow chart. [a]Two articles addressed both CGM and CSII

Fourteen studies, thirteen with observational and one with controlled design, were eligible for quality assessment. Two case studies[40,41] and one review[48] included in our synthesis were not assessed in terms of their quality. Eight studies were classified as having a moderate risk of bias.[11,12,34,35,37,42,44,47] Of the six remaining studies, three indicated a low[38,39,46] and three indicated a high risk of bias.[36,43,45] Notably, the quality assessment captures the studies' quality in terms of their main aims and hypotheses, which were, in some cases, not the findings we extracted for this review (Table 1).

Overall, evidence on DT use in people with T1DM and eating disorder symptomatology is scarce. Results on possible (dis)advantages of DT use in T1DM and eating problems are mostly based on case reports, observational data and small pilot trials in nonrepresentative samples (Table 1), which obviously limits validity and generalisability of the findings. The included publications do not always give a clear definition of the symptoms, behaviours or even diagnoses subsumed under the widely used term of 'disordered eating behaviour'. Only a few of the included studies directly focused on DT use in people with co-morbid eating disorders; most of the results summarized in the following sections stem from secondary analyses and were more of a by-product of the studies' original objects.

In the following, we summarize the identified publications on CSII, CGM and AID use in T1DM and disordered eating:

3.1 | Findings on continuous subcutaneous insulin infusion

The majority of studies included for synthesis of the results reports findings on CSII use in people with T1DM and dysfunctional eating behaviours or eating disorders. Findings predominantly stem from observational data (Table 1) and are, in most cases, secondary findings of the respective studies.

3.1.1 | Continuous subcutaneous insulin infusion in dysfunctional eating behaviours

To test the general feasibility of CSII treatment in female adolescents with T1DM and dysfunctional eating behaviours, Pinhas-Hamiel and colleagues conducted a retrospective pilot study with $N = 63$ girls, of whom $n = 15$ showed intentional insulin omissions, restrictive eating behaviour or binge-eating behaviour.[43] Of these 15 adolescents, $n = 8$ used CSII and had significantly lower HbA1c levels compared with the $n = 7$ adolescents on MDI. Despite limitations such as the prohibitively small sample size, Pinhas-Hamiel et al concluded that CSII is feasible in adolescents with T1DM and disordered eating behaviours.[43]

In a sample of $N = 151$ adolescents with 'high risk' ($n = 22$) or 'low risk' ($n = 129$) for eating disorders (according to Diabetes Eating Problem Survey scores[49]), Tse et al found that the number of CSII use did not differ between these groups (65.1% vs 63.6%, $p = 0.89$).[46] Doyle and colleagues report similar findings in a sample of $N = 60$ young adults with T1DM.[35] Of these, $n = 14$ scored high on the Diabetes Eating Problem Survey-Revised (DEPS-R) scale,[50] but rates of CSII were similar compared with those scoring low on the scale (71.4 vs 71.7%, $p = 0.61$).[35]

In contrast to these studies, Sanlier et al reported lower DEPS-R scores for those using CSII ($n = 24$) in a sample of $N = 149$ children and adolescents with T1DM.[45] The authors discuss that the use of CSII may help to 'normalise' eating behaviour in people with T1DM and should, therefore, be associated with fewer symptoms of disordered eating.[45]

In 2006, Battaglia and colleagues hypothesised that, due to the greater flexibility in eating, adolescents with T1DM using CSII would report a lower frequency of 'disordered eating' compared with adolescents using MDI.[34] In a cross-sectional self report study, they examined female adolescents using CSII ($n = 22$) or MDI ($n = 47$) who completed questionnaires on disordered eating, quality of life and self-efficacy.[34] The authors found no significant differences in self-reported disordered eating between the CSII and the MDI group, but girls on CSII reported better glycaemic control, self-efficacy and higher quality of life. Self-reported disordered eating scores varied highly across participants. The cross-sectional study from Battaglia et al also examined the omission of insulin doses in the two treatment groups (CSII vs MDI).[34] Interestingly, no adolescents in the CSII group reported insulin omission, whereas 15% of the participants in the MDI group reported to take less insulin or skip insulin doses.[34]

The association between frequency of insulin omissions and insulin delivery method was also examined by Merwin and colleagues.[39] The study originally aimed to identify the time of day when insulin restriction would be most common using an ecological momentary assessment (EMA) approach combined with CGM (see below). However, the authors also found that in their sample of $N = 59$ adults with high risk for disordered eating, frequency of insulin restriction was related to the method of insulin delivery: participants using MDI omitted insulin more frequently than those using CSII (2.71 ± 33.9 vs 1.24 ± 1.67 times a day, $p = 0.004$).[39]

In an earlier study, Merwin and colleagues investigated predictors of insulin omission in an EMA study in a larger sample of people with high ($n = 58$) and low risk ($n = 25$) for disordered eating. Here, they found that the frequency of insulin restriction was not significantly correlated to CSII use.[38]

To examine the effects of CSII on disordered eating over time, Markowitz et al conducted a prospective pilot study following $N = 43$ youth over 6 months after CSII initiation.[37] The authors argued that CSII initiation may lead to a decrease in disordered eating behaviour but could also

TABLE 1 Characteristics of the 17 included studies and key findings extracted for this review

Authors, year of publication	Study aim	Type of study/study design	Participants with T1DM
Findings on continuous subcutaneous insulin infusion (CSII)			
Battaglia et al (2006)[34]	To assess whether CSII is associated with a lower frequency of DEB, improved quality of life/self-efficacy, better glycaemic control	Cross-sectional	$N = 69$ female adolescents, $n = 22$ on CSII (age $M = 14.09 \pm 1.85$ years), $n = 47$ on MDI (age $M = 14.49 \pm 1.74$ years)
Doyle et al (2017)[35]	To assess the prevalence of DEB in emerging adults	Cross-sectional (pilot)	$N = 60$ young adults, 45% female, age $M = 21 \pm 2.5$ years
Hunger-Dathe et al (2003)[36]	To evaluate CSII therapy outcomes and to identify features associated with persistently increased HbA1c levels	Prospective cohort study	$N = 250$ adults, age $M = 36.0 \pm 13.1$ years
Markowitz et al (2013)[37]	To assess dysfunctional eating behaviours upon implementation of CSII therapy	Prospective cohort study (pilot)	$N = 43$ children and adolescents, 45% female, age $M = 13.3 \pm 1.9$ years
Merwin et al (2015)[38]	To identify predictors of insulin restriction using EMA and blinded CGM	Observational EMA study	$N = 83$ adults, 88% female, age $M = 41.89 \pm 12.43$ years
Merwin et al (2018)[39]	To examine the frequency of insulin omission by time of day using EMA and blinded CGM	Observational EMA study	$N = 59$ adults, 93.2% female, age $M = 41.3 \pm 12.4$ years
Minuto et al (2012)[40]	Case report on the use of CSII electronic diary as a source of information about excessive insulin administration	Case report	$N = 1$, 14-year-old girl
Napoli et al (2011)[41]	Case report on severe DKA due to self-induced vomiting and subsequent reduction of insulin boluses to prevent hypoglycaemia	Case report	$N = 1$, 26-year-old woman
Peterson et al (2018)[42]	To assess whether disruption of hunger and satiety is associated with bulimic symptoms when transitioning to CSII	Cross-sectional (pilot)	$N = 43$ children and adolescents, 54% female, age $M = 12.86 \pm 1.83$ years
Pinhas-Hamiel et al (2010)[43]	To test feasibility of CSII	Retrospective cohort study (pilot)	$N = 63$ girls, age ≥ 10 years
Prinz et al (2016)[44]	To assess use/discontinuation of CSII in persons with and without co-morbid mental health disorders	Retrospective cohort study	$N = 48{,}700$ children, adolescents and adults, 47.4% female, age between 5 and 30 years, median 15.6 [12.0–17.7] years
Reinehr et al (2019)[12]	To identify indications of EDs	Retrospective cohort study	$N = 31{,}556$ female children, adolescents, young adults
Sanlier et al (2019)[45]	To investigate associations of depression and EDs	Cross-sectional	$N = 149$, 45.6% female, age $M = 13.42 \pm 2.31$ years
Scheuing et al (2014)[11]	To compare characteristics/diabetes outcomes between people with and without ED	Retrospective cohort study	$N = 52{,}215$ children, adolescents, young adults, 47,24% female, age 8 to <30 years
Tse et al (2012)[46]	To examine associations of DEB with diet quality, diet-related attitudes, and diabetes management	Cross-sectional	$N = 151$ adolescents, 48% female, age $M = 15.6 \pm 1.5$ years

DEB/ED	Key findings for this review
DEB according to EDI-2 and EAT-26 scores; analysis included mean scores of both groups	No differences in DEB scores between CSII and MDI group; none of the adolescents on CSII reported insulin omission, while 15% in the MDI group did
DEB according to DEPS-R scores; $n = 14$ participants with DEPS-R scores ≥20	No differences in frequency of CSII use between participants at high vs low risk for ED
$n = 12$ participants with mental health disorders including AN and BN	Mental health disorders including eating disorders were found to be associated with persistently increased HbA1c levels
DEB according to DEPS-R scores; $n = 2$ participants with DEPS-R scores ≥20	Mean DEPS-R scores decreased over 6 months after CSII initiation
DEB (insulin restriction) assessed with EMA in $n = 74$ participants	No significant correlation between frequency of insulin restriction and CSII use
DEB according to DEPS-R scores in $N = 59$ participants, insulin restriction assessed with EMA	Frequency of insulin restriction was related to insulin delivery method; MDI users restricted insulin more frequently than CSII users
Binge-eating disorder	Analysis of CSII data revealed frequent additional insulin boluses the person administered to cover for following binge-eating episodes
DEB; purging behaviour (self-induced vomiting)	Napoli et al discuss that in the presence of DEB, CSII use might facilitate weight control through 'easy modulation' of insulin doses
Bulimic symptoms according to EDI-3 Bulimia subscale; disruption of hunger and satiety according to DTSS-20 scores	Combination of high depression scores and excessive hunger was associated with most bulimic symptoms; Peterson et al discuss that CSII better mimics the healthy metabolism which may improves uncontrollable hunger and, subsequently, bulimic symptoms
DEB in $n = 15$ participants	Of 15 adolescents with DEB, $n = 8$ used CSII and had significantly lower HbA1c levels compared with the $n = 7$ adolescents on MDI
ED diagnosis according to ICD-10 and DSM-IV, DSM-5 in $n = 395$ participants, ED diagnoses not specified	People with ED used CSII with a similar frequency than people without co-morbid mental health disorder; CSII discontinuation was higher in persons with co-morbid ED
ED diagnosis according to ICD-10 and DSM-IV, DSM-5 in $n = 514$ participants ($n = 155$ with AN, $n = 85$ with BN, $n = 45$ with binge-eating disorder, $n = 229$ with EDNOS)	Type of insulin delivery was not related to eating disorders, except for AN: CSII use decreased the likelihood for AN by almost one-half
DEB according to DEPS-R scores	Fewer DEB in children/adolescents on CSII
ED diagnosis according to ICD−10 and DSM-IV in $n = 467$ participants ($n = 141$ with AN, $n = 62$ with BN, $n = 264$ with EDNOS, including binge-eating disorder)	Frequency of CSII use was lower in people with co-morbid ED than in people without ED and lowest in people with co-morbid AN
DEB according to DEPS scores, $n = 22$ 'at risk'	No differences in frequency of CSII use between participants 'at low risk' vs 'at risk' for ED

(Continues)

TABLE 1 (Continued)

Authors, year of publication	Study aim	Type of study/study design	Participants with T1DM
Findings on continuous glucose monitoring (CGM)			
Eisenberg Colman et al (2018)[47]	To investigate whether an intervention to improve overall diet quality inadvertently increases DEB	Randomized controlled trial (secondary analysis)	$N = 90$ adolescents, 51.1% female, age $M = 13.7$ years
Merwin et al (2015)[38]	To identify predictors of insulin restriction using EMA and blinded CGM	Observational EMA study	$N = 83$ adults, 88% female, age $M = 41.89 \pm 12.43$ years
Merwin et al (2018)[39]	To examine the frequency of insulin omission by time of day using EMA and blinded CGM	Observational EMA study	$N = 59$ adults, 93.2% female, age $M = 41.3 \pm 12.4$ years
Findings on automated insulin delivery (AID)			
Kahkoska et al (2017)[48]	To discuss the role of dietary restraint in T1DM therapy and potential implications of AID use	Review	-

Abbreviations: AN, anorexia nervosa; BN, bulimia nervosa; CGM, continuous glucose monitoring; CSII, continuous subcutaneous insulin infusion; DEB, dysfunctional eating behaviours; DEPS, Diabetes Eating Problems Survey[49]; DEPS-R, Diabetes Eating Problems Survey-Revised[50]; DKA, diabetic ketoacidosis; DSM-IV, Diagnostic and Statistical Manual of Mental Disorders, fourth edition; DSM-5, Diagnostic and Statistical Manual of Mental Disorders, fifth edition; DTSS-20, Diabetes Treatment and Satiety Scale[62]; EAT-26, Eating Attitudes Test-26[63]; ED, Eating disorder; EDI-2, Eating Disorder Inventory-2[64]; EDI-3, Eating Disorder Inventory-3[65]; EDNOS, eating disorders not otherwise specified; EMA, ecological momentary assessment; HbA1c, glycated haemoglobin; ICD-10, International Statistical Classification of Diseases and Related Health Problems, 10th Revision; MDI, multiple daily injections; T1DM, type 1 diabetes; TAR, time above range; TBR, time below range.

intensify the focus on food intake, thus possibly increasing the risk for disordered eating. With only two persons being at 'high risk' for an eating disorder according to DEPS-R scores at baseline, DEPS-R scores for the sample still significantly decreased over time after initiation of CSII treatment. Markowitz and colleagues discuss that these positive effects of CSII treatment might emerge from greater lifestyle flexibility, normalisation in appetite and a renewed focus on diabetes treatment that may rather facilitate a (re)focusing on functional treatment decisions than intensifying the focus on food intake in a dysfunctional manner.[37] Notably, the small pilot sample did not score particularly high on the DEPS-R scale at any time,[37] so effects of CSII may be different in people with diabetes being at higher risk for disordered eating.

3.1.2 | Continuous subcutaneous insulin infusion in eating disorders

Prinz et al analysed data from the German/Austrian/Luxembourgian and Swiss Diabetes Patienten Verlaufsdokumentation (DPV) Registry and found that persons with eating disorder diagnosis ($n = 395$, diagnoses not specified) use CSII with a similar frequency than people with diabetes without co-morbid mental disorders.[44] Interestingly, the authors report that the rate of CSII discontinuation is higher in persons with a co-morbid eating disorder (10% vs 5.1%, $p < 0.05$).

Anorexia nervosa

Three studies report on the use of CSII in people with anorexia nervosa. Hunger-Dathe and colleagues examined $N = 250$ persons with T1DM on CSII to identify factors associated with consistently elevated HbA1c levels. In 43 people, CSII use did not lead to improvements in glycaemic control or reduction of acute diabetic complications. Twenty-eight percent of these people were afflicted by mental health disorders including anorexia nervosa and bulimia nervosa.[36] The authors discuss mental health issues as a general risk factor of poor glycaemic outcomes.

In a 2014 retrospective study, Scheuing et al analysed data from the DPV Registry ($N = 52{,}215$) to describe clinical characteristics of people with and without documented eating disorder (according to Diagnostic and Statistical Manual of Mental Disorders, fourth edition criteria).[11] The authors found worse glycaemic outcomes, a higher frequency of diabetes complications and lower use of CSII in people with T1DM and co-morbid eating disorder ($n = 467$) compared with people with T1DM without eating disorder. The lowest frequency of CSII use was found among people with T1DM and anorexia nervosa ($n = 141$; 13.1% vs 19.5%, $p = 0.037$; compared with no eating disorder).[11]

In a recent study, Reinehr et al argued that using CSII – which allows greater eating flexibility – is related to a lower risk for eating disorders.[12] The authors analysed follow-up data of $N = 31{,}556$ women from the DPV Registry, including $n = 514$ persons with a documented diagnosis of an eating disorder. They found that the type of insulin delivery was

DEB/ED	Key findings for this review
DEB according to DEPS-R scores	DEB were associated with higher mean glucose and TAR (>180 mg/dl), but not with TBR (<70 mg/dl) or glycaemic variability; CGM can be used to assess glycaemic associations of DEB
DEB (insulin restriction) assessed with EMA in $n = 74$ participants	Insulin restriction was correlated with higher mean glucose and TAR (>180 mg/dl); CGM can be used to assess glycaemic associations of DEB
DEB according to DEPS-R scores in $N = 59$ participants, insulin restriction assessed with EMA	Insulin restriction was less likely in the morning and more likely in the late afternoon; insulin restriction was associated with higher mean glucose; CGM can be used to assess glycaemic associations of DEB
-	The authors discuss that the flexibility in eating offered by AID may decrease the need for cognitive dietary restraint, thus promoting disinhibited eating

not related to any eating disorder diagnosis but anorexia nervosa. The use of CSII decreased the likelihood for anorexia nervosa in the underlying sample by almost one-half which (partly) confirmed the authors' hypothesis that CSII use is related to a lower risk for eating disorders.[12]

Bulimia nervosa

Two studies referred to CSII and symptoms of bulimia nervosa. Peterson et al argued that CSII may improve bulimic symptoms.[42] In a cross-sectional pilot study ($N = 43$), the authors examined the risk for bulimic symptoms in adolescents with T1DM transitioning from MDI to CSII. Results showed that a combination of high depression scores and excessive hunger was associated with the most bulimic symptoms in this sample.[42] Peterson and colleagues discuss that CSII is more flexible and better mimics the healthy metabolism, so they argue that the use of CSII could improve uncontrollable hunger in T1DM and consequently reduces bulimic behaviours.[42] Unfortunately, the study's design does not allow for further examination of the hypothetical relation between disrupted hunger, CSII use and bulimic symptoms, so this relationship still remains speculative.

On the other hand, Napoli and colleagues present the case of a pregnant 26-year-old woman with T1DM on CSII treatment who was hospitalised for diabetic ketoacidosis in her third trimester.[41] The person engaged into purging behaviour by self-induced vomiting and subsequently reduced her insulin doses to prevent hypoglycaemia. The authors point out that CSII may facilitate the manipulation of insulin delivery and discuss that CSII should not be considered in people with T1DM who show purging behaviour.[41]

Binge-eating disorder

A 2012 case report by Minuto et al describes the use of CSII data to identify disordered eating behaviour.[40] The authors report on a 14-year-old girl with T1DM who was diagnosed with binge-eating disorder after analysis of CSII data revealed frequent additional insulin boluses followed by food intake.[40] Despite these additional glucose intakes, the administered insulin boluses led to hypoglycaemic episodes. Minuto and colleagues point out that CSII data might help to understand if severe hypoglycaemic episodes are due to excessive insulin administration (after a binge-eating episode).[40]

3.2 | Findings on continuous glucose monitoring

Of the 17 included studies on diabetes and disordered eating, three studies referred to the use of CGM data in studies targeting dysfunctional eating behaviours in T1DM.

As described above, Merwin et al investigated daily frequencies of insulin omission by analysing continuously measured glucose data in $N = 59$ adults with T1DM and disordered eating (i.e. a score ≥20 on the DEPS-R).[39] Results showed that insulin omission was less likely in the morning and more likely in the late afternoon and that insulin omission was associated with higher blood glucose.[39] In an earlier

study, the authors also found a correlation between insulin restriction and higher mean glucose levels, as well as time spent in hyperglycaemia (assessed with blinded CGM).[38] Findings of a secondary trial analysis by Eisenberg Colman et al ($N = 90$ adolescents) also show an association between dysfunctional eating behaviours (i.e. higher DEPS-R scores) and glucose data recorded by CGM.[47] The authors found a significant association of higher DEPS-R scores with time spent in hyperglycaemia, but not with other CGM parameters such as time spent in hypoglycaemia or glycaemic variability, suggesting that chronic hyperglycaemia is the best CGM 'indicator' of dysfunctional eating behaviours for health care professionals.[47] The three studies demonstrate that CGM data may assist the assessment of disordered eating, complementing self-report measures and clinical interview data with a physiological indicator—as a high proportion of hyperglycaemic glucose values may hint to intentional hyperglycaemia that follows insulin omission.

3.3 | Findings on automated insulin delivery

One publication included for the synthesis of the results referred to AID and disordered eating behaviour.

In a 2017 review, Kahkoska et al discuss AID and its implication in the light of 'dietary restraint theory',[51] that implies that people with T1DM experience cognitive dietary restraint imposed by carbohydrate counting, treatment guidelines on food intake and eating in the absence of 'natural' hunger, that is, when glucose is low.[48] Applying the theory's assumptions to T1DM and AID systems, the authors hypothesise that the flexibility in eating offered by AID decreases the need for cognitive dietary restraint, thus promoting disinhibited eating behaviour.[48] Kahkoska et al suggest that the transition from 'traditional' insulin treatment to AID is a beneficial time point to promote education on healthy eating and cognitive reappraisal to avoid unintended behavioural consequences such as overeating.[48] However, the authors concede that data are critically needed to investigate the theory's implications in practice.

4 | DISCUSSION

In this systematic literature review, we aimed at identifying and integrating research on DT use in people with T1DM and dysfunctional eating behaviours or eating disorders. Overall, respective studies are scarce. Out of 70 publications initially identified, 17 met the inclusion criteria. The majority of these studies addressed the use of CSII in individuals with dysfunctional eating behaviours and not manifest eating disorders. Results on possible (dis)advantages of DT use in people with T1DM and eating problems are mostly based on case reports, observational data and small pilot trials in nonrepresentative samples. Of 14 studies assessed in terms of their quality, 11 indicated a moderate or high risk of bias, which further diminishes the validity of the already limited results.

Research on DT use in disordered eating is often based on studies in female adolescents/young adults. So far, men have been underrepresented in the eating disorder literature, but research from the last decade suggests that eating disorders in men are not as rare as it has long been assumed.[52] Additionally, tools to assess disordered eating have been criticised to rely on primarily 'feminine' indicators of disordered eating (e.g. drive for thinness), thus underestimating disordered eating when applied in male samples.[53] However, a recent study using a diabetes-specific questionnaire to measure dysfunctional eating behaviours found a similarly high rate of dysfunctional eating behaviours in male participant with T1DM.[35] Further research on disordered eating and DT use in T1DM should, therefore, include all genders.

The majority of the included publications does not give a clear definition of the symptoms, behaviours or even diagnoses subsumed under the widely used term of 'disordered eating behaviour'. Furthermore, few of the included studies focused DT use in people with co-morbid eating disorders directly; most of the presented results stem from secondary analyses and were more of a by-product of the studies' original objects.

The majority of the studies used observational data to describe associations between DT use and disordered eating. Results of these analyses are heterogenous: some of the included studies found an association between DT (i.e. CSII) use and disordered eating,[11,12,37,39,44,45] whereas others did not.[12,34,35,38,44,46] Certainly, the studies' observational designs do not allow for causal conclusion, leaving it unclear if DT has any effects on disordered eating or if people exhibiting disordered eating use DT less frequently. However, a DPV Registry analysis found that rates of CSII discontinuation appear to be higher among people with T1DM and co-morbid diagnosis of an eating disorder.[44] Table 2 summarizes the preliminary findings on potential benefits and pitfalls of DT use in disordered eating.

In terms of potential benefits of DT in dysfunctional eating behaviours, it was argued that the use of CSII could contribute to 'normalised' eating behaviours in T1DM. Given the higher flexibility in one's diabetes management, it was hypothesized that CSII use should lead to less disordered eating behaviours including deliberate insulin omission.[12,34,37,42,45] However, evidence on this hypothetical relation is lacking. Another plausible benefit of CSII use may lie in reduced daily insulin requirements[21,22] and, hence, possibly a less pronounced weight gain compared with injection therapies.[23] This may, again, reduce dysfunctional eating behaviours that target weight reduction and control, such as restrained eating or bulimic behaviours. One small prospective pilot study

TABLE 2 Preliminary findings on diabetes technology use in people with T1DM and dysfunctional eating behaviours or eating disorders

		Eating disorders		
	Dysfunctional eating behaviours	Anorexia nervosa	Bulimia nervosa	Binge-eating disorder
CSII	• Heterogenous findings on the frequency of use • Potential benefit: less dysfunctional eating behaviours including insulin omission through greater flexibility[34,37,39]	• Lower frequency of use[11,12]	• Potential benefit: greater flexibility may improve uncontrollable hunger and bulimic symptoms[42] • Potential pitfall: facilitation of insulin dose manipulation[41]	• Potential benefit: storage data can reveal additional boluses[40]; CSII data may be used to support the assessment of binge-eating patterns
CGM	• Potential benefit: dysfunctional eating behaviours may be reflected in CGM data,[38,39,47] complementing the diagnostic process	-	-	-
AID	• Potential pitfall: greater flexibility may lead to disinhibited eating[48]	-	-	-

Abbreviations: AID, automated insulin delivery; CGM, continuous glucose monitoring; CSII, continuous subcutaneous insulin infusion.

found initial hints that CSII use can lead to significant reductions in dysfunctional eating behaviour, even in a sample with comparatively low DEPS-R scores.[37] Regarding potential pitfalls of CSII use in disordered eating, the concern has been expressed that CSII may facilitate manipulation of insulin delivery.[41,54] This remains an anecdotal observation that has not been supported by robust evidence yet. Others argued that CSII initiation may intensifies the focus on food intake, thus possibly increasing the risk for disordered eating.[37] Prospective data from larger, representative samples are needed to reliably determine the hypothesised functional and dysfunctional effects of CSII on eating behaviours.

In terms of potential benefits of CGM use in people with T1DM and dysfunctional eating behaviours, findings suggest that CGM data can hint to episodes of insulin omission and that the proportion of time spent in hyperglycaemia is the best CGM indicator of disordered eating behaviour.[38,39,47] People with T1DM do not necessarily exhibit typical signs of an increased risk for an eating disorder[35] and mental co-morbidities appear to be often unrecognized.[44] Clinicians may consider using DT data to complement the diagnostic process of dysfunctional eating behaviours, after screening for other established 'yellow flags' for disordered eating (e.g. dieting frequency, body dissatisfaction and reduced quality of life).[55] CGM data may not only assist the diagnosis of disordered eating because insulin manipulation has also been related to other mental disorders and self management difficulties.[56] However, more research is needed to determine the value of CGM data next to known 'yellow flags' in the diagnostic process of mental health co-morbidities.

Additionally, it is important to note that people with dysfunctional eating behaviours and eating disorders typically intend to hide these behaviours, for example, by decreasing the frequency of glucose monitoring or not having their DT records and data with them for medical appointments.[19] People with co-morbid disordered eating may be uncomfortable with the prospect of sharing even more information on insulin administration and glucose control with the health care team when using DT—a potential issue that could explain lower frequency of DT use and higher rates of discontinuation found in recent registry data.[11,44] However, it appears that privacy concerns regarding DT use among people with dysfunctional eating behaviours or eating disorders have not been systematically addressed yet.

A previous study on insulin mismanagement using blinded CGM found that individuals with diabetes show some degree of 'disinhibited' eating (i.e. relinquishing control over type and amount of food) when they thought glucose levels were low.[57] Although carbohydrate intake is obviously in line with recommendations to avoid and treat hypoglycaemia, this kind of 'disinhibited' eating was related to feelings of guilt and shame and increased the likelihood of insulin omission to purge 'extra calories' that have been

ingested before.[57] CGM may provide a sense of increased safety in terms of hypoglycaemia, thus preventing 'disinhibited eating' due to anticipated hypoglycaemia and subsequent purging of extra calories. Future studies could use CGM data to further investigate the role of glucose patterns, particularly hypoglycaemic episodes, in disordered eating in T1DM.

Disadvantages of CGM use are also conceivable: people with T1DM engaging in insulin purging might perceive CGM data as an opportunity to ensure that glucose values are as high as intended to purge calories.[30,54] However, there appears to be no scientific evidence that CGM has been used in this way.

With regard to AID, our systematic search for literature only identified one theoretical work discussing hypothetical effects of AID systems on dysfunctional eating behaviours.[48] Although anecdotal examples of the proposed 'lift' of dietary restraints through AID seem to exist,[48] this effect has not yet been systematically examined in people with T1DM transitioning to AID therapy.

The studies included in this review were conducted in the USA,[34,35,37-39,42,46,47] Europe [11,12,36,44,45] and Israel.[43] Access to DT and medical indication for DT vary between countries, so it may be that people with co-morbid eating disorders are over- or underrepresented in the respective studies. Finally, one has to keep in mind that wearing DT can also have a negative impact on one's body image,[20,58] which is discussed as an important factor when it comes to the development of dysfunctional eating behaviours and eating disorders.[1,5]

In general, DT use is related to a multitude of positive effects in people with diabetes such as enhanced quality of life, lifestyle and eating flexibility or decreased depressive symptoms.[59] Due to limited and heterogeneous evidence on DT use in people with T1DM and disordered eating, it still remains to understand if the positive effects associated to DT use might alleviate the burden of daily self management. However, it is needless to say that the presence of mental health issues such as symptoms of disordered eating warrant referral to a mental health professional, as recommended by international treatment guidelines.[60,61] Changes in treatment such as the transition to DT cannot be expected to be sufficient to tackle mental health issues.

There are limitations to our findings worth noting: in terms of the methodology of this review, we cannot rule out that our systematic search for literature missed publications on DT use in people with disordered eating and T1DM (although we applied a broad search strategy). We did not screen grey literature, and our search was restricted to two databases and publications in English. Because of the heterogenous designs (observational, experimental, case studies) and heterogenous outcome measures, the results of our literature search do not allow quantitative synthesis via meta-analysis.

5 | CONCLUSIONS

Overall, empirical evidence on DT use in people with disordered eating is scarce. Single studies and anecdotal reports point out benefits of DT use in disordered eating, but further research is needed to systematically address possible advantages and disadvantages of DT use in people with T1DM and subthreshold dysfunctional eating behaviours or eating disorders. Providing the greatest flexibility, CSII may have positive effects on daily diabetes management tasks and ensures a constant supply of insulin—even in the presence of purging behaviour. Empirical evidence on the anecdotal idea that CSII devices facilitate manipulation of insulin doses is virtually nonexistent. Discontinuation of CSII use tends to be higher in people struggling with disordered eating—but the reasons remain unclear. CGM data may complement self-report measures and clinical interview data with a physiological indicator of disordered eating (i.e. time spent in hyperglycaemia), providing further hints towards dysfunctional eating behaviours. Although the same possible advantages and disadvantages are conceivable for the combined use of CSII and CGM in AID systems, AID use theoretically comes along with even more flexibility in eating that lifts former restraints and causes disinhibition in eating behaviour, so the phase of transitioning to AID (or DT in general) may be a valuable time point to screen for disordered eating.[48] Possible (dis)advantages of DT use addressed in this systematic review should be carefully considered in each individual with disordered eating and T1DM while referral to a mental health professional needs to be ensured.

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CONFLICTS OF INTEREST

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REFERENCES

1. Goebel-Fabbri AE. Disturbed eating behaviors and eating disorders in type 1 diabetes: clinical significance and treatment recommendations. *Curr Diab Rep*. 2009;9(2):133-139.

2. De Paoli T, Rogers PJ. Disordered eating and insulin restriction in type 1 diabetes: a systematic review and testable model. *Eat Disord*. 2018;26(4):343-360.
3. Russell-Jones D, Khan R. Insulin-associated weight gain in diabetes – causes, effects and coping strategies. *Diabetes Obes Metab*. 2007;9(6):799-812.
4. Mitri J, Hamdy O. Diabetes medications and body weight. *Expert Opinion on Drug Safety*. 2009;8(5):573-584.
5. Peterson CM, Fischer S, Young-Hyman D. Topical review: a comprehensive risk model for disordered eating in youth with type 1 diabetes. *J Pediatr Psychol*. 2015;40(4):385-390.
6. Colton PA, Olmsted MP, Daneman D, Rodin GM. Depression, disturbed eating behavior, and metabolic control in teenage girls with type 1 diabetes: depression and disturbed eating in diabetes. *Pediatr Diabetes*. 2013;14(5):372-376.
7. Daneman D, Olmsted M, Rydall A, Maharaj S, Rodin G. Eating disorders in young women with type 1 diabetes. *Horm Res Paediatr*. 1998;50(1):79-86.
8. Jones JM, Lawson ML, Daneman D, Olmsted MP, Rodin GM. Eating disorders in adolescent females with and without type 1 diabetes: cross sectional study. *BMJ*. 2000;320(7249):1563-1566.
9. Mannucci E, Rotella F, Ricca V, Moretti S, Placidi GF, Rotella CM. Eating disorders in patients with type 1 diabetes: a meta-analysis. *J Endocrinol Invest*. 2005;28(7):417-419.
10. Young-Hyman DL, Davis CL. Disordered eating behavior in individuals with diabetes: importance of context, evaluation, and classification. *Diabetes Care*. 2010;33(3):683-689.
11. Scheuing N, Bartus B, Berger G, et al. Clinical characteristics and outcome of 467 patients with a clinically recognized eating disorder identified among 52,215 patients with type 1 diabetes: a Multicenter German/Austrian Study. *Dia Care*. 2014;37(6):1581-1589.
12. Reinehr T, Dieris B, Galler A, et al. Worse metabolic control and dynamics of weight status in adolescent girls point to eating disorders in the first years after manifestation of type 1 diabetes mellitus: findings from the diabetes patienten verlaufsdokumentation registry. *J Pediatr*. 2019;207:205-212.e5.
13. Broadley MM, Zaremba N, Andrew B, et al. 25 Years of psychological research investigating disordered eating in people with diabetes: what have we learnt? *Diabet Med*. 2019;https://doi.org/10.1111/dme.14197.
14. Pinhas-Hamiel O. Eating disorders in adolescents with type 1 diabetes: challenges in diagnosis and treatment. *WJD*. 2015;6(3):517.
15. Neumark-Sztainer D, Patterson J, Mellin A, et al. Weight control practices and disordered eating behaviors among adolescent females and males with type 1 diabetes: associations with sociodemographics, weight concerns, familial factors, and metabolic outcomes. *Diabetes Care*. 2002;25(8):1289-1296.
16. Wisting L, Snoek F. Terminology matters: 'diabulimia' is insufficient to describe eating disorders in individuals with type 1 diabetes. *Diabet Med*. 2020;37(6):1075-1076.
17. Peyrot M, Rubin RR, Kruger DF, Travis LB. Correlates of insulin injection omission. *Diabetes Care*. 2010;33(2):240-245.
18. Baechle C, Castillo K, Straßburger K, et al. Is disordered eating behavior more prevalent in adolescents with early-onset type 1 diabetes than in their representative peers? Disordered eating behavior in type 1 diabetes. *Int J Eat Disord*. 2014;47(4):342-352.
19. Goebel-Fabbri AE, Fikkan J, Franko DL, Pearson K, Anderson BJ, Weinger K. Insulin restriction and associated morbidity and mortality in women with type 1 diabetes. *Diabetes Care*. 2008;31(3):415-419.
20. Pickup JC. Is insulin pump therapy effective in type 1 diabetes? *Diabet Med*. 2019;36(3):269-278.
21. Jeitler K, Horvath K, Berghold A, et al. Continuous subcutaneous insulin infusion versus multiple daily insulin injections in patients with diabetes mellitus: systematic review and meta-analysis. *Diabetologia*. 2008;51(6):941-951.
22. Pickup JC. Insulin-pump therapy for type 1 diabetes mellitus. *N Engl J Med*. 2012;366(17):1616-1624.
23. Bode BW, Sabbah HT, Gross TM, Fredrickson LP, Davidson PC. Diabetes management in the new millennium using insulin pump therapy. *Diabetes Metab Res Rev*. 2002;18(S1):S14-S20.
24. Alderisio A, Bozzetto L, Franco L, Riccardi G, Rivellese AA, Annuzzi G. Long-term body weight trajectories and metabolic control in type 1 diabetes patients on insulin pump or multiple daily injections: a 10-year retrospective controlled study. *Nutr Metab Cardiovasc Dis*. 2019;29(10):1110-1117.
25. Lind M, Polonsky W, Hirsch IB, et al. Continuous glucose monitoring vs conventional therapy for glycemic control in adults with type 1 diabetes treated with multiple daily insulin injections: the GOLD randomized clinical trial. *JAMA*. 2017;317(4):379.
26. Heinemann L, Freckmann G, Ehrmann D, et al. Real-time continuous glucose monitoring in adults with type 1 diabetes and impaired hypoglycaemia awareness or severe hypoglycaemia treated with multiple daily insulin injections (HypoDE): a multicentre, randomised controlled trial. *The Lancet*. 2018;391(10128):1367-1377.
27. Bally L, Thabit H, Kojzar H, et al. Day-and-night glycaemic control with closed-loop insulin delivery versus conventional insulin pump therapy in free-living adults with well controlled type 1 diabetes: an open-label, randomised, crossover study. *Lancet Diabetes Endocrinol*. 2017;5(4):261-270.
28. Barnard KD, Wysocki T, Thabit H, et al. Psychosocial aspects of closed- and open-loop insulin delivery: closing the loop in adults with type 1 diabetes in the home setting. *Diabet Med*. 2015;32(5):601-608.
29. Weissberg-Benchell J, Hessler D, Polonsky WH, Fisher L. Psychosocial impact of the bionic pancreas during summer camp. *J Diabetes Sci Technol*. 2016;10(4):840-844.
30. Goebel-Fabbri AE. Diabetes and eating disorders. *J Diabetes Sci Technol*. 2008;2(3):530-532.
31. Moher D, Liberati A, Tetzlaff J, Altman DG; The PRISMA Group. Preferred reporting items for systematic reviews and meta-analyses: the PRISMA statement. *PLoS Med*. 2009;6(7):e1000097.
32. NIH. Study Quality Assessment Tools [Internet]. 2020. Available from: https://www.nhlbi.NIH.gov/health-topics/study-quality-assessment-tools
33. Landis JR, Koch GG. The Measurement of observer agreement for categorical data. *Biometrics*. 1977;33(1):159.
34. Battaglia MR, Alemzadeh R, Katte H, Hall PL, Perlmuter LC. Brief report: disordered eating and psychosocial factors in adolescent females with type 1 diabetes mellitus. *J Pediatr Psychol*. 2006;31(6):552-556.
35. Doyle EA, Quinn SM, Ambrosino JM, Weyman K, Tamborlane WV, Jastreboff AM. Disordered eating behaviors in emerging adults with type 1 diabetes: a common problem for both men and women. *J Pediatr Health Care*. 2017;31(3):327-333.
36. Hunger-Dathe W, Braun A, Müller U, Schiel R, Femerling M, Risse A. Insulin pump therapy in patients with type 1 diabetes mellitus: results of the Nationwide Quality Circle in Germany (ASD) 1999–2000. *Exp Clin Endocrinol Diabetes*. 2003;111(07):428-434.

37. Markowitz JT, Alleyn CA, Phillips R, Muir A, Young-Hyman D, Laffel LMB. Disordered eating behaviors in youth with type 1 diabetes: prospective pilot assessment following initiation of insulin pump therapy. *Diabetes Technol Ther*. 2013;15(5):428-433.
38. Merwin RM, Dmitrieva NO, Honeycutt LK, et al. Momentary predictors of insulin restriction among adults with type 1 diabetes and eating disorder symptomatology. *Dia Care*. 2015;38(11):2025-2032.
39. Merwin RM, Moskovich AA, Honeycutt LK, et al. Time of day when type 1 diabetes patients with eating disorder symptoms most commonly restrict insulin. *Psychosom Med*. 2018;80(2):222-229.
40. Minuto N, Russo C, Parodi A, Calandra E, Lorini R, d'Annunzio G. Eating disorder in type 1 diabetes can be unmasked by information technology. *JNP*. 2012;24(1):E30-E31.
41. Napoli A, Framarino M, Colatrella A, et al. Eating disorders and diabetic ketoacidosis in a pregnant woman with type 1 diabetes: a case report. *Eat Weight Disord*. 2011;16(2):e146-e149.
42. Peterson CM, Young-Hyman D, Fischer S, Markowitz JT, Muir AB, Laffel LM. Examination of psychosocial and physiological risk for bulimic symptoms in youth with type 1 diabetes transitioning to an insulin pump: a pilot study. *J Pediatr Psychol*. 2018;43(1):83-93.
43. Pinhas-Hamiel O, Graph-Barel C, Boyko V, Tzadok M, Lerner-Geva L, Reichman B. Long-term insulin pump treatment in girls with type 1 diabetes and eating disorders—Is it feasible? *Diabetes Technol Ther*. 2010;12(11):873-878.
44. Prinz N, Bächle C, Becker M, et al. Insulin pumps in type 1 diabetes with mental disorders: real-life clinical data indicate discrepancies to recommendations. *Diabetes Technol Ther*. 2016;18(1):34-38.
45. Sanlier N, Ağagündüz D, Ertaş Öztürk Y, Bozbulut R, Karaçil EM. Depression and eating disorders in children with type 1 diabetes. *HK J Paediatr*. 2019;24:16-24.
46. Tse J, Nansel TR, Haynie DL, Mehta SN, Laffel LMB. Disordered eating behaviors are associated with poorer diet quality in adolescents with type 1 diabetes. *J Acad Nutr Diet*. 2012;112(11):1810-1814.
47. Eisenberg Colman MH, Quick VM, Lipsky LM, et al. Disordered eating behaviors are not increased by an intervention to improve diet quality but are associated with poorer glycemic control among youth with type 1 diabetes. *Dia Care*. 2018;41(4):869-875.
48. Kahkoska AR, Mayer-Davis EJ, Hood KK, Maahs DM, Burger KS. Behavioural implications of traditional treatment and closed-loop automated insulin delivery systems in type 1 diabetes: applying a cognitive restraint theory framework. *Diabet Med*. 2017;34(11):1500-1507.
49. Antisdel J, Laffel L, Anderson B. Improved detection of eating problems in women with type 1 diabetes using a newly developed survey (Abstract). *Diabetes*. 2001;50:A47.
50. Markowitz JT, Butler DA, Volkening LK, Antisdel JE, Anderson BJ, Laffel LMB. Brief screening tool for disordered eating in diabetes: internal consistency and external validity in a contemporary sample of pediatric patients with type 1 diabetes. *Diabetes Care*. 2010;33(3):495-500.
51. Herman CP, Mack D. Restrained and unrestrained eating. *J Personality*. 1975;43(4):647-660.
52. Murray SB, Nagata JM, Griffiths S, et al. The enigma of male eating disorders: a critical review and synthesis. *Clin Psychol Rev*. 2017;57:1-11.
53. Limbers CA, Cohen LA, Gray BA. Eating disorders in adolescent and young adult males: prevalence, diagnosis, and treatment strategies. *AHMT*. 2018;9:111-116.
54. Hanlan ME, Griffith J, Patel N, Jaser SS. Eating disorders and disordered eating in type 1 diabetes: prevalence, screening, and treatment options. *Curr Diab Rep*. 2013;13(6):909-916.
55. Eilander MM, de Wit M, Rotteveel J, et al. Disturbed eating behaviors in adolescents with type 1 diabetes. How to screen for yellow flags in clinical practice?: Disturbed eating behaviors in adolescents. *Pediatr Diabetes*. 2017;18(5):376-383.
56. Berger G, Waldhoer T, Barrientos I, et al. Association of insulin-manipulation and psychiatric disorders: a systematic epidemiological evaluation of adolescents with type 1 diabetes in Austria. *Pediatr Diabetes*. 2019;20(1):127-136.
57. Merwin RM, Moskovich AA, Dmitrieva NO, et al. Disinhibited eating and weight-related insulin mismanagement among individuals with type 1 diabetes. *Appetite*. 2014;81:123-130.
58. Schmidt S, Duun-Henriksen AK, Nørgaard K. Psychosocial factors and adherence to continuous glucose monitoring in type 1 diabetes. *J Diabetes Sci Technol*. 2012;6(4):986-987.
59. Prahalad P, Tanenbaum M, Hood K, Maahs DM. Diabetes technology: improving care, improving patient-reported outcomes and preventing complications in young people with Type 1 diabetes. *Diabet Med*. 2018;35(4):419-429.
60. International Diabetes Federation. Global IDF/ISPAD Guideline for Diabetes in Childhood and Adolescence [Internet]. 2020. Available from: https://idf.org/e-library/guidelines/80-the-global-idf-ispad-guidelines-for-diabetes-in-childhood-and-adolescence.html
61. American Diabetes Association. Standards of medical care in diabetes—2020. *Diabetes Care*. 2020;43:1-212.
62. Young-Hyman D, Davis C, Grigsby C, Looney S, Peterson C. Development of the diabetes treatment and satiety scale: DTSS-20. *Diabetes*. 2011;60(Suppl. 1):A218.
63. Garner DM, Olmsted MP, Bohr Y, Garfinkel P. The eating attitude test: psychometric features and clinical correlates. *Psychol Med*. 1982;12:871-878.
64. Garner DM. *Eating Disorder Inventory-2 Manual*. Odessa, FL: Psychological Assessment Resources; 1991.
65. Garner DM. *Eating disorder inventory-3 (EDI-3). Professional manual*. Odessa, FL: Psychological Assessment Resources; 2004.

SUPPORTING INFORMATION

Additional supporting information may be found online in the Supporting Information section.

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