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AN IDEA WORTH RESEARCHING

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The application of continuous glucose monitoring technology to eating disorders research: An idea worth researching

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Abstract

Continuous glucose monitoring (CGM) devices have revolutionized our capacity to measure blood glucose levels in real time using minimally invasive technology, yet to date there are no studies using CGM in individuals with eating disorders (EDs). Preliminary evidence suggests that eating disorder behaviors (EDBs) have substantial and characteristic impacts on blood glucose levels and glucose-related variables (e.g., binge-eating episodes cause rapid spikes in blood glucose levels, purging causes rapid drops in blood glucose to below normal levels). The aims of this article are to describe the benefits of CGM technology over older methods of measuring blood glucose levels and to discuss several specific ways in which CGM technology can be applied to EDs research to (a) improve our ability to identify and predict engagement in EDBs in real time, (b) identify relationships between blood glucose levels and maintenance factors for EDs, and (c) increase our understanding of the physiological and psychological impacts of disordered eating. We also present preliminary acceptability and feasibility data on the use of CGM devices in individuals with EDs. Overall, the article will describe several applications of CGM technology in EDs research with compelling potential to improve research methodologies.

KEYWORDS

affect, binge-eating disorder, bulimia nervosa, cognitive dysfunction, eating disorders, glucose, health outcomes, sensor technology, technology

1 | INTRODUCTION

1.1 | Role of blood glucose in physiological functioning

Glucose is essential to cellular function throughout all bodily systems. Metabolic homeostasis tightly controls blood glucose levels through energy intake and insulin release in healthy individuals and this maintenance of adequate glucose control is essential for health (Wasserman, 2009). Impaired glucose control is associated with physical and neuropsychological health consequences, including type 2 diabetes, cardiovascular disease, impaired cognitive function, and symptoms of anxiety and depression (Bancks et al., 2018; Bancks et al., 2019; Donohoe & Benton, 1999; Rausch, 2010). Glucose control exists along a continuum and even mild to moderate impairments in glucose control can impact physical and mental health. Eating disorder behaviors (EDBs), including fasting, objectively large binge episodes, and purging, impact momentary blood glucose levels. Over time, these repeated fluctuations in blood glucose levels likely contribute to broader dysregulations in glucose control including increased risk for type 2 diabetes (Raevuori et al., 2015) or other glucose control abnormalities like postprandial hypoglycemia (i.e., low glucose levels following meal consumption; Hart, Abraham, Franklin, Twigg, & Russell, 2011).

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1.2 | Limitations of existing research on glucose levels in individuals with eating disorders

Extant research examining glucose levels in individuals with eating disorders (EDs) has been limited by traditional methodologies for assessing glucose levels, like blood draws or glucose meters requiring finger pricks and self-initiation of measurement (Clarke & Foster, 2012). Therefore, research on glucose in individuals with EDs has largely examined single timepoint blood glucose levels (e.g., following a laboratory test meal or oral glucose tolerance test). These methodological limitations have prevented measurement of glucose responses to real-world EDBs and of glucose patterns over days or weeks in individuals with EDs.

1.3 | Benefits of using continuous glucose monitoring devices to measure glucose levels

Continuous glucose monitoring (CGM) devices, which continuously and passively measure glucose levels, address several of the limitations described above given their ability to continuously measure glucose levels over days or weeks (Clarke & Foster, 2012). Most commercially available CGMs contain a small, flexible needle inserted under the skin on the abdomen or arm to measure glucose levels in the interstitial fluid. While CGMs have been used by patients with diabetes since the early 2000s, recent advances in CGM technology have made these tools smaller, more comfortable, and less burdensome, increasing their potential as acceptable measurement tools in other populations. Because CGMs are worn for days or weeks while the wearer goes about daily life, these devices allow for the measurement of glucose levels during and following EDBs. Thus, CGM may allow for a complete examination of trajectories of change in glucose levels and associated markers of glucose control that are difficult or impossible to assess through single timepoint readings.

2 | FUTURE RESEARCH

2.1 | Use of CGM to detect and predict the occurrence of EDBs

Although research testing CGM's ability to detect EDBs is limited, preliminary evidence suggests that EDBs may be characterized by notable glucose patterns in the minutes to hours following the behavior. Fasting is characterized by remarkably stable glucose levels uninterrupted by meal-related increases (Wasserman, 2009), whereas binge-eating episodes, which typically involve ingestion of objectively large quantities of high-carbohydrate and high-fat foods (Raymond, Bartholome, Lee, Peterson, & Raatz, 2007), may be characterized by rapid increases in glucose levels and elevated and sustained peak glucose levels (Wolever, Jenkins, Jenkins, & Josse, 1991). Purging (Johnson, Jarrell, Chupurdia, & Williamson, 1994) and excessive exercise (Ahmed & Serener, 2016) have been shown to contribute to rapid decreases in glucose levels. Meal detection algorithms have been developed that interpret patterns in CGM data indicative of meal consumption and it may be possible to develop similar algorithms to detect EDBs (Weimer, Chen, Peleckis, Rickels, & Lee, 2016). Our team has recently piloted the use of CGMs in individuals with binge-spectrum EDs to collect acceptability, feasibility, and preliminary proof-of-concept data. Figure 1 illustrates glucose levels in an individual with bulimia nervosa while fasting, following meals and following binge-eating episodes; visual inspection of these data indicates distinct patterns associated with self-reported fasting and binge-eating episodes that suggest it may be possible to develop algorithms to detect EDBs.

Momentary, objective detection of EDBs from CGM data might improve upon real-time self-reporting or retrospective recall of these behaviors, which may be inaccurate or incomplete. Patients tasked with recording real-time EDBs (e.g., through ecological momentary assessments or through self-monitoring records) often fail to report all behaviors or record behaviors hours or days after they occur, prohibiting accurate measurement which is essential for examining momentary relationships between EDBs and precipitating variables. Additionally, if CGM data can detect the occurrence of EDBs, real-time identification of these behaviors could be used to predict risk for future EDBs. For instance, dietary restriction is an established momentary risk factor for binge eating (Zunker et al., 2011) and binge eating and purging are established short-term predictors of dietary restriction (Holmes, Fuller-Tyszkiewicz, Skouteris, & Broadbent, 2014). Given the possible relationship between EDBs and momentary glucose levels, there is clear potential for CGM data to objectively measure and predict EDBs in real-world settings.

2.1.1 | Using CGM to identify momentary relationships between disordered eating and affect and executive functioning

Momentary negative affect (Rausch, 2010) and momentary deficits in executive functioning (Donohoe & Benton, 1999), both of which are known maintenance factors for EDs, have been associated with episodes of hypoglycemia (low blood glucose levels) and hyperglycemia (high blood glucose levels) in individuals with and without diabetes. Although the temporal nature of these relationships has not been fully established, some evidence in individuals with diabetes indicates that hyperglycemia may precede and contribute to the experience of negative affect (Hermanns et al., 2007). Despite demonstrated associations between glucose levels and affect and executive functioning in other populations, to date no research has examined whether momentary changes in glucose levels contribute to these psychological consequences in individuals with EDs. If momentary fluctuations in glucose contribute to worsening negative affect or to inhibitory control difficulties in individuals with EDs, this would impact how we conceptualize and intervene on these factors in treatment. For example, if a period of hypoglycemia predicts the worsening of affective states like sadness, then individuals may be at elevated risk of binge eating

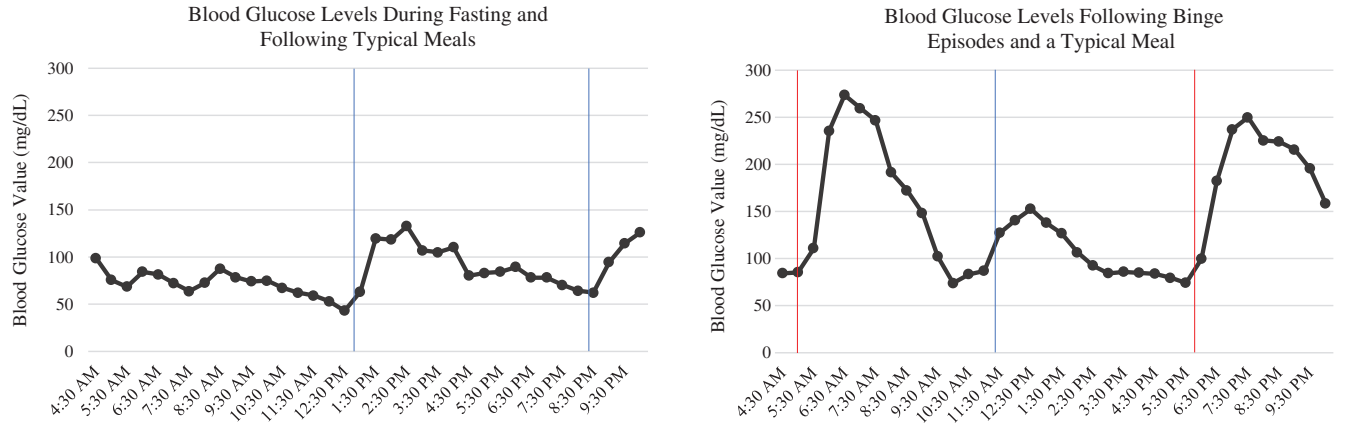

FIGURE 1 Blood glucose levels in an individual with bulimia nervosa measured by CGM [Color figure can be viewed at wileyonlinelibrary.com]

through both (a) dietary restriction, and (b) elevated negative affect at least partially due to dietary restriction. Psychoeducation could then be provided to patients about the connection between undereating and negative affective states. Patients can then use the experience of elevated negative affect as a cue that they may have undereaten earlier that day and should eat a meal or snack to improve affect and executive functioning.

2.1.2 | Potential for CGM to augment existing treatments

The ability to objectively predict and detect the occurrence of EDBs and associated momentary maintenance factors could powerfully enhance standard ED interventions by promoting between-session behavior change. For example, if clinicians had access to objective records of engagement in EDBs between sessions (via CGM data), they could have more informed in-session discussions with patients about their EDBs than with self-monitoring records alone. Clinician access to real-time CGM data may also increase the patient's sense of supportive accountability (i.e., accountability to a trustworthy, benevolent, and expert treatment provider) outside of the therapy office (Mohr, Cuijpers, & Lehman, 2011), thus increasing treatment adherence between sessions. This may be particularly relevant to individuals at risk of overreporting their eating episodes, like individuals with anorexia nervosa.

The dynamic, continuous, and objective nature of CGM data could also enhance the efficacy of just-in-time adaptive interventions (JITAIs; smartphone application-based systems that use real-time analysis of data to deliver momentary interventions at identified times of need), which may provide additional between-session support. A JITAI system utilizing CGM as a source of objective, real-time data on the occurrence of EDBs may facilitate more accurate detection and prediction of EDBs. For example, if the JITAI system detects fasting it could deliver an intervention targeting barriers to regular eating to increase frequency of meals. This might yield downstream improvements in other ED symptoms, like weight gain or reduced risk for binge eating. Although these treatment augmentations are likely universally applicable, they may be especially useful for patients in need of additional between-session support and accountability, like patients stepping down from a higher level of care or patients who are ambivalent toward treatment.

2.2 | Using CGM to understand long-term consequences of disordered eating

In addition to its utility in identifying, predicting, and intervening on momentary behaviors, CGM may offer valuable information about longer-term consequences of EDs, including medical consequences and cognitive impairment, that cannot be measured by traditional methods of assessing glucose and glucose control. One particularly promising variable is glucose variability, defined as the magnitude of oscillations in blood glucose levels over time (weeks or months may be the most relevant timeframe in individuals periodically engaging in EDBs).

2.2.1 | Predicting risk for and progression of medical consequences using CGM

In healthy populations, elevated glucose variability has been shown to confer risk for adverse medical outcomes, including cardiovascular events, development of diabetes, and mortality (Bancks et al., 2019) and CGM technology has been used to predict onset and progression of diabetes in children at risk for type I diabetes and adults with prediabetes (Price, 2016; Steck et al., 2019). Given that many individuals with EDs will experience high glucose variability due to repeated engagement in EDBs (e.g., individuals engaging in alternating restricting and binge-eating behaviors or those engaging in compensatory behaviors after binge-eating episodes), these relationships may be particularly relevant for ED populations. Future research should examine the association between glucose variability (measured by CGM over the course of several days or weeks) and the longitudinal development of medical consequences in individuals with EDs. If elevated glucose variability is

identified as a risk factor for the development or progression of common medical consequences in individuals with EDs, like diabetes (Raevuori et al., 2015) and cardiovascular complications, these findings could inform medical, psychological, and dietetic interventions (e.g., inpatient treatment and intensive medical monitoring for individuals at high risk of cardiovascular events due to elevated glucose variability; alterations to meal plans to rapidly stabilize glucose levels) to prevent the onset or exacerbation of these conditions.

2.2.2 | Identifying longer-term associations between blood glucose levels and executive functioning

Previous literature has also indicated that glucose variability can prospectively predict cognitive decline in healthy populations, including impairments in memory, processing, and inhibition (Bancks et al., 2018). If this association between elevated glucose variability and impaired cognition is observed in individuals with EDs, it might explain why some individuals with enduring EDs have persistently poor treatment response (e.g., individuals with severe and enduring anorexia nervosa). If individuals with elevated glucose variability have increased risk for developing deficits in executive functions like inhibitory control, planning, problem solving, and decision making, they may have difficulty utilizing behavioral strategies from many traditional interventions. If this pattern is observed, extant treatments could be adapted to better support behavior change in individuals with executive functioning deficits associated with elevated glucose variability (e.g., by spending increased session time on planning and problem solving).

3 | FEASIBILITY AND ACCEPTABILITY OF CGM

Research using CGM in individuals with EDs will need to assess feasibility and acceptability in this population. The potential burden, discomfort, and high financial costs of CGM may constitute barriers to feasibility and acceptability of CGMs for research or treatment in these individuals. Most commercially available CGM systems display user glucose data, which might increase distress about eating and exacerbate ED symptoms. Fortunately, ongoing developments in CGM technology continue to reduce user burden, cost, and discomfort. Fully noninvasive LED sensor-based CGMs are being developed and some CGM user interfaces can blind glucose values for patients and share data only with a clinician. Data from a recent pilot study by our team identified high feasibility (i.e., no participants discontinued participation in the two-week trial because of concerns about CGM device) and relatively low levels of burden, pain, and discomfort (see Table 1), suggesting adequate acceptability in this population with current CGM models. Nevertheless, further assessments of acceptability and feasibility of CGMs are needed among individuals with EDs.

TABLE 1 Acceptability of CGM devices, rated by 42 individuals with binge-spectrum EDs

	Median rating	Range
How burdensome was using the CGM system? *1 = Extremely burdensome to 5 = Not at all burdensome*	4	3–5
How painful was the insertion of the sensor? *1 = Extremely painful to 5 = Not at all painful*	5	4–5
How comfortable did you feel wearing the CGM device for 2 weeks? *1 = Completely uncomfortable to 5 = Completely comfortable*	4	2–5

4 | CONCLUSIONS

CGM constitutes a novel sensor technology with high potential to mitigate many of the limitations of previous research examining glucose in individuals with EDs. CGM may offer the opportunity to measure patterns in glucose levels associated with EDBs, objectively detect momentary risk for EDBs, and comprehensively assess the association between dysregulated glucose patterns and cognitive, affective, and physiological consequences of EDBs in individuals with EDs. This technology could improve understanding of the etiology and maintenance of disordered eating and could further be used to improve both personalized and standard treatment approaches.

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CONFLICT OF INTEREST

The authors have no conflict to declare.

DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available from the corresponding author, EKP, upon reasonable request.

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