Mindfulness
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REVIEW

Mindful Eating as a Tool for Diabetes Prevention and Management: A Review of Potential Mechanisms of Action

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Abstract

Objectives Diabetes is a complex condition that often requires the simultaneous employment of diverse approaches for prevention and treatment. Mindful eating may be a beneficial complementary approach. This narrative review analyzes potential mechanisms of action through which mindful eating may regulate blood glucose and thereby aid in diabetes prevention and management. Findings from this review may serve to inform both clinical practice and new research in the field.
Method We conducted a narrative review focusing on the meditation-independent mechanisms by which mindful eating could improve blood glucose regulation. Specifically, we analyzed the effects of mindful eating practices on eating behavior, calorie intake, weight control, and/or glucose control.
Results Evidence suggests that mindful eating can improve eating behaviors by decreasing automatic and disordered eating which, in turn, may regulate blood glucose levels. Moreover, by eating slowly, attentively, and according to hunger and satiety cues, mindful eating may help align energy intake to energy needs, thereby improving weight and glycemic management.
Conclusion Key mindful eating practices that may directly or indirectly improve glycemic management include eating slowly, eating with deliberate attention to the sensory properties of food, cultivating acceptance of thoughts and feelings concerning food and eating, decentering from food-related thoughts, and relying on hunger and satiety cues to guide eating. Future research may improve our knowledge of these interventions and their application to the prevention and treatment of diabetes.

Keywords Mindful eating · Mindfulness · Diabetes · Type 2 diabetes

Type 2 diabetes, hereafter referred to as diabetes, accounts for approximately 90% of diabetes cases worldwide (International Diabetes Federation, 2021). Its prevalence quadrupled from 1980 to 2014 and is expected to increase to 643 million by 2030 (International Diabetes Federation, 2021; Zhou et al., 2016). In the USA alone, diabetes and prediabetes have reached 11.3% and 38% of the adult population (Centers for Disease Control & Prevention, 2022). The elevated prevalence of diabetes and the associated cardiometabolic comorbidities (cardiovascular disease, renal disease, etc.) poses a significant public health challenge that results in elevated population-level morbidity and mortality (Forbes & Cooper, 2013). Worldwide, diabetes ranks ninth and eighth as the leading cause of death and disability, respectively (World Health Organization, n.d.).

Diabetes is a complex condition that often requires the simultaneous employment of diverse approaches for prevention and treatment. Current strategies for both prevention and management include nutrition and exercise, behavioral interventions, and pharmacological and surgical interventions that in turn facilitate calorie intake regulation and weight control (i.e., weight loss and/or maintenance), and/or

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have direct effects on blood glucose concentrations (American Diabetes Association Professional Practice Committee, 2022; Davies et al., 2018). To enhance these approaches, mindful eating can be incorporated into an integrated therapy for improving insulin resistance and glycemic control.

Mindful eating is the application of mindfulness to the process of eating (Mantzios, 2021). Mindfulness has been described as "the awareness that emerges through paying attention on purpose, in the present moment, and nonjudgmentally" to one's moment-by-moment experience (thoughts, emotions, bodily sensations, and/or behaviors) (Kabat-Zinn, 2003, p. 145). Although there is no clear consensus on how mindfulness should be defined, some appetite experts proposed that it involves three key features: present moment awareness, acceptance (i.e., an attitude of nonjudgment), and decentering (i.e., viewing one's thoughts and emotions as transient events separate from oneself) (e.g., Tapper, 2022). However, other experts only consider present moment awareness and acceptance as its key features (Mantzios, 2023). A lack of a clear definition of mindfulness has likely led to a lack of consensus on what mindful eating represents (Mantzios, 2021). Consequently, the term "mindful eating" has been used to describe a wide range of practices, some of the most common being paying deliberate attention to food's sensory properties and having an accepting, nonreactive stance towards cravings and food-related thoughts (for a review of common practices, see Tapper, 2022). Another practice used in programs such as Mindfulness-Based Eating Awareness Training (MB-EAT) involves present-moment awareness of internal bodily sensations, particularly, using hunger and satiety signals to guide eating behavior (Kristeller & Epel, 2014; Tapper, 2022). Since it may be difficult to be mindful of food's sensory properties and internal bodily sensations while eating quickly, the practice of eating slowly has been encompassed within mindful eating by some authors (Bays, 2017). For instance, compared to eating quickly, slow eating enables a longer oro-sensory exposure which can facilitate the awareness of the taste and/or texture of food (Lasschuijt et al., 2021; Li et al., 2020). It could also be hypothesized that slow eating facilitates awareness and response to satiety cues. Therefore, slow eating could act in synergy with other mindful eating practices.

It is important to note that while mindfulness-based interventions that include various forms of meditation have been proposed as an adjunctive strategy for the treatment of diabetes (Medina et al., 2017), mindful eating can be employed without a formal meditation practice and vice versa. Furthermore, a study by Mantzios and Wilson (2014) suggests there are independent effects of meditation and mindful eating. While a formal meditation practice can benefit health and well-being (Goldberg et al., 2022), it requires additional discipline and time investment (Kabat-Zinn, 2003). Time is one of the main barriers to any lifestyle intervention (Burgess et al., 2017), and the additional commitment required limits the practical application of meditation for patients with diabetes or prediabetes. Teaching mindful eating independent of a meditation practice can make it acceptable to patients that have barriers to implementing a meditation-based therapy. For these reasons, it is necessary to focus on the meditation-independent mechanisms by which mindful eating could improve blood glucose regulation.

Previous research has briefly discussed the potential application of mindful eating in individuals with diabetes (Miller, 2017) without addressing plausible meditation-independent mechanisms of action. Therefore, the objective of this narrative review was to analyze potential meditation-independent mechanisms of action through which mindful eating may regulate blood glucose and, therefore, aid in diabetes prevention and management. Specifically, we examined mechanisms through which mindful eating might influence eating behavior, calorie intake, weight control, and, ultimately, glucose control (Fig. 1). Our attempt was to answer one research question: what are the potential mechanisms of action through which mindful eating could aid in the prevention and treatment of diabetes? Answering this question may inform both clinical practice and new research in the field of diabetes prevention and treatment.

Method

The overarching goal of the present review was to propose mechanisms of action by which mindful eating practices could aid in the prevention and treatment of diabetes. To achieve this, we chose to conduct a narrative review that allowed us to answer our research question through a broader lens that integrated a wide range of studies with the purpose of deepening understanding and potentially creating new insights, an approach that would not have been possible within the confines of a systematic review (Greenhalgh et al., 2018). A PubMed search of articles published from inception to June 2022 was conducted. Inclusion criteria were as follows: (1) original intervention and observational studies, systematic reviews, and meta-analyses that reported the effects and associations of mindful eating practices on four key variables: eating behavior, calorie intake, weight control, and/or glucose control; (2) reviews that provide a theoretical background to the included intervention and observational studies; and (3) articles conducted in populations with different health status: apparently healthy or with obesity/overweight, prediabetes, or diabetes. The exclusion criteria were grey literature and case studies.

Search terms included a combination of the following terms: "mindful eating," "mindfulness," "slow eating," "fast eating," "eating speed," "eating rate," "eating pace," "attentive eating," "hunger," "satiety," "appetite

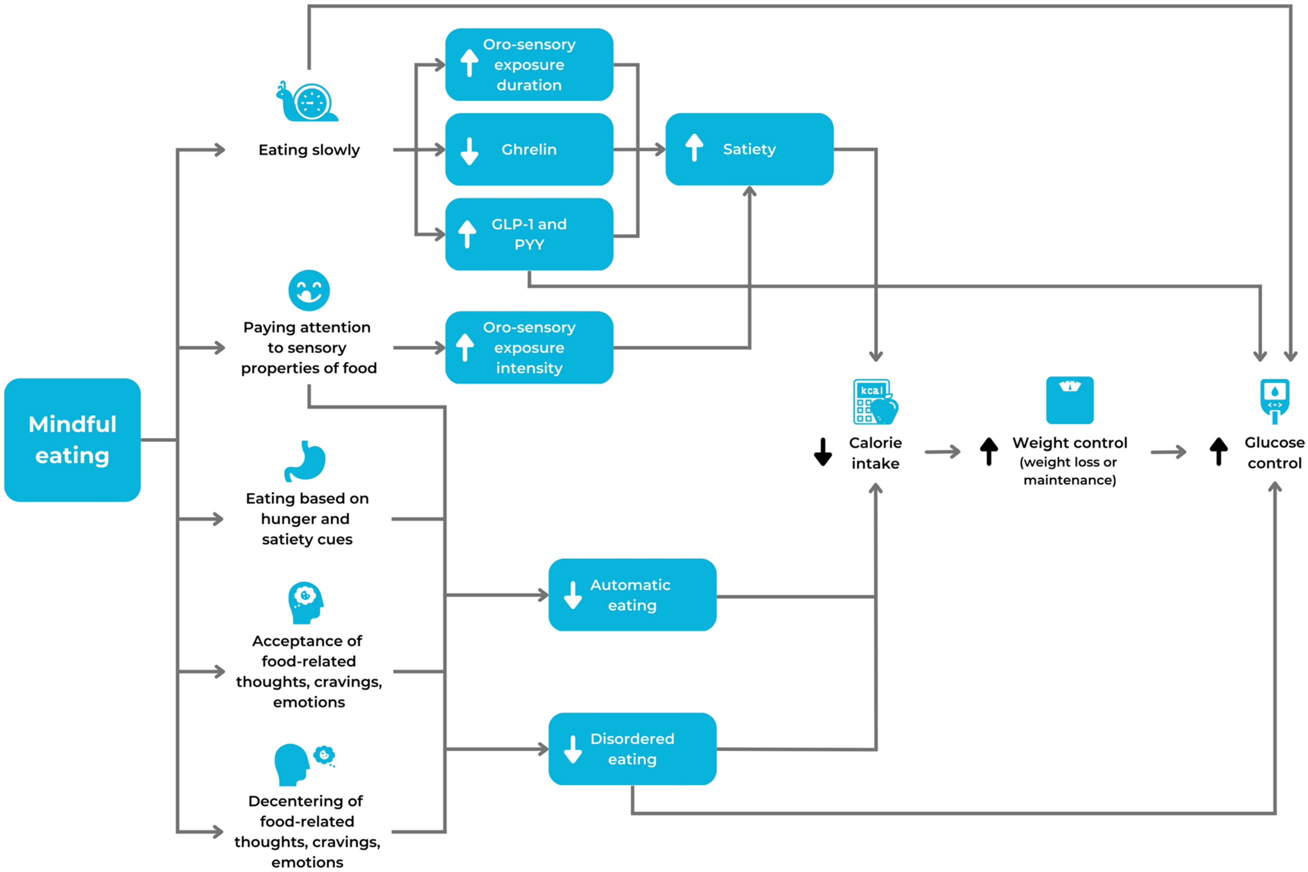

Fig. 1 Proposed mechanisms underlying the potential effects of mindful eating on blood glucose control. GLP-1, glucagon-like peptide-1; PYY, peptide YY

awareness," "acceptance," "decentering" or "cognitive defusion" AND "diabetes," "glucose," "eating behavior," "external eating," "emotional eating," "binge eating," "disordered eating," "calorie intake," "energy intake," "weight" or "glucose." Search terms were limited to those found in the title and abstract.

The retrieved articles were assessed for relevance by screening titles and abstracts. Articles were considered relevant for a full-text review if the objectives and methods described in the article's abstract fulfilled any of the inclusion criteria mentioned above. This process was carried out by the first author; however, additional relevant articles not identified by the aforementioned process were also added by co-authors.

Results

This review is organized into six main sections. The first three sections examine the effects of three specific behaviors—namely, eating slowly, paying deliberate attention to the eating experience, and eating according to hunger and satiety cues—on calorie intake, weight control, and/or glucose control. The following two sections then elaborate on how different mindful eating practices might mitigate automatic and disordered eating, which in turn might influence calorie intake, weight control, and/or glucose control. Finally, the last section presents the results of multi-component mindful eating interventions on glucose management.

Eating Slowly

Self-reported fast eating has been prospectively associated with diabetes. In a cohort study of 197,825 men and women self-reported fast eating was an independent risk factor for diabetes incidence (OR = 1.10, 95% CI = 1.04–1.17) after adjusting for BMI, weight change, and other confounders (Kudo et al., 2019). A smaller study with a similar design corroborated these results (Fujii et al., 2021). This association could suggest that eating slowly might be a useful strategy to prevent and treat diabetes, particularly in individuals who are habitual fast eaters. As will be elaborated below, eating slowly may help regulate calorie intake, weight control, and/or glucose control.

Effects of Eating Slowly on Calorie Intake

A systematic review and meta-analysis of controlled laboratory experiments found that compared to eating slowly, eating quickly is associated with a higher caloric intake within a single meal (Robinson et al., 2014a, b). Therefore, decreasing eating speed could be effective in regulating caloric intake. Studies have shown that eating in 20–30 min, rather than 8–10 min, can lead to eating from 58 to 266 fewer calories per meal (Andrade et al., 2008; Karl et al., 2013; Shah et al., 2014). Other studies have found that eating at 50% of the usual eating speed led to 70–164 fewer calories eaten (Martin et al., 2007; Scisco et al., 2011). However, the effects of eating speed on caloric intake across several days and weeks have not been determined.

Eating slowly could lead to a lower caloric intake within a single meal by increasing the subjective feelings of satiety more effectively than eating quickly (Andrade et al., 2008; Angelopoulos et al., 2014; Hawton et al., 2018; Karl et al., 2013; Kokkinos et al., 2010; Rigamonti et al., 2013; Scisco et al., 2011). Specifically, slower eating has induced greater satiety in studies with calorically fixed meals (Angelopoulos et al., 2014; Hawton et al., 2018; Kokkinos et al., 2010; Rigamonti et al., 2013) and equal satiety at a lower caloric intake in ad libitum studies (Andrade et al., 2008; Scisco et al., 2011; Shah et al., 2014). This effect has been observed in individuals with normal weight, overweight/obesity, and diabetes (Andrade et al., 2008; Angelopoulos et al., 2014; Hawton et al., 2018; Karl et al., 2013; Kokkinos et al., 2010; Rigamonti et al., 2013; Scisco et al., 2011). The greater satiety achieved by eating slowly may be partly explained by a longer oro-sensory exposure to the food consumed, that is, the receptors in the tongue and oral cavity are stimulated for a longer period of time (Lasschuijt et al., 2021). Furthermore, some studies have found that compared to eating quickly, slow eating upregulates the postprandial response of the anorexigenic hormones peptide YY (PYY) and glucagon-like peptide 1 (GLP-1) while suppressing the orexigenic hormone ghrelin, especially in adults with normal weight and overweight, as well as in adolescents with obesity (Hawton et al., 2018; Kokkinos et al., 2010; Rigamonti et al., 2013). However, these results have not been replicated in adults with obesity (Angelopoulos et al., 2014; Karl et al., 2013; Rigamonti et al., 2013, 2017) or diabetes (Angelopoulos et al., 2014), which is unsurprising given the altered appetite hormone responses typically seen with obesity (Lean & Malkova, 2016). In this latter population, the potential hormonal changes achieved by eating slowly may only be observed in the long term as suggested by a study by Galhardo et al. (2012) that found that after 12 months of eating slowly, a group of adolescents with obesity increased their basal and postprandial PYY levels and decreased their basal and postprandial ghrelin levels compared to a control group who received usual care. However, it is uncertain if this same long-term result would be obtained in adults with obesity. It should be noted that slower eating was positively associated with improvements in subjective hunger and satiety scores, independent of hormone response, in adult patients with obesity and patients with diabetes (Angelopoulos et al., 2014).

Effects of Eating Slowly on Weight Control

Given that eating speed is associated with caloric intake, it can be hypothesized that (1) fast eating increases the risk of weight gain, and (2) slow eating aids in weight loss. A systematic review and meta-analysis of 23 studies concluded that fast eating is associated with a greater risk of weight gain in individuals with and without diabetes (Ohkuma et al., 2015). For instance, in a prospective longitudinal study of 1314 young adults, self-reported fast eating predicted weight gain over 3 years (Yamane et al., 2014). However, to our knowledge, no intervention studies have examined the isolated effects of slow eating on weight control.

Effects of Eating Slowly on Glucose Control

One-day intervention studies examining the effects of slow eating on glucose levels have shown conflicting results. In healthy individuals, slow eating has led to lower postprandial glucose in two studies (expressed as the mean amplitude of glycemic excursion, glucose peak, and area under the curve, AUC) (Saito et al., 2020; Sun et al., 2015), no change in one study (Kokkinos et al., 2010), and an increase in another (Sobki et al., 2010). To our knowledge, the only study in individuals with diabetes that has evaluated eating speed on postprandial glucose levels (expressed as AUC) showed no difference between slow and fast eating (Angelopoulos et al., 2014). However, some studies suggest that eating slowly may upregulate the postprandial response of the glucose regulators (Manning & Batterham, 2014; Nadkarni et al., 2014) glucagon-like peptide 1 (GLP-1) and peptide YY (PYY) (Hawton et al., 2018; Kokkinos et al., 2010; Rigamonti et al., 2013), which in the long term may help in glucose management.

Summary of Effects of Eating Slowly

Laboratory studies suggest that eating slowly can reduce caloric intake within a single meal, an outcome that, if repeated across weeks and months, could potentially facilitate weight management, and indirectly improve glucose control. However, the long-term effects of slow eating on calorie intake and weight management have not been determined. Eating slowly may also directly regulate postprandial glucose levels, but inconsistent findings in this regard do not allow to draw firm conclusions.

Paying Deliberate Attention to the Eating Experience

Effects of Paying Deliberate Attention to the Eating Experience on Calorie Intake

A 2013 systematic review and meta-analysis of laboratory studies (Robinson et al., 2013) concluded that reduced attention to the eating experience caused by simultaneously engaging in another task (i.e., eating while distracted) may increase calorie intake. For example, eating while using a smartphone, reading, or watching television may increase energy intake by 56–117 kcal over the course of a meal compared to eating without distractions (Gonçalves et al., 2019; Hetherington et al., 2006). Therefore, it has been hypothesized that eating while paying deliberate attention to the eating experience, specifically to the sensory properties of food, may lead to decreases in energy intake. However, results have been inconsistent. Some laboratory studies have found that this practice leads to significant reductions in subsequent calorie intake (Allirot et al., 2018; Arch et al., 2016; Higgs & Donohoe, 2011; Mantzios et al., 2019, 2020; Robinson et al., 2014a, b; Seguias & Tapper, 2018), while others have observed no significant effects (Whitelock et al., 2018, 2019a). Relatedly, other laboratory studies have concluded that this practice leads to a reduction of calorie intake over the course of a single meal (Hussain et al., 2021), but others have not supported this finding (Long et al., 2011; Seguias & Tapper, 2018). Moreover, in half-day and 3-day free-living studies, this practice did not result in a lower self-reported caloric intake (Seguias & Tapper, 2022; Tapper & Seguias, 2020). Lastly, a randomized controlled trial found that compared to standard dietary advice, paying attention to the sensory properties of food while eating had no effect on 4-week and 8-week energy intake (Whitelock et al., 2019b). At this point, it is uncertain if this mindful eating practice can be employed to consistently reduce energy intake.

The contradictory findings may be explained by two potential reasons. First, eating speed might be a mediator and/or moderator of the link between paying deliberate attention to the eating experience and calorie intake, but eating speed was not assessed pre-intervention and was not controlled for in any of the studies. Habitual slow eaters may not reduce their calorie intake when instructed to pay deliberate attention to the taste, smell, and texture of food, while habitual fast eaters might. Furthermore, some individuals may naturally decrease their eating speed when instructed to food's sensory properties which may in turn lead to a lower caloric intake, while other individuals might not make this adjustment and, therefore, fail to reduce their intake. In addition to eating speed, baseline weight might be a confounding factor. It is possible that people with overweight/obesity are more likely to be regular fast eaters compared to normal-weight individuals (Ohkuma et al., 2015). It is worth noting that most of the studies have been conducted on participants with normal weight (Allirot et al., 2018; Arch et al., 2016; Higgs & Donohoe, 2011; Hussain et al., 2021; Long et al., 2011; Mantzios et al., 2019, 2020; Seguias & Tapper, 2018, 2022; Whitelock et al., 2019a), while only four studies recruited participants with overweight/obesity (Robinson et al., 2014a, b; Tapper & Seguias, 2020; Whitelock et al., 2018, 2019b). It could be hypothesized that reductions in calorie intake might only be seen in habitual fast eaters, particularly those with overweight/obesity, who are instructed to both eat slowly and pay deliberate attention to the taste, smell, and texture of food. However, it is currently not possible to draw firm conclusions.

If paying deliberate attention to the eating experience does indeed reduce calorie intake in some individuals, it could be explained by multiple factors. First, it may facilitate a slower eating pace (Simonson et al., 2020), which, as discussed above, may increase satiety thereby decreasing caloric intake. Second, some studies have found that compared to eating while distracted, eating with deliberate awareness of the sensory qualities of food leads to more enjoyment of the food eaten (Arch et al., 2016; Hong et al., 2014). This could translate to a more intense taste experience that can contribute to increased satiety and a reduction in energy intake (McCrickerd & Forde, 2016). Moreover, evidence suggests that deriving pleasure from food by deliberately experiencing its sensory qualities is associated with positive dietary outcomes, such as better diet quality and healthier food choices (Bédard et al., 2020). A third reason why eating attentively may lead to a lower caloric intake is that it may facilitate the awareness of internal hunger and satiety cues (Morris et al., 2020) which, as will be discussed below, may lead to better caloric intake regulation.

Effects of Paying Deliberate Attention to the Eating Experience on Weight Control

To our knowledge, only two studies have analyzed the effects of manipulating attention of the sensory properties of food on weight control. The first study by Mantzios and Wilson (2014) divided participants with a mean BMI of 25.8 ± 4.0 kg/m^2 into two groups: (1) a meditation group that had a daily meditation practice and (2) a mindful construal group that was instructed to pay attention to the taste, smell, and texture of food, as well as to cultivate self-compassionate awareness of their thoughts while eating. The mindful construal group achieved similar weight loss compared to the meditation group after 5 weeks (–3.90 ± 1.43 kg vs. –4.06 ± 1.49 kg), and greater weight maintenance over the meditation group at a 3-month follow-up (–3.33 ± 1.58 kg vs. –2.64 ± 1.79 kg). The second study by Whitelock et al. (2019b) was a randomized controlled trial that compared a smartphone-based attentive eating intervention (included attention to the sensory properties of food, photo food diary, and encouragement to eat slowly) and standard dietary advice to standard dietary advice alone in adults with obesity—of note, participants with diabetes could take part, but it was not specified if any were recruited. After 4 and 8 weeks of follow-up, both groups lost the same amount of weight (1.1–1.2 kg) suggesting that attentive eating does not confer additional weight loss benefits. The divergent results from these two studies could be related to differences in methodology: in addition to paying attention to the sensory experience of food, the Mantzios and Wilson (2014) study also included self-compassionate awareness of thoughts that might have influenced results. Evidence suggests that self-compassion might assist in weight management (Brenton-Peters et al., 2021). Interestingly, even though Whitelock et al. (2019b) instructed participants to pay attention to the sensory properties of food, and also encouraged them to eat slowly and without distractions, these did not confer benefits compared to standard dietary advice. As stated in the last section, attentive eating might only decrease calorie intake and weight in habitual fast eaters, but this was not assessed in the study. Relatedly, changes in eating speed were also not assessed.

Summary of Effects of Paying Deliberate Attention to the Eating Experience

Based on inconsistent findings and limited evidence, at this time it is not possible to conclude that paying deliberate attention to the eating experience is a practice that by itself could reduce calorie intake, aid in weight loss, and thereby improve glucose control. It might only lead to positive outcomes in habitual fast eaters if they decrease their eating speed as a consequence of paying attention to the sensory properties of food.

Eating According to Hunger and Satiety Cues

Eating according to physiological hunger and satiety cues involves two closely related, but independent practices: (1) initiating food consumption in response to physical hunger, and (2) stopping eating when physically satiated or when hunger is absent. These practices are relevant because a higher BMI is associated with altered interoceptive processing, or an altered ability to gauge and respond to internal physiological stimuli such as hunger and satiety (Robinson et al., 2021). One interpretation suggests that individuals with overweight/obesity have hypersensitivity to hunger signals and/or insensitivity to satiety signals, either of which could lead to a higher energy intake (Simmons & DeVille, 2017). Furthermore, eating in the absence of hunger has been associated with a higher pre-prandial blood glucose concentration which may mitigate diabetes prevention and treatment efforts (Schembre et al., 2020). Therefore, relearning to properly recognize and interpret physiological hunger and satiety cues may be a strategy to effectively regulate calorie intake, weight, and glucose levels.

Effects of Eating According to Hunger and Satiety Cues on Calorie Intake

To our knowledge, only two studies have examined the isolated effects of eating according to hunger and satiety cues on caloric intake. The first study was a 7-week intervention by Ciampolini et al. (2010a) which divided 181 healthy men and women with normal weight and overweight into two groups: (1) a hunger training group that was taught to eat according to hunger cues (satiety cues were not utilized) and given general recommendations on vegetable intake and physical activity and (2) a control group that was only given the vegetable and physical activity recommendations. To identify what the researchers called "internal hunger" the participants in the hunger training group were instructed to identify an "empty hollow sensation," physical contractions experienced in the epigastrium, and/or the subjective physical experience of light-headedness and general weakness. The researchers also compared the subjective physical hunger sensations with an objective marker: blood glucose concentrations. After identifying the physical sensations of hunger, the participants were trained to measure their blood glucose with a portable glucometer and thus learn to associate those sensations with blood glucose concentration. Since blood glucose concentration is an index of energy availability, the researchers posited that blood glucose slowly declines in the absence of food intake during the day until hunger emerges to trigger eating and that low blood glucose could be regarded as a biochemical marker for hunger. Therefore, participants were instructed to eat within 1 hr of the appearance of internal hunger and an associated measured blood glucose concentration of < 85 mg/dL. After a 5-month follow-up, overweight participants in the hunger training group saw a 687 kcal decrease in average daily self-reported calorie intake compared to a 418 kcal decrease in overweight participants of the control group. Among normal-weight participants, the subgroup that reduced their daily calorie intake with hunger training were those that at baseline ate while blood glucose concentrations were already elevated. They significantly reduced their caloric intake by 434 kcal compared to the control group.

In the second study, Martin et al. (2017) randomized 79 men and women with overweight/obesity into one of three group-based workshops: (1) a mindful eating group that was taught how to eat according to hunger and satiety cues; (2) a mindful decision-making group that was taught to cultivate awareness and acceptance of cravings and the cues that trigger them; and (3) a control group that received standard dietary guidance. Six weeks post-workshop, there were no statistically significant differences in self-reported calorie intake decrease between the mindful eating group (265 kcal) and the control group (444 kcal). These contrasting results could be explained due to the difference in the objective assessment of hunger performed in the former but not the latter study (further discussed in the next section).

Effects of Eating According to Hunger and Satiety Cues on Weight Control

The Ciampolini et al. (2010a) study mentioned in the last section also analyzed the effects of eating according to hunger cues on weight control. After the 5-month follow-up, participants in the hunger training group with normal weight and overweight lost an average of 2.5 kg and 6.7 kg, respectively. These changes were statistically significant in comparison to the control group in which normal-weight participants gained an average of 3.5 kg and overweight participants lost an average of 3.4 kg. Moreover, 17 participants with overweight were contacted 9–15 years after the study ended, and 14 of them continued eating according to their hunger cues and had maintained the lost weight achieved during training, while three participants gained weight. This suggests that eating according to hunger cues may facilitate not only weight loss, but also primary weight maintenance (i.e., maintenance of body weight within normal range over a lifetime) which prevents diabetes (Feldman et al., 2017). Eating according to hunger cues may also aid in secondary weight maintenance (i.e., prevention of weight gain after losing weight) which helps to retain the increased insulin sensitivity achieved through weight loss (Clamp et al., 2017).

In another study by Jospe et al. (2017a), 250 adults without diabetes and with a BMI $\geq$ 27 kg/m^2 (mean BMI = 33 kg/m^2) were randomized to either a control group or one of four weight loss support strategies: hunger training, brief support (monthly weigh-ins and meeting), calorie counting, and daily self-weighing. All groups received specific diet and exercise advice. In the first 2 weeks of the hunger training protocol, 37 participants learned to recognize what the authors called "real (biochemical) hunger" by associating feelings of hunger with blood glucose (similar to the intervention by Ciampolini et al., 2010a). During the next 2 weeks (weeks 2-4) and for 1 week every month for the following 11 months, participants used a hunger training diary to record the intensity of their perceived hunger before and after every eating episode on a 100-mm visual analog scale that ranged from "not at all hungry" to "extremely hungry." After 12 months, the frequency of hunger training diary use predicted weight loss. Men and women who filled out the hunger training diary for at least 60 days (out of 63 recommended days) lost an average of 12.7 kg and 5.2 kg, respectively (Jospe et al., 2017b). This weight loss was larger compared to other weight loss support strategies (Jospe et al., 2017a). While this study did not isolate the effects of hunger training, it suggests a potential amplification of results obtained by diet and exercise alone.

In the previously discussed Martin et al. (2017) study, weight loss was also assessed. After 6 weeks, there were no statistically significant differences in percent weight loss between the mindful eating group (taught to eat according to hunger and satiety cues) and the control group (standard dietary guidance): a 0.6% in the mindful eating group and 1.3% in the control group.

The contrasting results between the three studies could be related to the differences in methodology: the Ciampolini et al. (2010a) and Jospe et al. (2017a) studies used both subjective and objective measures to teach eating according to hunger (i.e., subjective hunger sensations and objective glucose monitoring), while the Martin et al. (2017) study only used subjective measures, although the specific details on how participants were instructed were not provided. Given the positive results seen in the Ciampolini et al. (2010a) and Jospe et al. (2017a) studies, we could assume that using both subjective and objective measures to teach eating according to hunger may be more effective.

Effects of Eating According to Hunger and Satiety Cues on Glucose Control

To our knowledge, the only intervention that has examined the effects of eating according to hunger and satiety cues on glucose control has been another study by Ciampolini et al. (2010b). In this study, 89 participants with normal BMI completed the same hunger training protocol described above and were compared to a control group. After a 5-month follow-up, the hunger training group saw a decrease in HbA1C (4.71 $\pm$ 0.42% to 4.50 $\pm$ 0.43%) and demonstrated significant improvements in insulin resistance (assessed by insulin AUC, insulin peak, and an insulin sensitivity index). These changes were statistically significant in comparison to the control group, although the changes in HbA1C might not be clinically relevant.

A post hoc analysis noted that the significant improvements in glucose control were specifically observed in participants that habitually used to eat while blood glucose concentration was still elevated and that the improvements were independent of baseline BMI (Ciampolini & Sifone, 2011). As an example, participants whose baseline pre-prandial blood glucose concentrations were above 100 mg/dL learned to initiate eating with levels 15–25 mg/dL lower. These participants likely used to eat in the absence of hunger at baseline, which may have been mitigated by hunger training as demonstrated by the ~ 500 kcal/day reduction seen in the 5-month follow-up. This hypothesis is supported by a 7-day free-living observational study that found that perceived eating in the absence of hunger was associated with a higher pre-prandial blood glucose concentration (Schembre et al., 2020). Chronically eating without hunger could affect glucose regulation and therefore increase diabetes risk and management.

Summary of Effects of Eating According to Hunger and Satiety Cues

Limited evidence suggests that eating according to hunger cues may reduce caloric intake and improve weight and glucose control in individuals that chronically eat without hunger. Whether stopping to eat according to satiety cues could offer similar benefits remains unanswered. Of note, no studies have analyzed the isolated effects of eating according to hunger and/or satiety on either weight or glucose control among individuals with prediabetes or diabetes.

Effects of Mindful Eating Practices on Automatic Eating

For most, eating habits are automatic, that is, they often occur mindlessly, unintentionally, and with little effort (Cohen & Farley, 2008; Fürtjes et al., 2020; Moldovan & David, 2012; van't Riet et al., 2011), which could lead to unhealthy eating and a higher BMI (Fürtjes et al., 2020), the main risk factor for diabetes development (Abdullah et al., 2010; Yacamán-Méndez et al., 2021). Mindful eating may be useful to counteract automatic eating, improve eating behavior, and thereby achieve glucose control. Specifically, mindful eating may reduce (over)eating that is automatically triggered by external or environmental cues (i.e., external eating) (Bilman et al., 2017) or by negative emotional cues (i.e., emotional eating) (van Strien, 2018). A 2017 review by Warren et al. (2017) found that in individuals with overweight/obesity, mindful eating practices reduced external eating in 4 out of 5 studies reported, and emotional eating in 7 of 10 studies. While external and emotional eating have been defined differently in the literature, evidence suggests that the distinction between them is not as clear as previously thought and that they may instead reflect a general concept of uncontrolled eating, characterized by low perceived self-control, high food cues reactivity, and a high motivation to eat (Bongers & Jansen, 2016; Vainik et al., 2015).

Given the heterogeneity and multi-component nature of most mindful eating studies published in this domain (for reviews, see Warren et al., 2017, and Grider et al., 2021), it is uncertain which specific mindful eating practices may lead to a reduction in automatic eating and, specifically, to less external and emotional eating. One potentially effective practice is eating with awareness and without distractions, as it has been linked to less external and emotional eating (Winkens et al., 2018a, 2019). Relatedly, cultivating awareness and acceptance of external and emotional cues as well as food-related thoughts that trigger eating may be helpful to override these drives in the long term (Alberts et al., 2010; Coffino et al., 2018; Martin et al., 2017; for a review, see Forman & Butryn, 2015). However, in the short term ($\leq$ 2 weeks), it may either increase the subjective experience of food triggers (e.g., an increase in cravings) (Alberts et al., 2013) or have no effect on them (Lacaille et al., 2014), and therefore might fail to reduce actual food consumption (Jenkins & Tapper, 2014). The lack of results seen in the short-term studies suggests that awareness and acceptance of food-related thoughts is a skill that may take more practice and time to develop. Decentering strategies (i.e., seeing cravings and food-related thoughts as transient mental states external to oneself) may also be effective in reducing reactivity to food cues (for a review, see Keesman et al., 2017; see also Wilson et al., 2021). Decenteri ng may act by decreasing the automaticity of eating behaviors (Jenkins & Tapper, 2014). Moreover, compared to cultivating acceptance strategies in isolation, practicing decentering may be more effective to cope with food triggers (Jenkins & Tapper, 2014; Lacaille et al., 2014). Better regulation of food triggers may in turn lead to calorie intake regulation and weight loss. Long-term weight loss studies (> 6 months) that have incorporated both acceptance and decentering strategies to standard behavioral treatment suggest that they augment weight loss achieved by standard behavioral treatment alone (Forman et al., 2013, 2016).

Another potentially useful practice that may reduce automatic eating is cultivating awareness of hunger and satiety cues and using those cues to guide eating behavior. Although they did not use a questionnaire-based method to assess external eating, Ciampolini et al. (2013) reported that participants stopped eating according to extrinsic cues and began to eat according to their internal hunger sensations. They summarized their intervention as an "effortless cessation of automatic feeding" (Ciampolini et al., 2013, p. 468). Similarly, the study by Jospe et al. (2017b) saw a reduction in external eating and emotional eating in the participants with high adherence to the hunger training protocol.

In summary, mindful eating may indirectly improve glucose control by interrupting automatic reactions to external food cues and emotional triggers that generally lead to biologically unnecessary food intake and weight gain. In other words, it might help individuals make more conscious and deliberate food choices and thereby increase self-regulation.

Effects of Mindful Eating Practices on Disordered Eating

Mindful eating may also indirectly assist in the prevention and treatment of diabetes by reducing glycemic excursions, overeating, and/or weight gain due to bouts of disordered eating, a term used to describe unhealthy or problematic eating behaviors and thoughts that do not meet the Diagnostic and Statistical Manual of Mental Disorders (DSM) criteria for an eating disorder (Anderson, 2018; Reba-Harrelson et al., 2009). Behaviors may include frequent dieting, binge eating, emotional eating, following rigid and strict rules surrounding food, and/or using compensatory behaviors (such as exercise, fasting, or purging) to diminish the effects of food rules transgressions and to control weight (Anderson, 2018; Miller et al., 2009). Problematic thoughts associated with disordered eating may include anxiety surrounding food, guilt or shame about overeating, and weight and shape concerns, as well as having "forbidden foods" or labeling them as "good" or "bad" (Alvarenga et al., 2010; Anderson, 2018).

Cross-sectional and prospective data associate disordered eating with a higher BMI (Nagata et al., 2018; Yoon et al., 2018, 2020), which in turn increases the risk for diabetes (Abdullah et al., 2010; Yacamán-Méndez et al., 2021). Therefore, disordered eating may be an indirect risk factor for diabetes. A longitudinal study found that disordered eating behaviors were associated with diabetes incidence after a 15-year follow-up (Yoon et al., 2019), where the risk of diabetes was proportional to patient-reported disordered eating (HR: 1.20 per endorsed behavior; 95% CI: 1.12–1.28); however, the association was attenuated but not fully eliminated after adjustment for BMI. Because disordered eating is a spectrum of behaviors and cognitions rather than a formal diagnosis, we have little data on its prevalence. While some studies examined the prevalence of disordered eating in patients with type 1 diabetes, few studies have described it among those with type 2 diabetes (Broadley et al., 2020). In the general population, studies have shown that between 16.7 and 54% of adults endorse at least one disordered eating behavior or cognition (Haynos et al., 2018; Nagata et al., 2018; Yoon et al., 2018).

A specific disordered eating behavior that may be mitigated by mindful eating is binge eating, which has been associated with higher caloric intake, higher BMI, more previous weight loss attempts, less weight loss per attempt, and higher HbA1C among individuals with diabetes (Chao et al., 2017; Huisman et al., 2023). Furthermore, individuals who binge eat are more likely to report external and emotional eating (Huisman et al., 2023). In the 2017 review by Warren et al. (2017), mindful eating practices reduced binge eating in all 13 studies reported. A more recent study supports this finding (Salvo et al., 2022). Mindful eating may also be effective in countering frequent dieting (i.e., intentional caloric restriction), a problematic eating behavior that may be employed by individuals with prediabetes or diabetes who have unsuccessfully lost and/or maintained weight loss. Frequent dieting has been prospectively associated with weight gain (Pietiläinen et al., 2012; Sares-Jäske et al., 2019; Siahpush et al., 2015), an association that may be mediated by external and emotional eating (van Strien et al., 2020), which, as was elaborated in the last section, may, in turn, be mitigated by mindful eating. Lastly, mindful eating may potentially aid in decreasing depressive symptoms (Winkens et al., 2018a, b) that are commonly linked to disordered eating (Lewis-Smith et al., 2020), an effect that may also be mediated by decreases in external and emotional eating (Winkens et al., 2018b, 2019).

It is currently unknown which specific mindful eating practices may lead to reductions in disordered eating. The same mechanisms that may decrease automatic eating may be effective for disordered eating behaviors, which can be argued, are likely automatic in nature. Since disordered eating behaviors are associated with less sensitivity to and reliance on hunger and satiety cues (Poovey et al., 2022), increasing awareness and trust in using these cues to guide eating may be an effective strategy. For instance, some studies have reported that Appetite Awareness Training led to significant reductions in episodes of binge eating and overeating in women (Allen & Craighead, 1999; Craighead & Allen, 1995; Goode et al., 2018). Another potential strategy that may reduce disordered eating behaviors is increasing awareness and acceptance of thoughts and feelings related to food and eating (for a review, see Forman & Butryn, 2015). For example, an 8-week intervention study with 26 women with disordered eating behaviors that emphasized acceptance and non-judgment of sensations, thoughts, and feelings led to reductions in dichotomous thinking (e.g., thinking about "good" and "bad" foods) which in turn may diminish problematic eating behaviors (Alberts et al., 2012).

In summary, mindful eating may indirectly prevent diabetes or assist in its treatment by reducing disordered eating behaviors such as binge eating and frequent dieting, possibly through improvements in depressive symptoms, how individuals relate to food and eating, and/or a greater reliance on hunger and satiety signals.

Effects of Multi-component Mindful Eating Interventions on Glucose Management

To our knowledge, only one study has examined the effects of a multi-component mindful eating intervention on glucose management in a population with diabetes. This 3-month study compared Mindfulness-Based Eating Awareness Training for Diabetes (MB-EAT-D) to a behavioral diabetes self-management education (DSME) program (Miller et al., 2012, 2014). In the MB-EAT-D group, participants were encouraged to meditate 6 days a week to cultivate awareness of the experiences, thoughts, and feelings associated with food intake (for example, learning to distinguish between physical and emotional hunger cues). They also received basic information about diet, physical activity, and glycemia, although no specific diet or activity goals were given. In the DSME group, participants were provided information about the effect of the type and quantity of carbohydrates and fats on blood glucose and lipid parameters. They also received calorie, carbohydrate, and fat intake goals. After 3 months of intervention and a 3-month follow-up, both groups achieved similar reductions in weight (-1.53 ± 0.54 kg in the MB-EAT-D group and -2.92 ± 0.54 kg in the DSMES group) (Miller et al., 2012, 2014) and improvements in HbA1c ($-0.83 \pm 0.24\%$ vs. $-0.67 \pm 0.24\%$) (Miller et al., 2012). Unfortunately, it is difficult to assess the direct role of mindful eating on weight and glycemic outcomes as the MB-EAT-D group also had a formal meditation practice which, as previously discussed, may have independent effects from mindful eating.

In summary, there is scarce evidence that a multi-component mindful eating intervention could improve glycemic outcomes by itself, or augment results when combined with a standard dietary intervention. However, new research is underway (Mason et al., 2019).

Discussion

In this narrative review, we attempted to answer one research question: What are the potential mechanisms of action through which mindful eating could aid in the prevention and treatment of diabetes? We highlighted five potential ways mindful eating might directly or indirectly influence glucose control: (1) eating slowly, (2) paying deliberate attention to the sensory properties of food, (3) relying on hunger and satiety cues to determine when to start and stop eating, (4) cultivating acceptance and non-judgmental awareness of food-related thoughts, cravings, and emotions, and (5) decentering from food-related thoughts, cravings, and emotions (Fig. 1).

While eating slowly does not necessarily connote mindful eating, eating slowly may be both an outcome and a facilitator of other mindful eating practices, such as paying deliberate attention to the sensory properties of food and eating according to satiety cues. Eating slowly has been shown to decrease caloric intake within a single meal, possibly through increases in the subjective feeling of satiety and/or the upregulation of satiety and glucose-regulating hormones GLP-1 and PYY, which in the long term may lead to weight loss/maintenance and glucose control that is relevant to both prevention and treatment of diabetes. However, at this point, it cannot be determined if slow eating in isolation may acutely or chronically lead to weight or glucose control.

Paying deliberate attention to the eating experience has led to inconsistent findings regarding its effects on calorie intake and weight control. This practice might only reduce calorie intake (and therefore assist in weight and glucose control) when coupled with eating slowly, particularly in habitual fast eaters with overweight/obesity. It may also have the added benefit of increasing the enjoyment of food (Arch et al., 2016; Hong et al., 2014), an aspect that is commonly lacking in diets used to treat diabetes and that is a common complaint among individuals (Beverly et al., 2018).

Eating according to hunger cues may help regulate calorie intake and may facilitate weight and glucose control, particularly in individuals that frequently eat automatically based on either external or emotional cues. It is unknown if the practice of stopping to eat when physically satiated may benefit in isolation or augment the effects of eating according to hunger. While eating based on hunger and satiety cues is potentially relevant to both the prevention and treatment of diabetes, individuals with uncontrolled diabetes (HbA1C > 7%) and obesity that have altered interoceptive processing might first have to prioritize other strategies. This is because individuals with obesity experience altered hunger/satiety hormones, such as the attenuated postprandial release of the anorexigenic hormones GLP-1 and PYY, as well as reduced postprandial suppression of the orexigenic hormone ghrelin, which in normal weight individuals would induce satiety (Lean & Malkova, 2016). Once weight loss has been achieved and diabetes is controlled, they may then practice eating according to hunger and satiety and progressively develop their interoceptive abilities for maintenance purposes. Likewise, individuals that take GLP-1 receptor agonists which decrease hunger (i.e., liraglutide, semaglutide, and more recently tirzepatide) may not derive benefits from this practice.

Finally, acceptance and decentering of food-related thoughts, cravings, and emotions are skills that may improve eating behavior (e.g., decreasing external, emotional, and disordered eating) which may, in turn, help individuals regulate their weight and glucose levels and ultimately help both prevent and treat diabetes. With enough practice, these skills can be developed by anyone regardless of their baseline characteristics (weight, insulin sensitivity, glucose levels, diabetes status).

While providing an extensive description of how to implement mindful eating interventions is beyond the scope of this review, a summary can be found in Supplementary Material. For patients with additional lifestyle and medication demands, clinicians can design and implement mindful eating interventions in a stepwise fashion to increase adherence and acceptability as its components can be mastered independently. Mastering components independently also create the ability to utilize some practices more than others, and the embedment according to personal preference and outcomes may be a further step into optimizing personal care that is affordable and that accounts for individual differences of patients. A "one size fits all" may not be appropriate and could be avoided with a stepwise delivery. An example of the integration of mindful eating practices can be seen in Fig. 2.

Limitations and Future Research

The broader approach taken in this narrative review provides a theoretical basis of the mechanisms of action through which mindful eating might be useful for diabetes prevention and management; however, it must be interpreted considering its limitations: (1) the non-systematic approach taken and the exclusion of gray literature may increase the risk of selection bias, and (2) the use of PubMed as the only searched database excludes articles that are only available in other databases. To help decrease biases, throughout the text, we provided evidence of contradictory findings, and we proposed potential explanations of the roots of these differences. Moreover, it should be noted that the key features of mindfulness mentioned in this review (i.e., present moment awareness, acceptance, and decentering) are not universally agreed upon in the scientific literature (e.g., Tapper, 2022; cf. Mantzios, 2023). Specifically, it is unclear whether decentering is a true feature of mindfulness or a by-product of it. This area warrants deeper exploration in future research.

With its limitations in mind, this review serves as a launching point for additional research examining the application of mindful eating for diabetes prevention and treatment. The following seven recommendations for future research would help advance the field: (1) Arrive at a consensus of which practices or behaviors can be considered under the term "mindful eating". Researchers have used the term "mindful eating" to refer to interventions that include a wide range of practices, which makes it difficult to compare results between studies and therefore reach conclusions about the potential health benefits of specific practices and behaviors. Some authors suggest differentiating between *decision-making for mindful eating* (e.g., eating according to hunger cues) and *mindful eating behavior* (e.g., eating with attention to the sensory experience of eating with an accepting awareness of thoughts and feelings), and that mindful eating should potentially refer to interventions that train people in both behaviors (Mantzios, 2021). (2) Conduct long-term studies on individual or combined mindful eating practices. While numerous studies have analyzed the long-term effects of multi-component interventions that include elements of mindful eating (for reviews, see Fuentes Artiles et al., 2019, Grider et al., 2021, and Warren et al., 2017), few long-term studies have focused on the isolated effects of specific or combined mindful eating practices independent of other lifestyle or behavior-change modalities (exercise, dietary advice, meditation, etc.). This makes it difficult to determine the effectiveness of individual mindful eating practices or their potential synergistic effects when used in combination. Suggestions of combined practices that may theoretically be effective can be found in the Supplementary

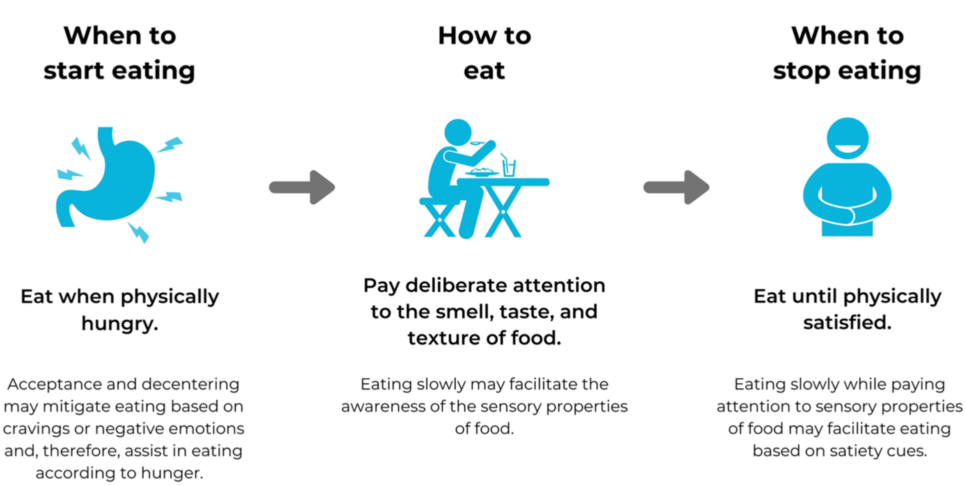

Fig. 2 Example of the integration of mindful eating practices over the trajectory of a meal

Material. (3) Compare mindful eating practices plus standard care to standard care alone. It is plausible that mindful eating practices alone may not be enough to achieve significant changes in calorie intake, weight control, and/or glucose control, but they may augment results obtained by standard care (e.g., Forman et al., 2013, 2016; Jospe et al., 2017a). (4) Study the isolated effects of eating according to hunger and/or satiety cues. With the exceptions of Ciampolini et al. (2010a), Jospe et al. (2017a), and Martin et al. (2017), experimental research in this area is almost non-existent. (5) Provide specific details on how individuals were instructed to implement mindful eating practices. This enables the replication and comparison of findings. (6) Conduct more studies on individuals at risk for developing diabetes (i.e., individuals with overweight/obesity and insulin resistance) and with diabetes. These are currently lacking. If mindful eating practices are to be confidently implemented as complementary tools for the prevention and/or treatment of diabetes, more studies need to be conducted in these populations. (7) Evaluate changes in glucose control as an outcome. Various measures of glucose control (e.g., repeated fasting glucose measurements, HOMA-IR, HbA1C) need to be assessed pre- and post-intervention to draw direct conclusions about the effects of mindful eating for the prevention and treatment of diabetes.

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Data Availability No data were collected.

Declarations

Ethics Approval This review was not a study that involved human participants, and therefore did not require ethics approval.

Informed Consent Not applicable since this review was not a study that involved human participants.

Use of Artificial Intelligence AI tools were not used.

Conflict of Interest Michail Mantzios, Jeffrey N. Schellinger, Sarah E. Messiah, and Elisa Morales Marroquin have no relevant financial or non-financial interests to disclose. Guillermo Muñoz Mireles independently developed an eating program that incorporates mindful eating practices. This program has no ties to any company and, although it is not currently on sale, it is planned to be released to the market in 2023.

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