Intuitive eating is associated with improved health indicators at 1-year postpartum in women with Gestational Diabetes Mellitus

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Abstract

We evaluated the associations between intuitive eating during and after pregnancy with metabolic health at 1-year postpartum in women with gestational diabetes mellitus (GDM) and in high-risk GDM subgroups. One-hundred-and-seventeen women who consented and completed the French intuitive eating questionnaire during and after pregnancy were included. We found an association between intuitive eating during and after pregnancy with lower BMI, weight retention, fasting glucose and HbA1c at 1-year postpartum in women with GDM and in high-risk GDM subgroups with overweight/obese or with prediabetes in the postpartum period. Our results suggest that, intuitive eating could be an effective intervention for weight and glucose control in women with GDM..

Keywords: Intuitive eating; Gestational diabetes mellitus; Body mass index; Glycemic control; Weight retention

Introduction

Gestational diabetes mellitus (GDM) refers to any degree of glucose intolerance that is diagnosed in the second or third trimester of pregnancy but does not fulfil the criteria of overt diabetes (American Diabetes Association (ADA), 2019). Between 3-20% of pregnant women develop GDM globally (Feig et al., 2018) and 10.9% of all pregnancies in Switzerland are complicated with GDM (Rüetschi et al., 2016). The adverse maternal and fetal outcomes of GDM are well known (Damm et al., 2016; Nehring et al., 2011). Indeed, about 48% of women with GDM are at risk of prediabetes (Huopio et al., 2014) and between 20%–60% of women with GDM develop diabetes 5 to 10 years after delivery (Buchanan et al., 2012). Overall, the conversion of GDM to prediabetes and subsequent development of diabetes is well known and continues to be on the rise, making GDM a significant risk factor of type 2 diabetes (Feig, 2018).

Pre-pregnancy body mass index (BMI), excess weight gain during pregnancy and postpartum (PP) weight retention contribute to the risk of prediabetes and diabetes among women with GDM (Kim, 2015; Miao et al., 2017). Weight retention is indeed a prevalent problem: Studies show that, at the early postpartum period, women retain an average of 2–7kg of weight gained during pregnancy, and at least two-thirds of women will still be above their pre-pregnancy weight (Fadzil et al., 2018; Ha et al., 2019; Walker et al 2005). Given that postpartum weight retention is predictive for GDM recurrence (Ehrlich et al., 2011), prediabetes and future diabetes (Bao et al., 2015; Liu et al., 2014), weight loss in the postpartum period is critical for women with previous GDM. In the Diabetes Prevention Program (DPP) for example, weight loss reduced the risk of future diabetes by 16% for every kilogram of weight lost (Hamman et al., 2006) and an intensive lifestyle intervention also led to 50% reduction in the risk of diabetes (Ratner et al., 2008). Apart from overweight/obesity, prediabetes in the postpartum period has also been shown to augment the risk of diabetes in women with GDM (Bao et al., 2015; Meron and Grajower, 2017). Focusing on these two high-risk groups (i.e., overweight/obese women and women with prediabetes) is therefore crucial.

Lifestyle interventions are usually recommended as the primary therapeutic strategy in the postpartum period for women with previous GDM to reduce diabetes risk factors (Gilbert et al., 2019). These interventions consist of nutrition and physical activity advice for weight and glucose control to reduce and or prevent the risk of diabetes in these women. Even though lifestyle interventions have achieved some results in women with GDM, recent systematic and meta-analyses have shown that results from lifestyle intervention studies have been unsatisfactory and inconsistent. In a recent Cochrane review of lifestyle intervention trials among women with GDM, three trials included the incidence of type-2 diabetes and prediabetes in the postpartum period, but only one found a difference between the intervention and the control group (Brown et al., 2017). In another recent systematic review and meta-analysis of 15 trials in women with previous GDM, half of the lifestyle interventions led to a reduction of weight and the incidence of diabetes, but effect sizes were small and their sustained effects were inconsistent (Goveia et al., 2018).

There is therefore a need to identify other novel approaches that can help reduce weight gain during pregnancy and weight retention in order to lower the risk of prediabetes and future diabetes in women previously diagnosed with GDM. Compared to studies (Moses et al., 2009; Xu and Ye, 2018) that focused on lifestyle interventions and nutritional advice, such as total energy intake, macronutrient contents of foods, type of carbohydrates, portion sizes and eating frequency, intuitive eating (IE) represents an interesting and different approach to weight loss and glycemic control. IE is an adaptive eating behavior that deals with the ability to accurately interpret and adhere to instinctive feedback regarding the required amount of food and when to eat (Tylka, 2006). IE correlates with lower weight, BMI and improved glycemic control in the general population (Van Dyke and Drinkwater, 2014; Wheeler et al., 2016). A study that evaluated the relationship between IE and weight in women in the late postpartum period found that IE was associated with weight loss and lower BMI (Leahy et al., 2017). Even though we have earlier demonstrated that, IE is associated with weight and glucose control during pregnancy and in the early postpartum period in women with GDM (Quansah et al., 2019), no study has investigated the potential long-term association between IE during and after pregnancy with weight, weight retention and glycemic control in the general perinatal population nor in women with GDM and their metabolically high-risk subgroups with high BMI or prediabetes. In these high-risk subgroups, the risk of diabetes is higher. To fill this gap, we evaluated the associations between IE during and after pregnancy with BMI, weight retention and glycemic control at 1-year postpartum in all women with GDM and in high-risk GDM subgroups with pre-pregnancy overweight/obesity or with prediabetes in the postpartum period.

Methods

Participant consent and recruitment

This study is part of an ongoing cohort of women with GDM. We invited pregnant women diagnosed with GDM according to the American Diabetes Association (ADA) and the International Association of the Diabetes and Pregnancy Study Groups (IADPSG) guidelines (Dorsey et al., 2018; Metzger, 2010) to participate in the GDM cohort at the gestational diabetes clinic at a Swiss University Hospital. We sought for written informed consent before participation in the cohort. The Human Research Ethics Committee of the Canton de Vaud approved the study protocol (326/15).

Inclusion and exclusion criteria

Women who were ≥18 years, with GDM diagnosis in the second trimester (Metzger et al., 2010) that were followed in our clinic between 2015 and 2018, who understood French or English, consented to participate, and completed the French Intuitive Eating Scale-2 (IES-2) questionnaire at their first visit and at the 1-year visit were included in this study.

Out of a cohort population of 333 participants that consented, we removed participants who did not come for 1-year postpartum appointment visit (N=144) as they did not have valid data for our main questions and hypothesis. Participants with known type 1 diabetes (N= 2), known type 2 diabetes (N= 6), had GDM at ≤13 weeks (N= 10), had diabetes diagnosed during pregnancy at ≤20 weeks (N= 8), with HGPO results that were normal (N= 3), with glucose intolerance but no GDM (N= 1) and were participating in a lifestyle intervention study (N=42) who are part of our cohort database were also excluded as they did not meet the inclusion criteria. Overall, 117 women were eligible and thus included in the final analysis. Figure 1 shows the details of how participants in this study were selected.

Assessment of Intuitive eating (IE)

We assessed IE with the French Intuitive Eating Scale-2 (IES-2) due to the language capacities of our population (Camilleri et al., 2015). The French IES-2 is an18-item validated self-report questionnaire that assesses individuals' tendency to follow their physiological, hunger and satiety in relation to eating. The French IES-2 contains three (3) subscales. These are (1) the Eating for physical rather than emotional reasons (EPR, 8 items) subscale; that assesses how much eating is affected by emotional responses, (2) the Reliance on hunger and satiety cues (RHSC, 6 items) subscale; that evaluates the extent to which individuals are aware and able to trust internal signals rather than relying on external rules/cues, and (3) the Unconditional permission to eat (UPE, 4 items) when hungry subscale that assesses whether an individual purposefully tries to ignore hunger and satiety signals (Camilleri et al., 2015; Daundasekara et al., 2017). The English IES-2 (23-item questionnaire), however, consists of four subscales.

These are the EPR (8 items) subscale, the RHSC (6 items) subscale, the UPE (4 items) and the Body-Food Choice Congruence (BFC-C, 5 items) subscale (Tylka, 2006; Tylka and Van Diest, 2013). Both the French and English IES-2 questionnaires have demonstrated good psychometric properties in pregnant women (Daundasekara et al., 2017). In an earlier study, the Cronbach's alphas (α) for the two subscales were 0.92 and 0.87 for EPR and RHSC respectively, which suggests a good internal reliability among the subscales (Daundasekara et al., 2017). IE has interoceptive abilities that are suggested to determine when and how much to eat, and to accurately perceive and respect one's hunger and satiety cues. Thus, IE tendencies are related to emotional, psychological, and physical well-being (Saunders and Nichols-Lopez, 2018). Details of the IES-2 questionnaire have been previously described (Tylka and Van Diest, 2013).

For the purpose of our study, we removed the UPE subscale (4 items) from the French IES-2. This is because women involved in this study had in general one pre-partum visit with a registered dietician during pregnancy and another one in the early post-partum period (6-8 weeks postpartum). The latter was of short duration and done together with the diabetologist or diabetes educator and focused predominantly on reporting the results of the postpartum oral glucose tolerance testing (oGTT). Women had no further dietician appointment after this visit. Allover, in the general population of our women with gestational diabetes, about 85% see a dietician, but we do not have the exact numbers for the study population. In the general clinic population, reasons for not being able to see a dietician included appointment-scheduling problems or participants visited the GDM clinic at an advanced stage of their pregnancy. We believe that, discussions during diet counselling could significantly influence participant responses to the UPE subscale questions such as *"I try to avoid certain foods high in fat, carbohydrates, or calories"*. This is because during the one-hour diet counselling during the pregnancy, participants were advised on carbohydrate content of their foods and to avoid or limit certain food like soft drinks, sweet products, added sugar and fruits juice in order to improve their eating habits and glycemic profile. We measured weight, BMI and glycemic control variables before the pre-partum counseling with the dietician. This was to ensure that, diet counselling with a dietician does not influence study outcomes. We then measured the metabolic health outcomes again at 1 year postpartum.

We therefore used the EPR and RHSC subscales of the French IES-2 and, an English translation using the forward-backward translation and cultural adaption method (Wild et al., 2005) made by our research team (with the same 14 items; EPR has 8 items and RHSC has 6 items); they were given to participants who speak French and English, respectively. Women completed the EPR and RHSC subscales of the IES-2 questionnaire during the first GDM visit and at the one-year postpartum visit by responding to a 5-point Likert scale ranging from one 'strongly disagree' to five 'strongly agree' to each item in both subscales. We then calculated the EPR and RHSC subscale scores as recommended, by dividing the total scores obtained from the sum of 1-5 from each item by the total number of items in each subscale (EPR by 8 and RHSC by 6), leading to a possible subscale score between one and five. Higher scores indicated greater levels of IE. A higher score of the EPR subscale reflects eating as an answer to hunger and a lower score meant eating to cope with emotional distress, whereas a higher score of the RHSC subscale signifies trust in internal cues, and a lower score reflects less ability to regulate food intake.

Assessment of glycemic control variables

All women involved in this study were diagnosed with GDM during pregnancy (at 24-32 weeks) if one of the following criteria were met during a 75g oGTT: fasting venous glucose $\geq$ 5.1 mmol/L, 1-hr glucose $\geq$ 10.0 mmol/L, or 2-hr glucose $\geq$ 8.5 mmol/L, using the IAPDSG guidelines (Metzger, 2010). For the purpose of this analysis, we used the fasting glucose at

GDM diagnosis, as women with fasting glucose of ≥ 5.1 mmol/L did not have an oGTT. During the first GDM visit after diagnosis, we measured HbA1c using a chemical photometric method (conjugation with boronate; Afinion®). At 1-year PP, patients had a fasting venous glucose and HbA1c measured. The HbA1c was measured using a High Performance Liquid Chromatography method (HPLC) (Jeppsson et al., 2002). Both methods are traceable to the International Federation of Clinical Chemistry and Laboratory Medicine (IFCC) Reference Method for Measurement of HbA1c (Jeppsson et al., 2002). Prediabetes was diagnosed when a participant's fasting glucose at 1-year postpartum was between 5.6-6.9 mmol/l, or HbA1c at 1-year postpartum was between 5.7- 6.4%.

Anthropometric measures

We measured the height and weight of participants during the first GDM visit. Weight and BMI before pregnancy were taken from participants' medical charts or, if missing, was self-reported; we asked for the weight in the 1-2 months before pregnancy if this information is not available in the participants' medical chat. We measured weight at 1-year postpartum to the nearest 0.1 kg in women wearing light clothes and no shoes with an electronic scale (Seca®) and height at the first GDM visit to the nearest 0.1 cm with a regularly calibrated Seca® height scale. We calculated weight retention as the difference between weight at 1-year postpartum and weight before pregnancy. We calculated BMI as the ratio of weight in kilograms to the square of height in meters (kg/m^2). We defined overweight and obesity as BMI between 25.0-29.9 kg/m^2 and ≥30 kg/m^2 respectively.

Measurement of other variables

Sociodemographic characteristics of our participants included age, educational level, nationality, employment status, family history of type-2 diabetes, history of GDM, parity, and smoking and alcohol status during pregnancy. These were obtained from the patients' medical charts, which were completed during the first face-to-face visit. We grouped educational level into four categories. These were compulsory school achieved; general and vocational training levels; high school and university education. Nationality consisted of the following five regions: Switzerland; Europe and North America; Africa; Asia and Western pacific; and Latin America. Employment status was categorized as student; employed; housewife/at home; and unemployed. We categorized family history of type-2 diabetes, history of GDM, smoking, and alcohol intake during pregnancy as either 'yes' or 'no'.

Statistical analyses

We performed all analyses with the SPSS software version 25 (IBM Corp., 2017). All descriptive variables were presented as either means (±standard deviation) or in percentages (%), where appropriate (Table 1 & 2). Both predictor (EPR and RHSC subscales of the IES-2 questionnaire at first GDM visit and at 1-year postpartum visit) and outcome (BMI, weight retention, HbA1c and fasting glucose at the different time points) variables were normally distributed. The EPR and RHSC subscales showed a moderate correlation of 0.42 ($p<0.001$) at the first GDM visit and 0.51 ($p<0.001$) at 1-year postpartum. We conducted a linear regression analysis to determine the associations between IE at the first GDM visit (longitudinal) and at the 1-year postpartum visit (cross-sectional) with BMI, weight retention, fasting glucose, and HbA1c at 1-year postpartum (Table 3). We adjusted for socio-demographic characteristics that showed statistical significance with at least one of the metabolic health outcome variables (BMI, weight, weight retention, fasting glucose and HbA1c) at 1-year postpartum. Thus, we tested for age, gestational age at the first GDM visit, education level, nationality, employment status, family history of type-2 diabetes, history of GDM, smoking and alcohol intake during pregnancy, parity, and breastfeeding in the early postpartum period (at 6-8 weeks postpartum,). Of these potential confounder variables, age and gestational age showed significance with at least one of the metabolic health outcomes. We therefore adjusted for age and gestational age at the first GDM visit as confounders for all analyses. When the outcome was HbA1c or fasting glucose, we further adjusted for BMI at first GDM visit (Table 3). We did this to see if the relationship was mediated by BMI. We conducted all analyses separately for EPR and RHSC subscales at the first GDM visit and at 1-year postpartum. We also evaluated the associations between the two subscales of IES-2 at the first GDM visit and at 1-year postpartum with metabolic health outcomes in the high-risk GDM subgroups with prediabetes or overweight/obesity and in the respective low-risk subgroups (Tables 4 & 5). In the Supplementary Analyses, we also compared the metabolic health outcomes with the IE scores between the high-risk and low-risk subgroups by performing an ANOVA test (Supplementary Table 1 & 2). Both IE scores at both time points were analyzed using correlation analyses and paired t-tests (between first visit and 1-year postpartum, Supplementary Table 3). All statistical significances were two sided and accepted at $p < 0.05$.

Results

Table 1 shows the summary of the general characteristics of our study participants (N=117). The mean age, gestational age at the first GDM visit, and gestational age at delivery were 33.21±5.4 years, 28.83±2.87 weeks and 38.8±1.6 weeks, respectively. More than one-third of the study participants were university graduates (38.2%) and 44.8% were of Swiss nationality. About 59% of the participants had a family history of diabetes and only 4.3% had a history of GDM.

Table 2 describes the study variables at the first GDM visit and at 1-year postpartum. The mean pre-pregnancy weight and BMI were 69.46±13.99 kg and 25.82±4.69 kg/m^2 respectively. At 1-year postpartum, these numbers were 72.79±16.22 kg and 27.06±5.54 kg/m^2, which translates to weight retention of 3.32±7.18 kg. Mean HbA1c was 5.37±0.42% at the first GDM visit and 5.27±0.33% at 1-year postpartum, while fasting glucose at diagnosis was 5.24±0.93 mmol/l and 5.49±0.58 mmol/l at 1-year postpartum. Before pregnancy, 46.2% of women were overweight/obese and this was the same at 1-year postpartum. At 1-year postpartum, 46.1% women had prediabetes.

The mean EPR subscale at the first GDM visit was 3.86 and 3.76 at 1-year postpartum ($p<0.001$), and these numbers were 3.53 and 3.42 for the mean RHSC subscales ($p<0.001$). Correlation between the first GDM visit and 1-year postpartum were 0.42 for the EPR and 0.32 for the RHSC subscales (both $p<0.001$, see also Supplementary Table 3).

Table 3 represents the associations between the two subscales of IES-2 at the first GDM visit and at 1-year postpartum with metabolic health indicators at 1-year postpartum. After adjusting for confounders the EPR subscale at the first GDM visit was associated with lower BMI ($p=0.017$), fasting glucose ($p=0.014$) and tended to predict lower HbA1c ($p=0.062$) at 1-year postpartum. On the other hand, RHSC at the first GDM visit had no association with any of the metabolic health variables at 1-year postpartum (all $p>0.2$). However, both EPR and RHSC at 1-year postpartum were associated with lower weight retention (both $p\leq0.037$) and lower BMI (both $p\leq0.012$). The EPR subscale was also associated with lower HbA1c and lower fasting glucose (both $p=0.018$). When fasting glucose and HbA1c were the outcome variables, we further adjusted for BMI at the first GDM visit as a potential confounder, which led to the attenuation of the observed associations between the two subscales of IES-2 and metabolic parameters (all $p\geq0.066$).

We also focused on two high-risk GDM subgroups with pre-pregnancy overweight/obese or with prediabetes and their lower-risk counterparts. The Supplementary Table 1 shows that at 1-year postpartum all metabolic health indicators, including weight retention, were significantly higher in women with prediabetes (all $p\leq0.026$), whereas women with normal glucose values had significantly higher scores of the EPR ($p=0.025$). The Supplementary Table 2 shows that all metabolic health indicators at 1 year postpartum except weight retention were significantly higher in women who were overweight/obese (all $p \leq 0.042$) and they had significant higher scores of the EPR subscale ($p=0.040$).

In the subgroup of women with prediabetes (Table 4), EPR and RHSC at the first GDM visit predicted lower fasting glucose at 1-year postpartum (both $p \leq 0.024$). At 1-year postpartum, both EPR and RHSC were associated with lower weight retention (both $p \leq 0.034$) and BMI (both $p \leq 0.005$), while no associations were observed in the women with normal glucose tolerance (all $p \geq 0.10$).

In the subgroup of women with overweight/obese (Table 5), EPR at the first GDM visit predicted lower fasting glucose at 1-year postpartum ($p=0.041$), whereas the RHSC subscale showed no significance with any of the metabolic variables. At 1-year postpartum, both EPR and RHSC subscales were associated with lower weight retention (both $p \leq 0.009$) and fasting glucose (both $p=0.030$). The EPR was also associated with lower BMI ($p<0.001$). We found no associations between the two subscales of IES-2 and metabolic health in the subgroup of women with normal weight. In both high-risk subgroups, the associations of IES-2 subscales with fasting glucose were independent of BMI.

Discussion

To our knowledge, no previous study has looked at the relationship between intuitive eating and metabolic health during pregnancy up to the 1-year postpartum period. In the context of identifying novel approaches to prevent weight retention and diabetes in women after GDM, we evaluated the longitudinal and cross-sectional associations between the two subscales of the French intuitive eating questionnaire (the EPR and RHSC subscales) during and after pregnancy with weight retention, BMI, fasting glucose, and HbA1c at 1-year postpartum in women with GDM. This was also studied in two high-risk GDM subgroups, those with prediabetes (46.1%) and those with overweight/obese status (46.2%). IE at the first GDM visit and at 1-year postpartum visit was associated with better metabolic health at 1-year postpartum in all women with GDM and in the two high-risk subgroups. Specifically, the longitudinal analyses revealed that the EPR subscale at the first GDM visit predicted lower postpartum BMI and fasting glucose. In the cross-sectional analyses, the EPR and RHSC subscales at 1-year postpartum visit were associated with lower BMI and lower weight retention, while the EPR subscale was additionally associated with lower fasting glucose and HbA1c. The (cross-sectional and longitudinal) associations between IE and improved metabolic health were also observed in both GDM high-risk subgroups (those with overweight/obese and those with prediabetes), but not in the respective low-risk subgroups.

In women with GDM, there is a tight relationship between weight gain during pregnancy, weight retention, and diabetes in the postpartum period (Mamun et al., 2013; Bao et al., 2015; Institute of Medicine (IOM), 2009; Nehring et al., 2011). Increased weight retention is related to increased insulin resistance, subsequent dysfunction of the beta cells, and development of glucose intolerance (Moyce and Dolinsky, 2018). This is partly attributed to the subtle changes in appetite regulatory mechanisms associated with weight gain and weight retention (Ciampolini et al., 2010; Perry and Wang, 2012). Alterations in leptin (a hormone released from fat cells in adipose tissue altering food intake and control energy expenditure over the long term) signaling also act to increase the risk of diabetes in these women (Moyce and Dolinsky, 2018; Oh et al., 2018). It is therefore of utmost importance to decrease weight retention and to improve glucose control in order to reduce diabetes risk in this population. Traditional lifestyle interventions that are used to manage weight and glucose control and to prevent the progression to diabetes in the postpartum period have, however, been unsatisfactory and their sustained effects are controversial (Brown et al., 2017; Michel et al., 2018). In order to reduce weight retention and improve glycemic control in women with GDM, eating intuitively could help to exert less cognitive control over eating and rely more on satiety cues, irrespective of current innate satiety cues, and help to eat in response to hunger and satiety signals. We thus explored the relationship between IE and metabolic health in women with GDM.

In our longitudinal analyses, we found that the EPR subscale at the first GDM visit was associated with lower BMI and fasting glucose at 1-year postpartum. These findings are in concordance with a previous study conducted in a general non-pregnant population where the EPR subscale was associated with lower weight gain and lower fasting glucose (39). The EPR subscale assesses the extent to which eating is affected by emotion (Tylka, 2006), and women with GDM who engage in eating habits or behaviors driven by emotion rather than physical symptoms of hunger during and after pregnancy may have more problems with weight loss and glucose control in the postpartum period (Leahy et al., 2017). Adhering to IE prevents or reduces eating in response to negative emotional states, such as anxiety, depression, boredom, or loneliness that often leads to overeating, weight retention, higher BMI, and poor glucose control in women with GDM (Lauzon-Guillain et al., 2006). Compared to a study that found a cross-sectional association between the EPR subscale with lower levels of HbA1c in a population with type-1 diabetes, our results found a weak longitudinal relationship between this subscale and HbA1c (p=0.06). In addition to frequent (emotional) overeating, loss of sleep (Dashti et al., 2015) in the postpartum period might influence weight and glucose metabolism and confound some of these findings (Kim et al., 2015; St-Onge, 2017). Other factors, such as breastfeeding in the postpartum period reduce glucose levels and may influence HbA1c levels, and also confound some of the analyses (Gunderson et al., 2012). Indeed, about 87% of women in our sample reported they were breastfeeding during the early postpartum period, but breastfeeding was not a significant confounder in our analyses.

We found no longitudinal relationship between the RHSC subscale at the first GDM visit with any of the metabolic health variables studied at 1 year postpartum. This lack of association between RHSC and the metabolic health variables such as BMI, weight retention, fasting glucose, and HbA1c in our longitudinal analyses suggests that in the long-term, eating for physical rather than emotional reasons overshadows the potential importance of relying on one's hunger and satiety signals to regulate food intake in this sample. Therefore, it was not surprising that the mean difference between the scores of the EPR subscale during and after pregnancy was around 10% higher than that of the RHSC subscale.

In our cross-sectional analyses however, IE at the 1-year postpartum visit was associated with several metabolic health parameters. Thus, the EPR subscale was associated with lower weight retention, BMI, fasting glucose and HbA1c, while the RHSC subscale was associated with lower weight retention and BMI. Either other parameters interfere less in the cross-sectional analyses, or the nature of IE in the postpartum in general relates better to metabolic health compared to the pregnancy period and may account for these associations. Thus, aiming to improve IE in pregnancy and the ability to keep this practice stable and higher in the postpartum period might help to improve overeating and metabolic health in these women.

Despite their future diabetes risk, most women with GDM have normal glucose values after delivery (Retnakaran et al., 2010), but up to 50% have prediabetes within 12 months as observed in our sample and that of another study (Huopio et al., 2014). It is important to prevent further glucose intolerance in these GDM subgroups with prediabetes and overweight/obese who are at higher risk of progressing to diabetes (Feig, 2018). In the subgroup of women with prediabetes or with overweight/obese, we found that IE was associated with fasting glucose in the longitudinal analyses and with weight retention, BMI and/or fasting glucose in the cross-sectional analysis. This results show that special focus should be placed on these women for follow-up, but also to test early interventions to improve IE. This is particularly important because, in women with GDM and in high-risk GDM subgroups, each kilogram of weight lost in the postpartum period is associated with a 16% decrease in the risk of diabetes (Bao et al., 2015; Hamman et al., 2006; Meron and Grajower, 2017). The EPR and RHSC subscales moderately correlated with each other during the first GDM visit (r=0.41) and at 1-year postpartum (r=0.51). The mean score of the EPR subscale was about 10% higher than the mean score of the RHSC subscale. Our results are consistent with another study involving a healthy non-pregnant population (correlation between EPR and RHSC subscale: r=0.35 and 0.37 in women and men respectively) (Tylka and Van Diest, 2013). Although these subscales correlate with each other, only 20% of the variability of one subscale seemed to be explained by the other and thus they cover different aspects of IE.

Our study has several strengths. Clinically, our results if confirmed by an intervention trial could help address the issue of postpartum weight retention in women with GDM. It could also help augment the management and prevention of diabetes in women with GDM and in the high-risk subgroups with prediabetes or overweight/obese, especially when results from several existing lifestyle interventions still remain controversial (Gilbert et al., 2019) and inconsistent (Brown et al., 2017; Goveia P et al., 2018; Michel et al., 2018). We studied the novel relationship between IE with BMI, weight retention and glycemic control during pregnancy and in the postpartum period up to 1 year postpartum in a longitudinal cohort of women with GDM. We also measured IE with a validated tool that has shown to have construct validity and reliability among pregnant women (Camilleri et al., 2015, Daundasekara et al., 2017).

A limitation of this study is the relatively small sample size, which may limit our ability to generalize our findings. Furthermore, the nature of the observational study design does not allow the modification of IE scores, reduces the control over external, confounding variables, although we did test and adjust for potential significant confounders in our regression models, as described in the statistics section above. The inability to include the UPE subscale due to the fact that, discussions during diet counselling could significantly influence participant responses to the UPE subscale may be a source of limitation since the effect of an overall IES-2 subscale would have been interesting. Other factors, such as the intention to lose weight in the postpartum period and a variety of other behavioral or socioeconomic variables that could influence weight loss or impact on metabolic health were not studied. Even though the IES-2 has been validated both in the general and pregnant population, it is not validated in women with GDM and could be a limitation of our study. It is also important to indicate that the IES-2 questionnaire is self-reported, and therefore the likelihood of over- or under-reporting may influence our analyses. We obtained weight before pregnancy from patients' medical chart when available; otherwise, we relied on self-reported pre-pregnancy weight, which may be a limitation. Further research that utilizes IE as an intervention to reduce weight retention and improve glucose control in a larger population during pregnancy and in the postpartum period is needed to determine the causality of these associations in women in general and specifically those with GDM.

Conclusions

We found an association between IE during and after pregnancy with lower BMI and weight retention at 1-year postpartum, both in cross-sectional and longitudinal analyses. In addition, eating for physical rather than emotional reasons was associated with lower fasting glucose and HbA1c in this cohort of women with GDM. High-risk GDM subgroups with prediabetes or overweight/obese each represented almost 50% of the population. In these high-risk groups, IE was associated with lower BMI, weight retention, and fasting glucose. Our results suggest that higher sustenance of IE behavior could represent an interesting and novel approach for reduced BMI, weight retention, and improved glucose control in women with GDM, and especially in high-risk subgroups. IE could therefore be a future target for screening and a potential intervention in women with GDM.

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Tables and Captions

[Table 1] General characteristics of study participants

Variable	Mean	SD	Frequency	Percent (%)
Age (yr.) (N=117)	33.21	5.37		
Gestational age at the first GDM visit (N=117)	28.83	2.82		
Education level (N=89)				
Compulsory school achieved			15	16.9
High school			13	14.6
General and vocational education			27	30.3
University			34	38.2
Nationality (N=116)				
Swiss			52	44.8
Europe + North America			37	31.9
Asia + Western pacific			6	5.2
Africa			20	17.2
Latin America			1	0.9
Employment status (N=109)				
Student			1	0.9
Professional worker			82	75.2
Housewife			13	11.9
Unemployed			13	11.9
Family history of diabetes (N=117)				
1st degree[1]			41	35.0
2nd degree[2]			28	23.9
No			48	41.0
History of previous GDM (N=117)				
No			112	95.7
Yes			5	4.3
Smoking status during pregnancy (N=117)				
Yes			22	18.8
No			95	81.2
Alcohol intake during pregnancy (N=117)				
Yes			6	5.1
No			111	94.9
Parity (N=117)*				
0			68	58.1
1			36	30.8
2			11	9.4
≥3			2	1.7
Breastfeeding (N=117)[3]				
Yes			102	87.2
No			15	12.8

[1] 1st degree means 1 degree of relationship of the participant (at least 50% of genetic link, which included mother, father, brother, sister, daughter, son)

[2] 2nd degree means 2nd degree of kinship of the participant (at least 25% of genetic link that included grandparents, grandchildren, nephews, niece, half-brother, half-sister)

[3] At 6-8 weeks postpartum

*10.2% of women who were multiparous had history of previous GDM

All results are frequency and percentage unless otherwise stated

GDM means gestational diabetes mellitus

[Table 2] Mean and standard deviations of study variables (N=117)

Variable	Mean	SD
First GDM visit		
Pre-pregnancy weight (kg)[1]	69.46	13.99
Pre-pregnancy BMI (Kg/m^2)[2]	25.82	4.69
Weight at the first GDM visit (kg)	80.26	14.55
BMI at the first GDM visit (Kg/m^2)	29.87	4.89
HbA1c at the first GDM visit (%)	5.37	0.42
Fasting glucose at GDM diagnosis (mmol/l)	5.24	0.93
EPR at the first GDM visit	3.86	0.94
RHSC at the first GDM visit	3.53	0.89
1-year postpartum		
Weight at 1-yr postpartum (kg)	72.79	16.22
ΔWeight retention (kg)[3]	3.32	7.18
BMI at 1-yr postpartum (kg/m^2)	27.06	5.54
Waist circumference at 1-yr postpartum (cm)	88.82	11.99
HbA1c at 1-yr postpartum (%)	5.27	0.33
Fasting glucose at 1-yr postpartum (mmol/l)[4]	5.49	0.58
EPR at 1-yr postpartum	3.76	0.97
RHSC at 1-yr postpartum	3.42	0.94

[1]Data reported at the first GDM visit or taken from the medical charts
[2]Body mass index before pregnancy; data reported at the first GDM visit or taken from the medical charts
[3]Weight retention means the difference in weight at 1-yr postpartum and pre-pregnancy weight
[4]N=116; one missing
GDM means gestational diabetes mellitus
HbA1c means glycated hemoglobin
BMI means body mass index
EPR means Eating for Physical Rather than Emotional Reasons subscale of the Intuitive Eating scale2 (IES-2)
RHSC means Reliance on Hunger and Satiety Cues subscale of the Intuitive Eating scale2 (IES-2)

[Table 3] Associations between the two subscales of IES-2 at the first GDM visit and at 1-year postpartum and metabolic health at 1-year postpartum

Variable	Regression coefficient	95% CI		P-value[a]	P-value[b]
IES-2 at the first GDM visit (longitudinal)					
EPR at the first GDM visit					
Metabolic health at 1-yr pp					
ΔWeight retention (kg)[1]	-0.087	-2.026	0.730	0.350	
BMI (kg/m^2)	-0.219	-2.281	-0.151	**0.017**	
HbA1c (%)	-0.171	-0.119	0.008	0.062	0.137
Fasting glucose (mmol/l)	-0.229	-0.251	-0.026	**0.014**	**0.068**
RHSC at the first GDM visit					
Metabolic health at 1-yr pp					
ΔWeight retention (kg)[1]	0.078	-0.815	2.084	0.400	
BMI (kg/m^2)	-0.090	-1.637	0.645	0.332	
HbA1c (%)	0.044	-0.048	0.086	0.634	0.327
Fasting glucose (mmol/l)	-0.104	-0.184	0.058	0.272	0.458
IES-2 at 1-yr pp (cross-sectional)					
EPR at 1-yr pp					
Metabolic health at 1-yr pp					
ΔWeight retention (kg)[1]	-0.230	-2.976	-0.370	**0.012**	
BMI (kg/m^2)	-0.337	-2.825	-0.829	**<0.001**	
HbA1c (%)	-0.216	-0.129	-0.008	**0.018**	**0.066**
Fasting glucose (mmol/l)	-0.222	-0.236	-0.018	**0.018**	0.237
RHSC at 1-yr pp					
Metabolic health at 1-yr pp					
ΔWeight retention (kg)[1]	-0.193	-2.847	-0.083	**0.037**	
BMI (kg/m^2)	-0.243	-2.469	-0.313	**0.012**	
HbA1c (%)	-0.095	-0.098	0.032	0.311	0.547
Fasting glucose (mmol/l)	-0.194	-0.230	0.002	0.042	0.208

[1]means the difference in weight at 1-yr postpartum and pre-pregnancy weight
EPR means Eating for Physical Rather than Emotional Reasons subscale of the Intuitive Eating scale2 (IES-2)
RHSC means Reliance on Hunger and Satiety Cues subscale of the Intuitive Eating scale2 (IES-2)
PP means postpartum
P-value[a]: adjusted for age and gestational age at the first GDM visit
P-value[b]: adjusted for age and gestational age and BMI at the first GDM visit

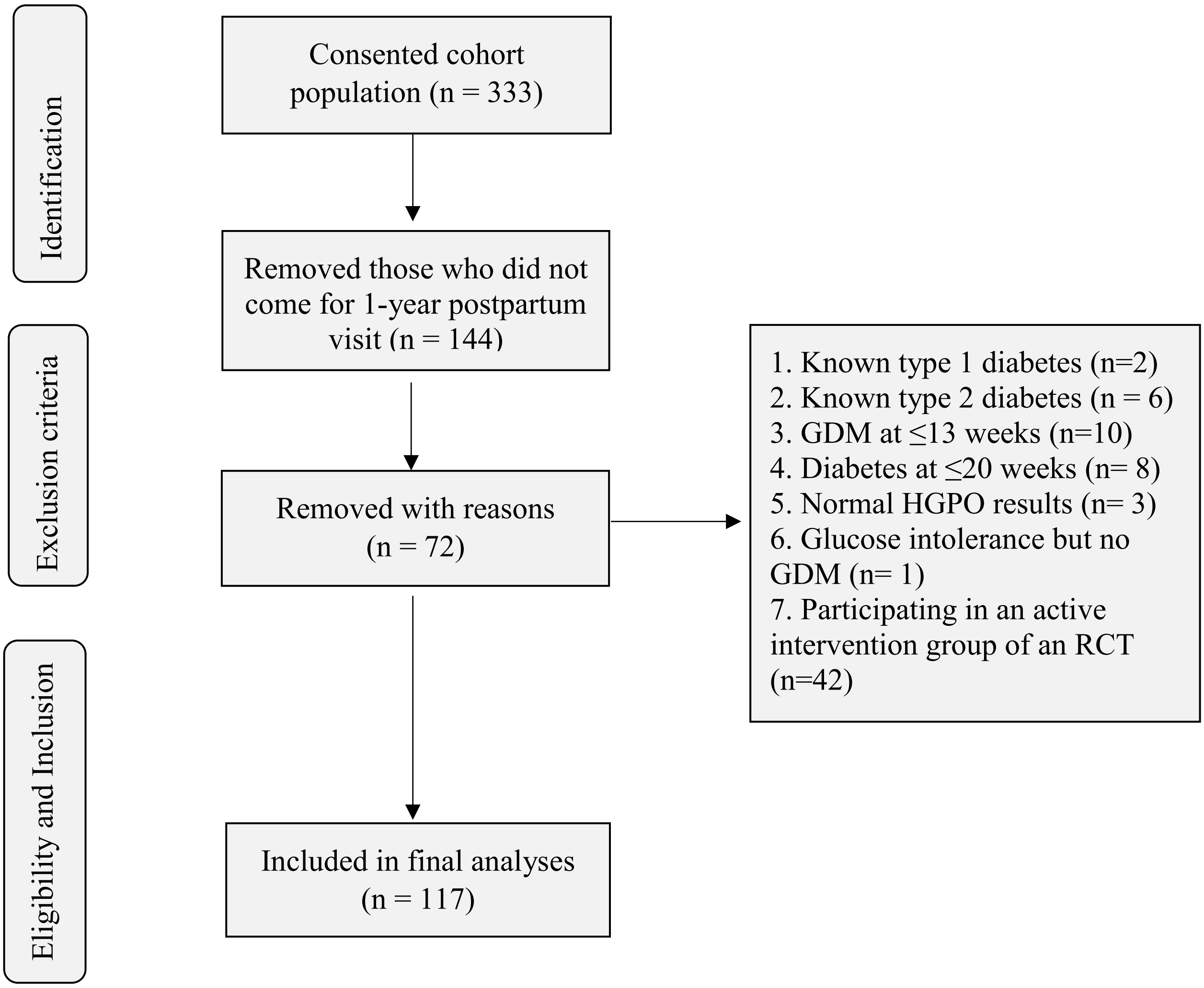

Fig 1. Flow chart describing how the study participants were selected. Removed participants did not meet the inclusion criteria (see methods section).

[Table 4] Associations between the two subscales of IES-2 at first GDM visit and at one-year postpartum visit with metabolic health at one year postpartum stratified by glucose tolerance

	Prediabetes (n=54)					Normal (n=63)			
Variable	Regression coefficient	95% CI		P-value[a]	P-value[b]	Regression coefficient	95% CI		P-value
IES-2 at first GDM visit (longitudinal)*									
EPR at the first GDM visit									
ΔWeight retention (kg)[1]	-0.098	-2.598	1.239	0.480		-0.052	-2.461	1.628	0.685
BMI (kg/m^2)	-0.169	-2.415	0.576	0.223		-0.214	-2.748	0.213	0.092
HbA1c (%)	-0.173	-0.158	0.036	0.211	0.189	-0.076	-0.095	0.051	0.553
Fasting glucose (mmol/l)	-0.437	-0.303	-0.063	**0.001**	**0.004**	-0.029	-0.106	0.084	0.820
RHSC at the first GDM visit									
ΔWeight retention (kg)[1]	-0.090	-2.459	1.254	0.518		0.294	0.453	4.959	0.076
BMI (kg/m^2)	-0.075	-1.857	1.068	0.591		-0.082	-2.300	1.178	0.521
HbA1c (%)	0.043	-0.080	0.109	0.760	0.751	0.060	-0.064	0.104	0.641
Fasting glucose (mmol/l)	-0.308	-0.247	-0.004	**0.024**	**0.025**	0.101	-0.066	0.152	0.432
IES-2 at 1-year pp (cross-sectional)									
EPR at 1-yr pp									
ΔWeight retention (kg)[1]	-0.288	-3.572	-0.142	**0.034**		-0.114	-3.111	1.184	0.373
BMI (kg/m^2)	-0.384	-3.248	-0.645	**0.004**		-0.180	-2.698	0.450	0.158
HbA1c (%)	-1.582	-0.159	0.019	0.120	0.125	-0.001	-0.077	0.077	0.995
Fasting glucose (mmol/l)	-0.204	-0.207	0.031	0.142	0.765	0.083	-0.067	0.132	0.515
RHSC at 1-yr pp									
ΔWeight retention (kg)[1]	-0.394	-4.388	-0.935	**0.003**		-0.030	-2.361	1.861	0.814
BMI (kg/m^2)	-0.378	-3.376	-0.639	**0.005**		-0.047	-1.851	1.272	0.712
HbA1c (%)	-0.130	-0.139	0.050	0.349	0.253	0.157	-0.028	0.121	0.219
Fasting glucose (mmol/l)	-0.137	-0.190	0.065	0.329	0.842	-0.043	-0.114	0.082	0.740

*for the fasting glucose, this corresponds to the time point of the GDM diagnosis before the first GDM visit.

[1]means the difference in weight at 1-yr postpartum and pre-pregnancy weight

EPR means Eating for Physical Rather than Emotional Reasons subscale of the Intuitive Eating scale2 (IES-2)

RHSC means Reliance on Hunger and Satiety Cues subscale of the Intuitive Eating scale2 (IES-2)

P-value[a]: Adjusted for age and gestational age at the first GDM visit

P-value[b]: Adjusted for age, gestational age and BMI at the first GDM visit

PP means postpartum

[Table 5] Associations between the two subscales of IES-2 and metabolic health at one year postpartum stratified by BMI category

Variable	Obese/overweight (n=54)					Normal weight (n=63)			
	Regression coefficient	**95% CI**		**P-value[a]**	**P-value[b]**	**Regression coefficient**	**95% CI**		**P-value**
IES-2 at first GDM visit (longitudinal)*									
EPR at the first GDM visit									
ΔWeight retention (kg) [1]	-0.111	-3.466	1.475	0.422		0.026	-1.281	1.567	0.842
BMI (kg/m^2)	-0.132	-1.779	0.643	0.351		-0.144	-1.183	0.304	0.241
HbA1c (%)	-0.195	-0.157	0.037	0.165	0.169	-0.076	-0.112	0.061	0.553
Fasting glucose (mmol/l)	-0.288	-0.337	0.003	**0.041**	**0.043**	-0.083	-0.191	0.098	0.522
RHSC at the first GDM visit									
ΔWeight retention (kg) [1]	0.176	-0.924	4.241	0.203		0.054	-1.188	1.819	0.676
BMI (kg/m^2)	0.213	-0.319	2.219	0.137		-0.073	-1.028	0.556	0.554
HbA1c (%)	-0.010	-0.108	0.101	0.967	0.963	0.194	-0.020	0.160	0.127
Fasting glucose (mmol/l)	-0.111	-0.260	0.111	0.419	0.424	0.039	-0.130	0.176	0.765
IES-2 at 1-year pp (Cross-sectional)									
EPR at 1-yr									
ΔWeight retention (kg) [1]	-0.347	-5.152	-0.562	**0.009**		0.006	-1.349	1.409	0.965
BMI (kg/m^2)	-0.430	-2.873	-0.735	**<0.001**		-0.098	-1.019	0.442	0.432
HbA1c (%)	-0.177	-0.156	0.034	0.201	0.233	-0.155	-0.134	0.032	0.225
Fasting glucose (mmol/l)	-0.301	-0.345	-0.015	**0.030**	**0.025**	0.001	-0.140	0.140	0.997
RHSC at 1-yr									
ΔWeight retention (kg) [1]	-0.405	-6.529	-1.494	**0.002**		0.077	-0.891	1.656	0.550
BMI (kg/m^2)	-0.245	-2.467	-1.370	0.780		-0.120	-1.036	0.371	0.348
HbA1c (%)	-0.135	-0.162	0.055	0.329	0.299	0.074	-0.055	0.100	0.564
Fasting glucose (mmol/l)	-0.302	-0.395	-0.021	**0.030**	**0.032**	0.040	-0.110	0.151	0.755

*for the fasting glucose, this corresponds to the time point of the GDM diagnosis before the first GDM visit

[1]means the difference in weight at 1-yr postpartum and pre-pregnancy weight

EPR means Eating for Physical Rather than Emotional Reasons subscale of the Intuitive Eating scale2 (IES-2)

RHSC means Reliance on Hunger and Satiety Cues subscale of the Intuitive Eating scale2 (IES-2)

P-value[a]: Adjusted for age and gestational age at the first GDM visit

P-value[b]: Adjusted for age, gestational age, and BMI at the first GDM visit

PP means postpartum

Supplementary tables

[Table 1] 1-year postpartum metabolic health indicators and IE scores according to glucose tolerance

Variable	N	Mean	SD	P-value*
Weight at 1-year pp (kg)				
Normal	63	69.15	15.07	**0.008**
Prediabetes	54	77.03	16.62	
∆Weight retention (kg)[1]				
Normal	63	1.96	7.22	**0.026**
Prediabetes	54	4.92	6.86	
BMI (kg/m^2)				
Normal	63	25.72	5.35	**0.004**
Prediabetes	54	28.63	5.40	
HbA1c (%)				
Normal	63	5.14	0.25	**<0.001**
Prediabetes	54	5.41	0.34	
Fasting glucose (mmol/l)				
Normal	63	5.10	0.33	**<0.001**
Prediabetes	54	5.96	0.46	
EPR				
Normal	63	3.95	0.85	**0.025**
Prediabetes	54	3.55	1.06	
RHSC				
Normal	63	3.53	0.87	0.171
Prediabetes	54	3.29	1.01	

[1]means the difference in weight at 1-yr postpartum and pre-pregnancy weight
*P-value from ANOVA test
GDM means gestational diabetes mellitus
HbA1c means glycated hemoglobin
BMI means body mass index
EPR means Eating for Physical Rather than Emotional Reasons subscale of the Intuitive Eating scale2 (IES-2)
RHSC means Reliance on Hunger and Satiety Cues subscale of the Intuitive Eating scale2 (IES-2)
PP means postpartum

[Table 2] 1-year postpartum metabolic health indicators and IE scores according to weight status/category

Variable	N	Mean	SD	P-value*
Weight at 1-year pp (kg)				
Normal	63	61.79	7.70	**<0.001**
OW/OB	54	85.61	13.98	
∆Weight retention (kg)[1]				
Normal	63	2.13	4.78	**0.053**
OW/OB	54	4.71	9.08	
BMI (kg/m^2)				
Normal	63	23.11	2.61	**<0.001**
OW/OB	54	31.67	4.37	
HbA1c (%)				
Normal	63	5.21	0.29	**0.042**
OW/OB	54	5.33	0.36	
Fasting glucose (mmol/l)				
Normal	63	5.34	0.48	**0.002**
OW/OB	53	5.67	0.64	
EPR				
Normal	63	3.94	0.88	**0.040**
OW/OB	54	3.57	1.04	
RHSC				
Normal	63	3.55	0.95	0.110
OW/OB	54	3.27	0.91	

[1]means the difference in weight at 1-yr postpartum and pre-pregnancy weight
*P-value from ANOVA test
GDM means gestational diabetes mellitus
HbA1c means glycated hemoglobin
BMI means body mass index
EPR means Eating for Physical Rather than Emotional Reasons subscale of the Intuitive Eating scale2 (IES-2)
RHSC means Reliance on Hunger and Satiety Cues subscale of the Intuitive Eating scale2 (IES-2)
PP means postpartum
OW/OB means Overweight/Obese

[Table 3] Paired t-test and correlation between the two scales of IES-2 at the first GDM visit and at 1-year postpartum (N=117)

Variable	Mean	SD	P-value (t-test)	r.	P-value (r)
EPR at the first GDM visit	3.86	0.94	0.862	0.422	<0.001
EPR at 1-yr pp	3.76	0.97			
RHSC at the first GDM visit	3.53	0.89	0.995	0.320	<0.001
RHSC at 1-yr pp	3.42	0.94			
EPR at the first GDM visit	3.86	0.94	<0.001	0.415	<0.001
RHSC at the first GDM visit	3.42	0.89			
EPR at 1-yr pp	3.76	0.97	<0.001	0.510	<0.001
RHSC at 1-yr pp	3.42	0.94			

EPR means Eating for Physical Rather than Emotional Reasons subscale of the Intuitive Eating scale2 (IES-2)
RHSC means Reliance on Hunger and Satiety Cues subscale of the Intuitive Eating scale2 (IES-2)
PP means postpartum
r means correlation