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ENERGY INTAKE UNDER-REPORTING INCREASES OVER PREGNANCY: AN INTENSIVE LONGITUDINAL STUDY OF WOMEN WITH OVERWEIGHT AND OBESITY

A Thesis in

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by

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ABSTRACT

Background: Energy intake under-reporting is widespread, yet poorly understood during pregnancy. Adequate energy intake and energy balance are essential for optimizing maternal and fetal outcomes, including gestational weight gain.[1, 2] Inaccurate self-reported energy intake may result in erroneous nutrition education from health professionals during pregnancy.[3]

Objective: This study aimed to examine the trends (i.e., changes over gestation), magnitude (i.e., degree of severity), and predictors (i.e., gestational age, anthropometrics, demographics, perceived stress, and eating behaviors) of energy intake under-reporting using intensive longitudinal data in a sample of pregnant women with overweight and obesity in the United States.

Methods: This is a post hoc analysis using data from the *Healthy Mom Zone Study*. Pre-pregnancy weight and demographics were reported at study enrollment (at 8-12 weeks gestational age). Validated questionnaires were completed weekly to assess perceived stress and monthly to assess eating behaviors.[4, 5] Mobile health technology was used to measure daily weight (Wi-Fi Scale) and physical activity (activity monitor) and tri-weekly self-reported energy intake (smartphone app).[6, 7] An energy balance model was used to calculate energy intake with the inputs of measured weight, physical activity, and resting metabolic rate.[8, 9] Reporting accuracy was defined as: *[(self-reported EI – back-calculated EI) / back-calculated EI)] * 100%*. Linear fixed effects modelling was used to test whether each predictor was associated with under-reporting.

Results: Women were, on average, 30.7 years old, married, well-educated, pregnant with their first child (64%), and had overweight or obesity (mean BMI=31.5). Women under-reported by 36% of their estimated energy intake, on average. Energy intake under-reporting increased significantly between trimesters from 28% (first) to 33% (second) to 39% (third) ($p<0.001$). We also found a significant positive association between under-reporting and gestational age (in days) ($p<0.001$), pre-pregnancy body mass index ($p<0.01$), perceived stress ($p<0.05$), and uncontrolled eating ($p<0.05$). The following variables were not associated with reporting accuracy: age, education, income, parity, gestational weight gain, treatment group, birth weight, cognitive restraint and emotional overeating.

Conclusions: This study contributes to the literature by evaluating the accuracy of self-reported energy intake multiple times in each trimester. These findings suggest that under-reporting during pregnancy is complex. Whereas additional research on predictors of under-reporting in pregnancy is needed, this preliminary study could help inform gestational weight gain intervention efforts by identifying individuals who may be more susceptible to under-estimating energy intake during pregnancy.

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Abbreviations: American College of Obstetricians and Gynecologists (ACOG), basal metabolic rate (BMR), body mass index (BMI), calories (kcal), Dietary Reference Intake (DRI), doubly-labelled water (DLW), energy intake (EI), estimated energy requirement (EER), food frequency questionnaire (FFQ), gestational weight gain (GWG), Institute of Medicine (IOM), mobile applications (apps), mobile health (mHealth), resting metabolic rate (RMR), total energy expenditure (TEE), under-reporting (UR), United States Department of Agriculture (USDA)

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Chapter 1

Introduction

The Scope and Significance of Maternal Prenatal Overweight and Obesity

In the United States, approximately two-thirds of women of childbearing age have overweight or obesity.[10] In addition to entering pregnancy with an elevated body mass index (BMI), most women gain more weight during pregnancy than is recommended by the Institute of Medicine (IOM) (approximately 71% of women with overweight and 61% of women with obesity).[11, 12] This is problematic because elevated pre-pregnancy BMI and excess maternal gestational weight gain (GWG) are associated with higher risk of pregnancy complications and adverse outcomes in both the mother and child.[12-15] Women who enter pregnancy with elevated BMI and/or exceed the GWG recommendations may be at higher risk for gestational diabetes, preeclampsia, complications during delivery, increased risk for unsuccessful breastfeeding, and both short- and long-term post-partum weight retention.[16-24] In the offspring, risks of high pre-pregnancy BMI and GWG include macrosomia (birth weight >4000 grams),[25-27] large for gestational age (birth weight >90th percentile),[25] higher child BMI-for-age z-scores,[28] increased body fat and elevated systolic blood pressure in children at age 3 years,[28] and overweight during adolescence.[29, 30]

Because of the associated risks with excess maternal weight, in 2009 the IOM established new guidelines with specific GWG recommendations based on pre-pregnancy BMI category. The recommendation states that women with overweight should gain 7.0-11.5 kilograms (15-25 pounds) and women with obesity should gain 5.0-9.0 kilograms (11-20 pounds), compared to a recommended 11.5-16.0 kilograms (25-35 pounds) for normal weight women (Table 1-1).[11] A growing body of literature suggests that these guidelines may remain excessive. Observational studies show that weight loss or limited weight gain may be ideal for pregnant women with classes 2 and 3 obesity,[28, 31] though prospective randomized trials are needed to confirm these findings. Regardless, many women exceed the current guidelines and there is a need for effective interventions to help women, especially those with overweight and obesity, to manage GWG for optimal pregnancy outcomes. Effective clinical and public health interventions to improve GWG will require an understanding of prenatal energy balance.

Table 1-1: IOM Recommendation for Gestational Weight Gain[11]

Category	**Pre-pregnancy BMI (kg/m2)**	**GWG Range (lb.)**	**Rates of GWG 2nd-3rd Trimester (M range in lb./wk.)**
Underweight	<19.8	28-40	1 (1-1.3)
Normal	19.9-24.9	25-35	1 (0.8-1)
Overweight	25.0-29.9	15-25	0.6 (0.5-0.7)
Obese (all classes)	> 30.0	11-20	0.5 (0.4-0.6)

Energy Balance During Pregnancy

A critical factor for achieving GWG is energy balance, or the relationship between energy intake (EI) and total energy expenditure (TEE). Pregnancy is not considered a period of steady state energy balance since GWG is often required to support fetal development. The relationship between EI and GWG is moderated by energy expenditure, primarily through energy deposition (accumulated maternal and fetal tissue), changes in basal metabolic rate (BMR), and physical activity level.[1]

Within the limitations of these physiologic and metabolic adaptations, GWG is thought to be affected by changes in EI. Gilmore et al. found that EI in calories (kcal) from 22 to 36 weeks of gestation was significantly higher in high gainers (3437±99 kcal/d) versus low and ideal gainers (2687±110; $p<0.001$) using gold standard measures of EI and body composition [i.e., doubly labeled water (DLW) and the 4-compartment body composition model] to measure energy intake.[2] Meanwhile, they observed no significant differences between BMR and physical activity energy expenditure between high and low/ideal gainers. These findings suggest that increased EI is the primary driver of excessive GWG and not thrifty energy expenditure (i.e., compensatory reductions in physical activity), as was previously theorized.[32] Additionally, research indicates that women with overweight and obesity may have lesser energy expenditure during pregnancy, compared with normal weight women. Basal metabolism has been shown to increase in women with healthy BMI during pregnancy[33] but women with elevated BMI do not exhibit the expected rise in BMR.[1] Also, physical activity is low for most pregnant women in the United States, but especially for women with obesity, with only 15-23% of women with obesity meeting the exercise recommendations.[34-36] These factors may predispose some women, especially those with obesity, to excess GWG, which exacerbates the effect of excess EI on GWG.

Estimated Energy Requirement for Pregnant Women

While low energy expenditure may contribute, EI is thought to be the main determinant of energy balance during pregnancy and thus GWG. The Estimated Energy Requirement (EER) is defined as the average EI that is predicted to maintain energy balance in a healthy adult of a defined age, gender, weight, height, and level of physical activity, consistent with good health. In pregnant women, the EER includes energy needs associated with the deposition of tissues (i.e., fetus, placenta, and maternal tissues) at rates consistent with positive outcomes.[37]

In the 2005 Dietary Reference Intake (DRI) for energy, the formula for EER during pregnancy is: $EER_{pregnant} = EER_{nonpregnant} + \textit{additional energy expended during pregnancy} + \textit{energy deposition}$. This was broken down by trimester: for the first trimester, no increases in TEE or energy deposition need to occur, so EER for the first trimester is equivalent to EER for non-pregnancy. In the second trimester, an additional 160 kcal increased TEE (8 kcal/week) and 180 kcal of energy deposition is assumed so a total of 340 kcal is added to the pre-pregnancy EER. In the third trimester, 272 kcal increased TEE (8 kcal/week) and 180 kcal energy deposition sums to the recommended 452 kcal increase in EER.[33] Energy deposition of 180 kcal/day in the second and third trimesters is equivalent to approximately 34,020 kcal over the pregnancy. Unlike GWG recommendations, the EER is not tailored to a woman's specific pre-pregnancy BMI category.

Table 1-2: Estimated Daily Energy Requirements for Pregnant Women[33]

Trimester	**Total Energy Expenditure (TEE) (kcal)[a]**	**Energy Deposition (kcal)[b]**	**Total Added Energy (kcal)**
1	0	0	0
2	160	180	340
3	272	180	452

[a] Determined in studies of well-nourished pregnant women with BMI 18.5-25 kg/m^2
[b] Mean results for all BMI categories (i.e., underweight, normal, overweight, and obese BMI)

In fact, there is little evidence to support the assumptions that underlie the current IOM kcal guidelines for women with overweight and obesity. The EER from the 2005 DRI is based on the most widely cited energy intake recommendation, that women should consume an additional 300 kcal/day during pregnancy. This number is derived from the study by Hytten et al., which estimated the energy cost of a full-term pregnancy to be 85,000 kcal, or approximately 300 kcal/day, based on theoretical calculations that assumed a 3.4 kg infant, deposition of 0.9 kg (2.0 lb.) of protein and 3.8 kg (8.4 lb.) of fat, and an increase in basal metabolism.[37-39]

The validity of Hytten's estimations have been challenged, especially for use with women with overweight and obesity, based on several limitations. First, the increase in TEE was determined from data that included only well-nourished, normal weight pregnant women.[40] These data show no association between change in TEE and BMI, but it is unclear whether this would differ among women with overweight and obesity. Second, women with obesity may not need any additional calories for energy deposition during the second and third trimester. Using four-component body composition model data, Lederman et. al. estimated that total (net) energy deposition is 40,376 kcal/day for normal, 31,126 kcal/day for overweight, and -324 kcal/day for obese pregnant women.[33, 38, 41] In other words, women with obesity must use existing energy stores, rather than EI, for energy deposition in order to meet the GWG guidelines. Finally, studies used to determine the EER for pregnancy used the 1990 GWG recommendations for women with obesity (at least 6.8 kg). This was reduced to 5-9 kg in the 2009 recommendation based on the current evidence of risk at that time.[11] Thus, Hytten's calorie estimations and others performed before 2009 would likely be too high for this population based on appropriate GWG alone. Overall, this evidence suggests that the IOM formula to determine EER in the second and third trimesters over-estimates EER for women with obesity, making it difficult for pregnant women and their clinicians to know how much they need to eat to gain the appropriate amount of weight.

Adequacy of Nutrition Education in Prenatal Care

In addition to a lack of sound energy recommendations, women with overweight and obesity report not receiving adequate prenatal nutrition education, which may also contribute to excess GWG.[3] Both the IOM and American College of Obstetricians and Gynecologists (ACOG) advise clinicians to provide prenatal nutrition counselling to all women, and this may be especially beneficial for those at risk of excessive GWG or with other risk factors,[42-44] but there are many barriers which can prevent clinicians from meeting this standard of care. Providers, especially physicians, report lacking the training and knowledge to counsel on healthy eating behaviors.[45, 46] Additionally, providers say they often avoid or delay weight gain counselling for fear of shaming, stigmatizing, or causing anxiety in the patient.[45]

In contrast, pregnant women report wanting more information on healthy eating and weight gain. A qualitative study by Downs et. al. used semi-structured interviews and focus groups to characterize pregnant women's knowledge of GWG and healthy eating behaviors known to impact GWG.[47] This study found that 43.8% of the women interviewed did not feel as though they received adequate information from their healthcare provider about how to meet the nutrition recommendations. Additionally, many women in this sample (42%) had no knowledge of recommended GWG and only 15.7% mentioned receiving any guidance on energy intake [e.g., "eat more", "increase intake by 200-300 calories/day")]. These findings highlight the importance of incorporating information on weight and EI into routine prenatal care.

Clinical Methods to Monitor Energy Intake

Dietary assessment is foundational to nutrition counselling and intervention. It allows patients and clinicians to recognize food habits to identify opportunities for dietary improvement and management of GWG. A recent systematic review and meta-analysis by Shieh et. al. found that kcal goals and self-monitoring of EI improve the efficacy of interventions aimed at limiting excessive GWG among pregnant women with overweight and obesity.[48, 49] Vesco et. al. developed a daily calorie intake goal to create a sufficient calorie deficit to maintain weight as part of an intervention designed to help limit GWG among pregnant women with obesity and obsese.[50] This intervention was effective, resulting in a mean difference in GWG of 3.4 kg across pregnancy [95% CI(-5.1-1.8)] between the intervention and control groups.[51]

Traditional methods for collecting information on EI include 24-hour recalls, food records, and food frequency questionnaires (FFQ). These methods have been validated for use in pregnancy[52-54] but their accuracy is still limited.[55] Once food intake is recorded it requires diet analysis programs to estimate nutrient intake, which can be a burdensome and expensive process. There is a need for research to develop and validate practical methods of assessing EI that are inexpensive, convenient, and can be incorporated into prenatal care.

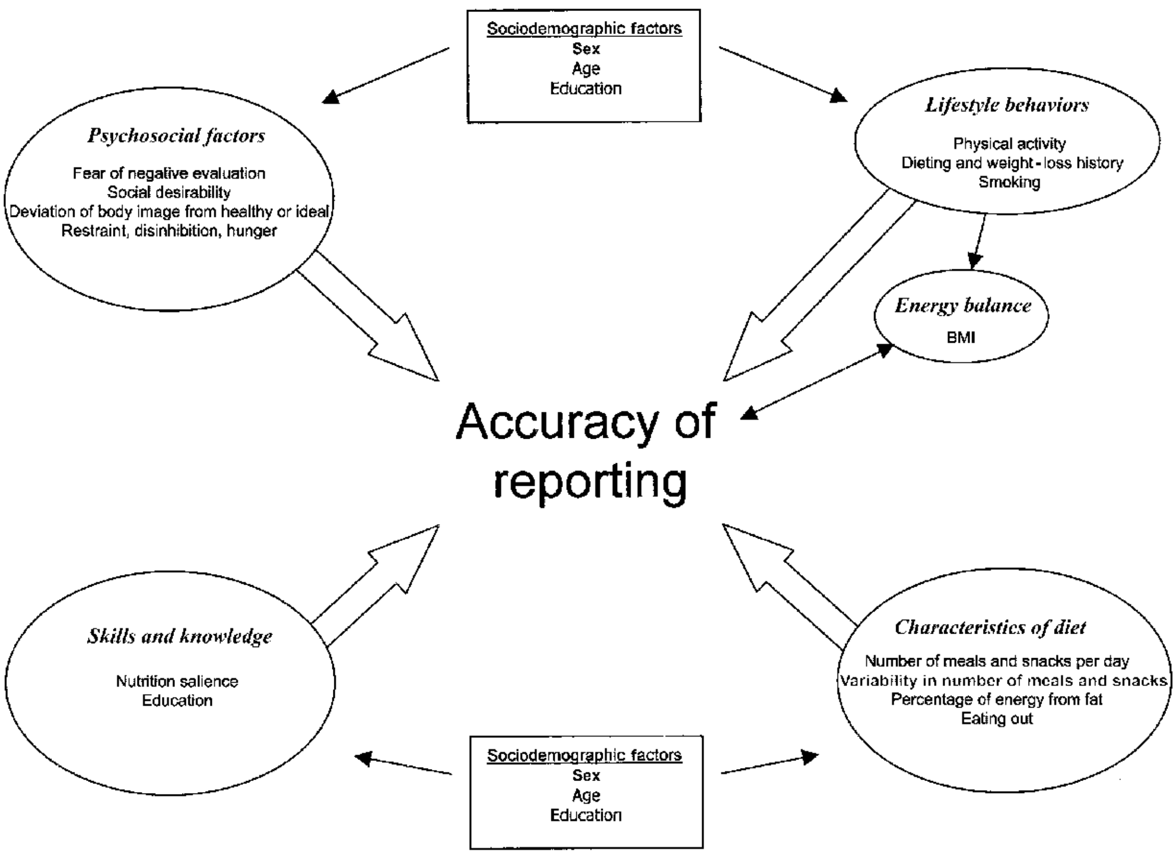
Mobile health (mHealth) technologies are a novel method of recording EI that are increasingly popular among healthcare providers and patients.[56] Using diet and weight-tracking mobile applications (apps) have produced clinically significant weight loss in randomized controlled trials of non-pregnant women.[57, 58] Though the nutrient-content of many of the foods within these apps have not been verified, the online diet tracking app, MyFitnessPal has been shown to provide estimates of EI that are comparable to 24-hour weighted food records and have nutrient profiles similar to United States Department of Agriculture (USDA) Food Composition Databases, which are also subject to errors and are unlikely to precisely represent the energy content of the foods and beverages actually consumed.[59-61] Apps such as MyFitnessPal are favored by patients for the monitoring of dietary intake when compared to traditional paper records,[62] and mobile tools such as this should be studied and improved upon as a method for self-monitoring EI in the clinical setting. Regardless, self-monitoring of EI is important to achieve optimal GWG and should be incorporated into prenatal care. The best method to use in a particular clinic will depend on the purposes of the data collection and practical considerations within the clinic. Self-monitoring of food intake and kcal goals are strategies that have effectively reduced excessive GWG,[63] yet there remain challenges to using these methods.

Energy Intake Under-Reporting

One of the greatest challenges in using these data is questionable accuracy of self-reported EI and widespread under-reporting (UR) of EI.[64-68] UR is determined by comparing self-reported EI (e.g., 24-hour recall, food record, FFQ) to estimated TEE or BMR using DLW, calorimetry, or predictive equations. [69-71] Using NHANES data, Murakami et. al. classified 27% of women and 37% of individuals with obesity as under-reporters of energy intake.[72] A recent review of the UR literature in the general adult population showed that under-reporters under-estimate kcal intake by 5-42% using DLW to determine estimated EI.[73] The degree of under-reporting was highly variable within studies using the same method, with 24-hour recalls having less variation and degree of UR compared to other methods.[73] Magnitude of EI UR ranged from 11-41% in traditional food records, 6-24% in technology-based food records, 8-30% in 24-hour recalls, and 5-42% in FFQs.[73] In sum, UR is widespread in the general population, especially in women with obesity, and there is no method that eliminates energy misreporting with all methods of self-reported EI showing variable reliability.

A variety of factors have been attributed to poor reporting of EI (Figure 1-1), including: sociodemographic factors (e.g., sex, age, education), lifestyle behaviors (e.g., physical activity, dieting history), psychosocial factors (e.g., social desirability), skills/knowledge (e.g., nutrition salience and education), and characteristics of the diet (e.g., eating away from home, number of meals/snacks). Because energy is in nearly every food and beverage, small errors add up, leading to errors larger in magnitude than for other nutrient and food components.[61]

Figure 1-1: Analytic Framework of Under-Reporting of Energy Intake in Adults



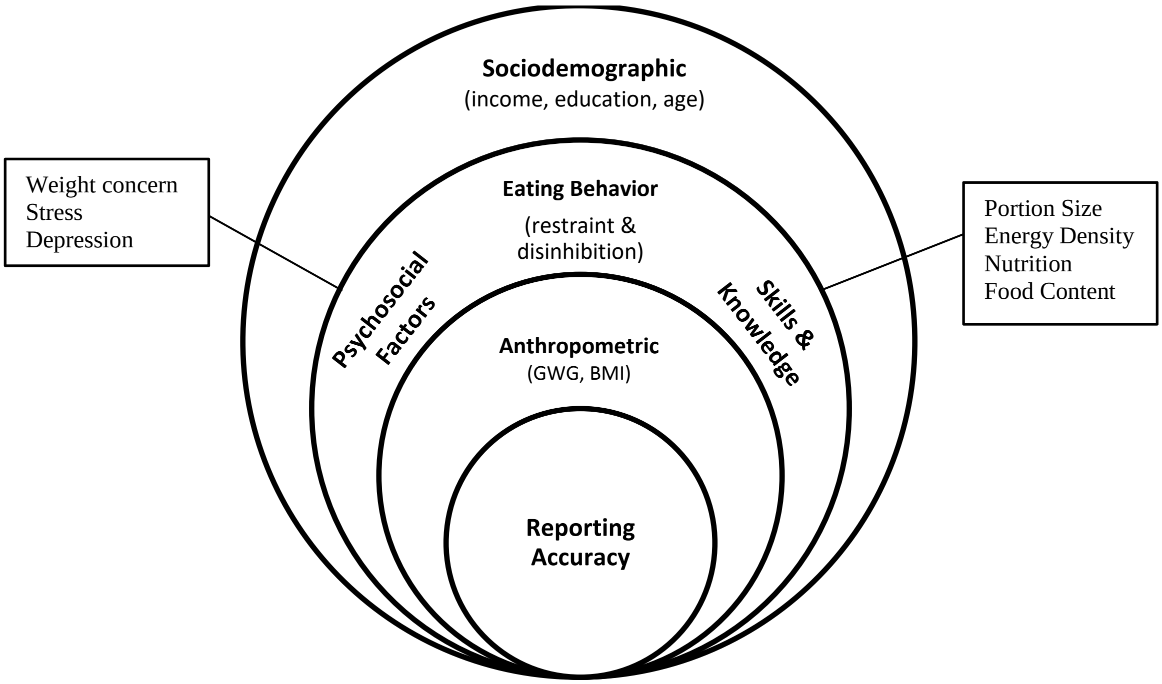
Tooze et al. Am J Clin Nutr, 2004[65]

Estimates of food and nutrient intake involve random error (e.g., inaccurate food databases, day-to-day variation in recall) and systematic error which can be either unintentional (e.g., incomplete recordkeeping, recording fatigue, memory disturbances, misrepresentation of portion size) or intentional (e.g., social desirability bias, embarrassment or denial of consumption, noncompliance due to inconvenience of reporting).[74-76] Characteristics of the diet and lack of skills/knowledge related to nutrition and portion sizes have been linked to UR, including reporting an incomplete or simplified version of what is consumed, or inaccurate portion size estimation.[68, 77-79] Certain types of foods (e.g., sauces, oils, and beverages) and eating occasions (e.g., snacks) are systematically under-reported.[80, 81]

UR is generally higher and occurs more often in females, older adults, people with less education, [64-67, 80, 82-90] and in people with higher BMI. Studies also show behavioral and psychosocial influences on UR, including social desirability, body image, dieting history, depression, anxiety, and fear of negative evaluation.[65, 67, 69, 82-84, 86, 87, 91-100] Eating behaviors, such as eating restraint and disinhibition,[65, 92, 94-96, 98, 100-103] have also been associated with UR in the general population. Dietary restraint and disinhibited eating (emotional and uncontrolled), as measured by the Three Factor Eating Questionnaire,[5, 104] are psychological constructs that assess behavioral control and attitudes toward food and eating. Cognitive dietary restraint is defined as a tendency to consciously restrict or control food intake, regardless of physiological signs of hunger and satiety. Uncontrolled eating is defined as a tendency to overeat relative to physiologic need and feeling of lack of control, whereas emotional eating is the tendency to overeat during depressed and melancholic states. Previous research has indicated that a high disinhibition score, by itself or combined with a low cognitive restraint score, is significantly correlated with a heavier body weight and obesity in the non-pregnant population and with GWG in pregnant women.[92, 105-110]

While the characteristics of under-reporters have been well documented in general populations; there are fewer studies investigating the characteristics of under-reporters in the prenatal period. Estimated prevalence of EI UR among pregnant women has ranged from 13-50%, with the highest prevalence among women with pre-pregnancy overweight and obesity.[111-117] Several studies have found that UR was associated with pre-pregnancy BMI.[113, 118] In the study by McGowan et. al., nearly half of pregnant women under-reported daily EI, and women who were classified as overweight or obese were 4.4 times more likely than normal weight women to be under reporters.[117] Only one study in Japan found a significant association between UR and GWG.[118] The only study to examine UR in a United States sample used a predictive model to calculate EI and self-reported EI was determined using FFQ. They found that UR at 24-29 weeks gestation was significantly associated with birth weight, gestational diabetes, higher income, and education.[119] Moran et al. examined UR in 945 pregnant women with overweight and obesity participating in the LIMIT randomized trial in Australia. They found the prevalence of energy UR at 36 weeks was higher than at 14 weeks gestation. BMI at study entry, socioeconomic status, dieting behavior, and risk of depression were independent predictors of EI UR.[114] There is strong evidence that psychological factors such as social desirability, eating restraint, and history of dieting are associated with UR, but these studies are lacking in pregnant women.[64, 75, 102, 114, 120-123] Characteristics which may be associated with UR during pregnancy are conceptualized in Figure 1-2, which was adapted for this purpose from Tooze et al.[65]

Figure 1-2: Conceptual Model of Predictors of Under-Reporting Among Pregnant Women



Adapted from: Tooze et al. Am J Clin Nutr 2004

Obtaining accurate objective measurement of energy expenditure throughout pregnancy can be difficult. Indirect calorimetry and DLW are burdensome to obtain across pregnancy, energy cost of weight gain is often overestimated by excessive extracellular fluid expansion, and toward the end of pregnancy rate of energy deposition tends to decrease.[2] The Goldberg method which calculates the ratio of reported EI to estimated basal metabolic rate [(BMR) EI:BMR] and assumes a constant physical activity level, is commonly used to categorize individuals into categories of plausible or implausible reporters.[124, 125] Therefore, the current understanding of EI UR in pregnant women is based on sparse, cross-sectional data with a lack of research in American samples.[119] Further, the majority of these studies calculate and report the prevalence of under-reporters using a variety of methods to estimate reporting accuracy (e.g., threshold cutoffs) for the sole purpose of excluding “implausible” reporters from analyses of interest. In sum, the estimated magnitude of misreporting in pregnant women is unknown.

Aims & Hypotheses

The overall objective of this project was to examine the trends, magnitude, and associated characteristics of reporting accuracy using intensive longitudinal data in a sample of pregnant women with overweight and obesity. The first aim was to describe the trends and magnitude of self-reported EI, back-calculated EI, and reporting accuracy of EI. The second aim was to examine potential group-level differences in reporting accuracy by time (i.e., gestational age), anthropometric measures (i.e., pre-pregnancy BMI, GWG), treatment group assignment (i.e., intervention or control), demographics (i.e., maternal age, education, parity, household income), perceived stress, eating behaviors (i.e., dietary restraint, uncontrolled eating, and emotional overeating), and infant birth weight. Based on previous literature in pregnant and non-pregnant adults, we hypothesized that EI UR would be prevalent and that the following characteristics would be positively associated with UR: gestational age, pre-pregnancy BMI, GWG, intervention treatment group assignment, perceived stress, dietary restraint, uncontrolled eating, emotional eating, and infant birth weight. This study adds to the current body of literature by using a predictive equation to estimate EI and evaluate the accuracy of self-reported EI using intensive longitudinal data in a sample of pregnant women with overweight and obesity in the United States.

Chapter 2

Methods and Results

Study Subjects

This is a secondary analysis using a convenience sample of pregnant women from the *Healthy Mom Zone Study*, a randomized controlled feasibility trial testing an individually tailored, adaptive intervention for managing GWG in pregnant women (ClinicalTrials.gov identifier #NCT03945266).[126] This was an optimization trial within the multiphase optimization strategy (MOST) framework and full details of the design of the HMZ intervention have been published previously.[127] Study participants were recruited from 2016 to 2017 through referrals by local obstetricians at the first prenatal appointment. Inclusion criteria were 8-12 weeks gestation and within the BMI range of 24.5 and 45 (BMI=40-45 with physician consent) at time of enrollment. Including individuals with BMI ≥ 24.5 is clinically relevant as lower cutoffs are commonly used in clinical screening.[128] Exclusion criteria included pre-existing diabetes and other conditions known to impact fetal growth or GWG, severe allergies or dietary restrictions, contraindications to prenatal physical activity, and not residing in the area for duration of the study. Thirty-one participants were randomized to the intervention or a standard of care control group. All participants received usual prenatal health care and the intervention offered nutrition and physical activity guidance beyond what is offered in standard care. Participants were followed from study enrollment to approximately 36 weeks gestation. This analysis includes 25 women with complete data (one participant was missing all EI data, one participant dropped out of the study, one participant had BMI below 24.5, and three participants had a miscarriage in the first trimester). The study was approved by the Pennsylvania State

University Institutional Review Board and all participants provided written informed consent prior to participation.

Measures

Demographic data and pre-pregnancy height and weight (self-reported) was collected from participants at the baseline visit using questionnaires. Height and weight at study entry were obtained by trained nurses. Gestational age was defined as the first day of the last menstrual cycle. Participants were instructed to weigh themselves daily from home using a Fitbit Aria Wi-Fi Smart Scale (Fitbit Inc., San Francisco, CA, USA) throughout the study. Final maternal weights within 10 days of delivery were abstracted from medical records (*n=22*) or using Aria Wi-Fi Smart Scale data if medical record data was not available (*n=1*). GWG was calculated for participants with a final maternal weight (*n=23*) by subtracting the last available weight of the participant (within 10 days of delivery) from self-reported pre-pregnancy weight. Infant birth weight was extracted from the medical record.

At study enrollment and every four weeks thereafter, women completed the 10-Item Perceived Stress Scale (PSS)[4] (Appendix A) and the 21-Item Three Factor Eating Questionnaire (TFEQ)[5] (Appendix B) via online surveys through Research Electronic Database Capture (REDCap).[129] The TFEQ, which has a four point response scale ranging from (1) definitely true to (4) definitely false, measures three subscales: cognitive restraint (e.g., “I consciously hold back on how much I eat at meals to keep from gaining weight.”), uncontrolled eating (e.g., “Sometimes when I start eating, I just can’t seem to stop.”), and emotional eating (e.g., “I start to eat when I feel anxious.”). Scores for each subscale were calculated by averaging respective items. Internal consistencies ranged from acceptable to excellent with a standardized Cronbach alpha of 0.66 for the restrained eating subscale, 0.85 for the uncontrolled eating subscale, and 0.91 for the emotional eating subscale.

Participant self-reported EI was obtained using a smart phone app (MyFitnessPal), which was used for the purpose of participant self-monitoring of food intake during the study. Participants were trained on use of the app and instructed to record all foods and drinks consumed over 24-hours on three days per week (two weekdays and one weekend day) for the duration of the study. RMR was estimated daily using the quadratic formula: $RMR=0.1976(\text{weight in kg})^2 - 13.424(\text{weight in kg}) + 1457.6$ to account for an assumed increase in RMR across gestation.[8, 40] Measurements of physical activity were assessed at baseline and throughout the study using data from wrist-worn actigraphy (Jawbone UP 4, Jawbone Inc., San Francisco, CA, USA) to extract daily activity time and estimated energy expenditure data.[130]

Back-calculated EI was determined daily for each participant using a predictive equation with the inputs of daily weights measured from home using Aria Wi-Fi Scale, estimated RMR, and kcal expended from physical activity assessed with the Jawbone activity monitor (Appendix D).[8, 9] To calculate reporting accuracy, self-reported and back-calculated EI data were matched by date. Unmatched data were excluded from analyses. A reporting accuracy variable was created using the following equation: *Reporting accuracy = [(self-reported EI – back-calculated EI / back-calculated EI)] * 100%*.[121, 131] This continuous variable represents reporting accuracy of EI or the discrepancy between self-reported and back-calculated kcal. Positive values indicate over-reporting, and negative values indicate EI UR.

Statistical Analysis

Statistical analysis was performed in SAS version 9.4 (SAS Institute Inc., Cary, NC). Sample means were calculated for continuous demographic variables (pre-pregnancy BMI, GWG, and age). Frequencies and percentages were calculated for categorical demographic variables (pre-pregnancy BMI category, race, ethnicity, marital status, employment status, education, income, gravidity, and parity). Means were also determined for self-reported EI, back-calculated EI, and daily reporting accuracy.

Linear mixed effects models, which accommodate multilevel data structures and unevenly spaced longitudinal data,[132] were used to test whether reporting accuracy was associated with the following predictors: gestational age, anthropometric measures (i.e., pre-pregnancy BMI, GWG), treatment group assignment (i.e., intervention or control), demographics (i.e., maternal age, education, parity, household income), perceived stress, eating behaviors (i.e., dietary restraint, uncontrolled eating, and emotional overeating), and infant birth weight. Using multilevel modeling (PROC MIXED), reporting accuracy was tested against each predictor in an individual two-level model in which time points were nested within individual. Each model used the restricted maximum likelihood and compound symmetry covariance structure (CS). Determination of model fit was based on several criteria including model convergence, a positive definite G matrix, and Akaike information criteria. Intraclass correlation coefficients (ICCs) were calculated as the ratio of between-subjects variance to total variance. The alpha level was set at 0.05.

Results: Demographic Data

Participant demographics can be found in Table 2-1. Age of women at study entry ranged from 24-37 years of age (*M*=30.7±3.0). Participants were predominantly overweight or obese with a mean pre-pregnancy BMI of 31.5±6.9. Forty percent of participants reported pre-pregnancy obesity (BMI>30 kg/m^2) and 60% did not report obesity prior to pregnancy. The majority (92%) of participants were married and pregnant with their first baby (64% no prior live births, 36% had 1 previous live birth). Participants were, on average, well-educated and fairly affluent. Moreover, the majority (84%) of women were employed full-time. Mean GWG was 24.1±15.5 pounds (lb.) [Intervention: *M*=23.9±17.6 lb., Control: *M*=24.3±14.1 lb.].

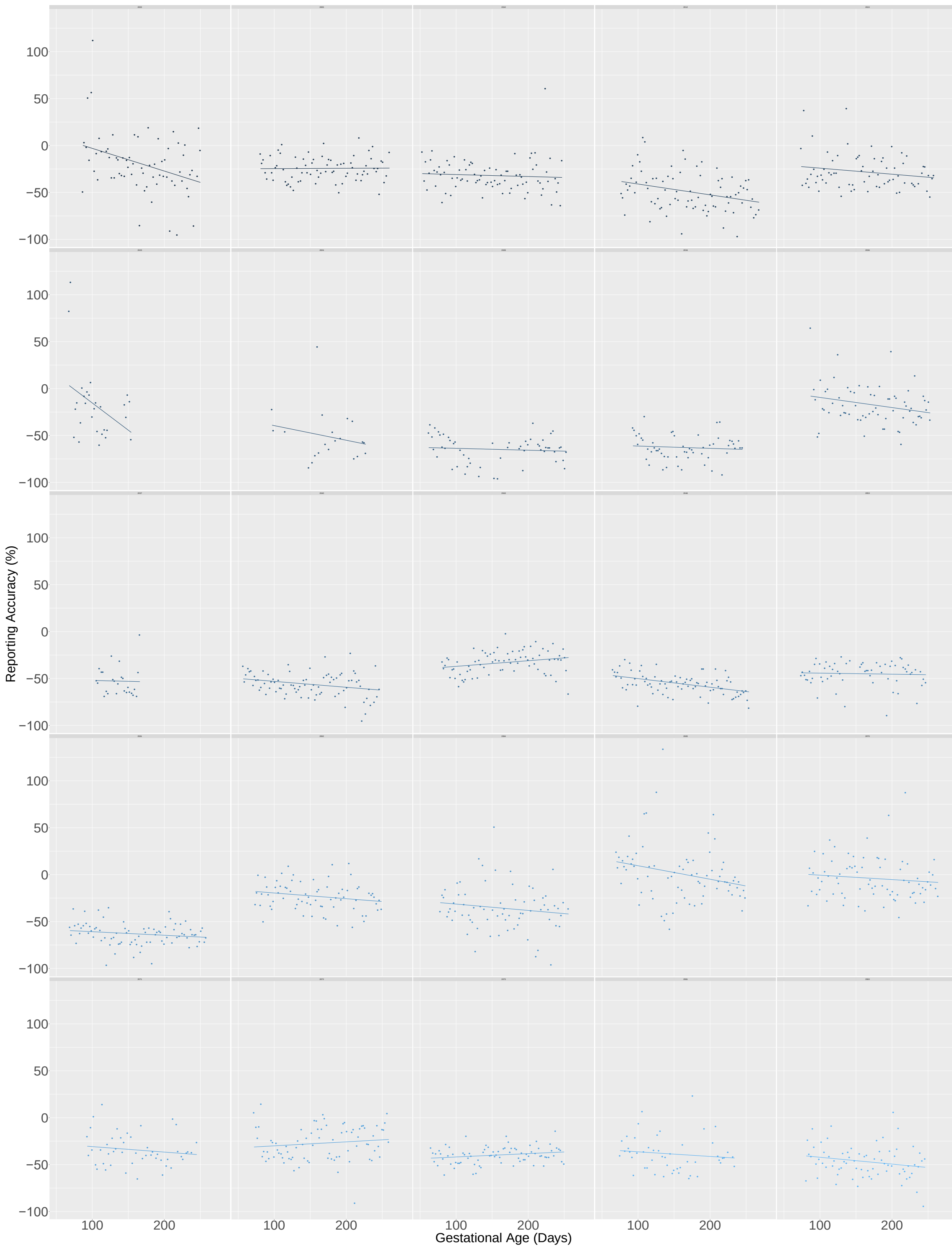
Energy Intake Under-Reporting

EI UR was pervasive in this sample with mean of all reporting accuracy observations of -36%±26 (range: -97% to 134%, representing an approximately 1044 kcal underestimation). Ninety-seven percent of reporting accuracy observations were negative values, indicating UR. There was considerable variation both between and within participants (Figure 2-1). The ICC indicates that about 89% of the variation in the UR variable was within-person, rather than between-person.

Table 2-1: Baseline Descriptive Characteristics	
Characteristic	Overall sample (*n=25*)
Maternal Age, years	30.7±3.0
Preconception BMI, kg/m^2	31.5±6.9
% BMI = 24.5-29.9	15 (60%)
% Obese (BMI ≥ 30)	10 (40%)
Gestational Weight Gain, lb.	24.1±15.5
Race	
White	24 (96%)
Asian	1 (4%)
Ethnicity	
Non-Hispanic	25 (100%)
Marital Status	
Divorced	1 (4%)
Married	23 (92%)
Single	1 (4%)
Maternal Education	
High School	1 (4%)
College	13 (52%)
Graduate prof	11 (44%)
Gravidity	
1	12 (48%)
2	10 (40%)
3	2 (8%)
No response	1 (4%)
Parity	
0	16 (64%)
1	9 (36%)
Employment	
Full-Time	21 (84%)
Part-Time	2 (8%)
Self-Employed	1 (4%)
Other	1 (4%)
Income	
<$20,000	1 (4%)
$20,000-$40,000	4 (16%)
$40,000-100,000	11 (44%)
≥$100,000	9 (36%)

*Continuous variables (maternal age and BMI: body mass index) data presented as mean plus/minus SD.
**Categorical variable (gravidity, parity, education and income) data presented as count (percentage).

Figure 2-1: Variability of Between- and Within-Subject Reporting Accuracy Across Gestation

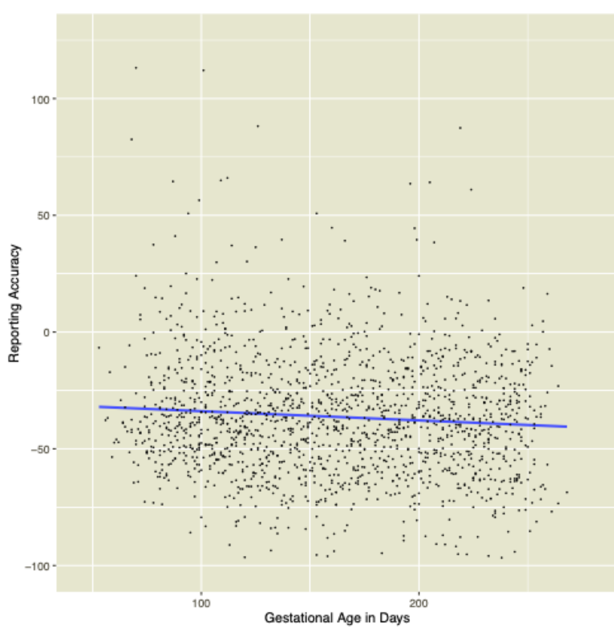


*Each panel represents a single participant

Change in Reporting Accuracy Throughout Pregnancy

Linear mixed modelling shows a main effect of gestational age (in days) as a continuous variable on reporting accuracy such that reporting accuracy increases as pregnancy progresses (p<0.001) (Table 2-2). In a separate model, gestational age was examined as a categorical variable and there was a main effect of trimester on reporting accuracy (p<0.001), whereas reporting accuracy in the first trimester (LS mean -28%±6) was significantly lower than in the second (-33%±5) and third trimesters (-39±5%) (p<0.001) (Figure 2-3). Differences in self-reported and back-calculated EI by trimester were each examined in separate models. Mean self-reported kcal intake did not significantly differ between the first (M=1685±65), second (M=1670±61), and third trimesters (M=1676±62). Meanwhile, as expected, back-calculated EI increased by an average of 243 kcal from the first (M=2627±129) to the second trimester (M=2870±127; p<0.001) and 107 kcal from the second to the third trimester (M=2977±128; p<0.001) (Figure 2-4, Table 2-3).

Figure 2-2: Reporting Accuracy Across Gestation



* Trend line shown in blue

Figure 2-3: Self-Reported and Back-Calculated Energy Intake by Trimester

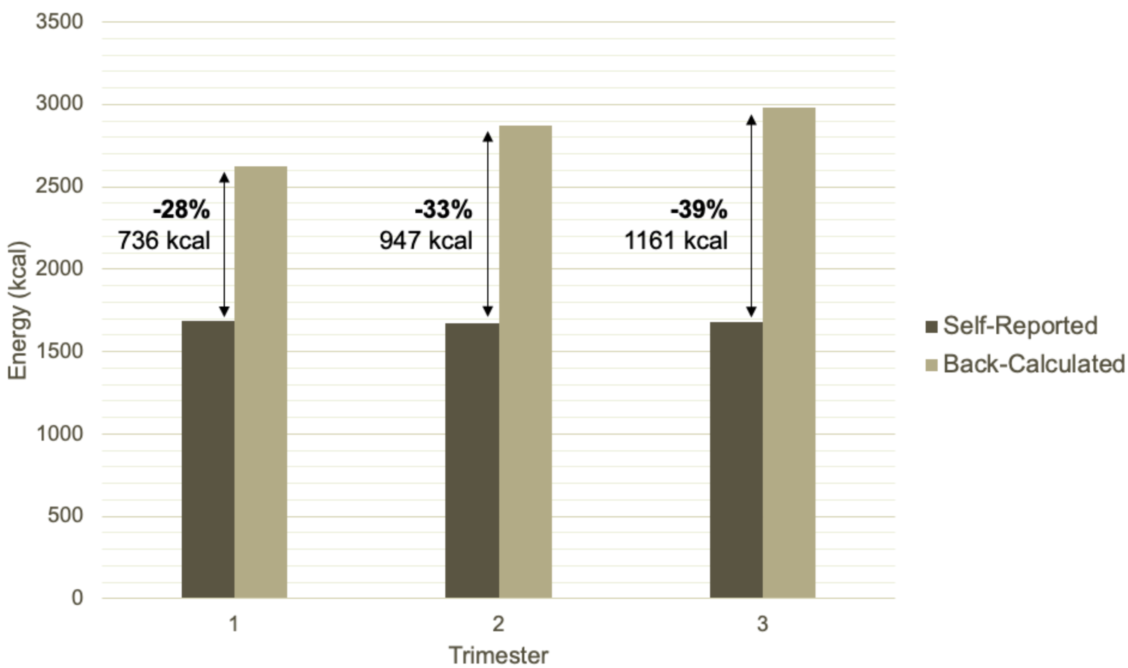
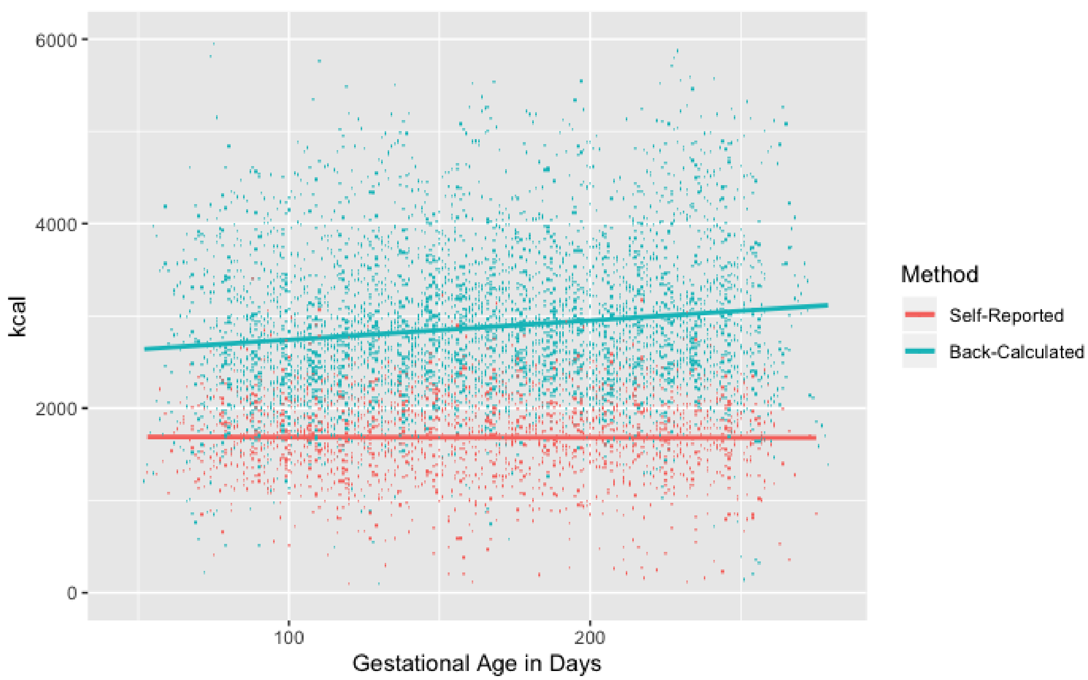


Figure 2-4: Back-Calculated and Self-Reported Energy Intake Across Gestation

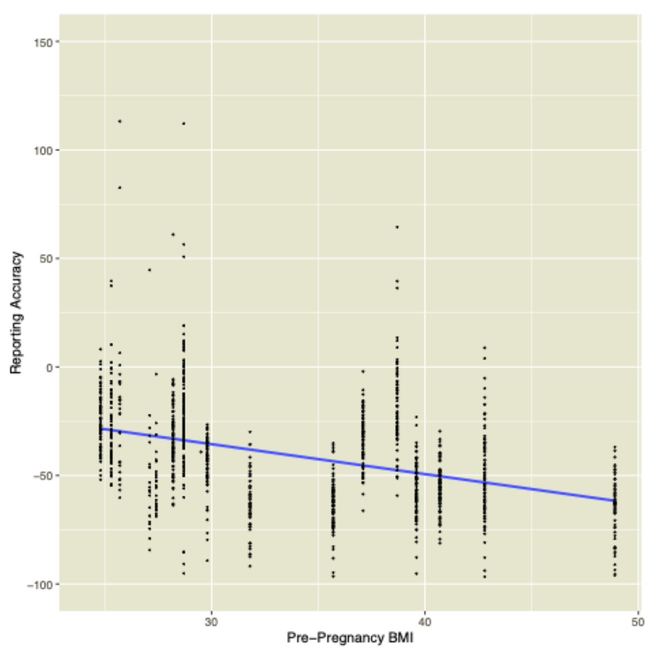


*Trend lines of the data points are shown for the purpose of visualization of trends. Back-calculated energy intake (blue-green) trended up, compared with self-reported energy intake (orange), which stayed stable.

Predictors of Under-Reporting

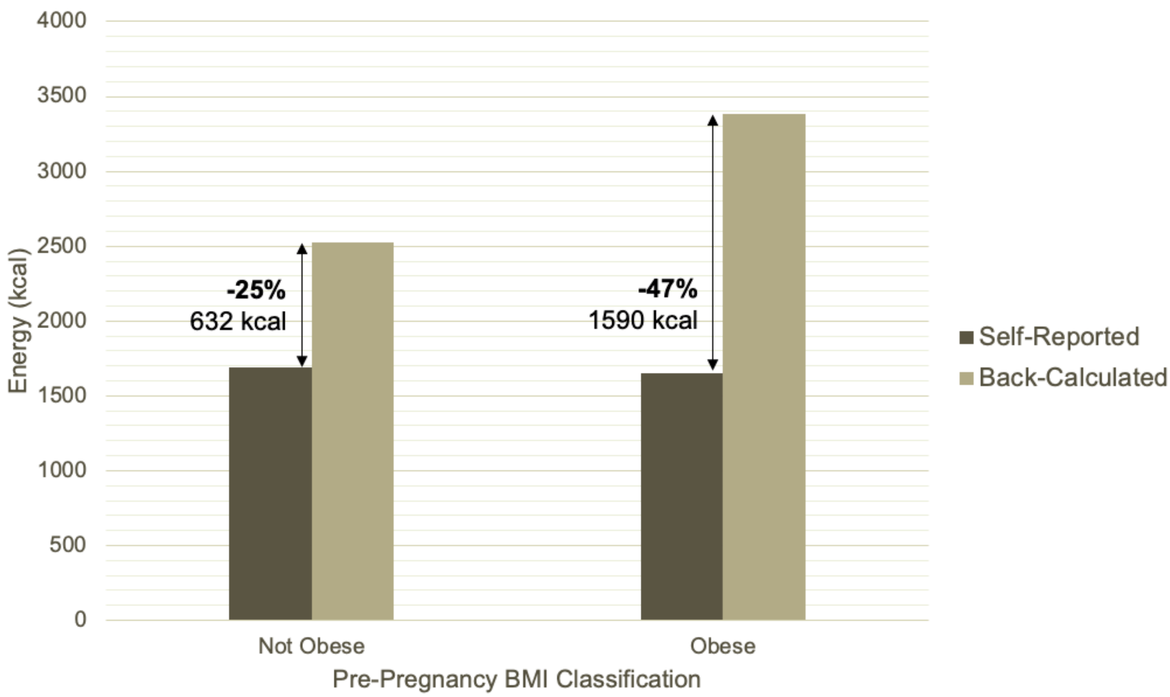
Linear mixed modelling results show a main effect of pre-pregnancy BMI as a continuous variable on reporting accuracy such that a higher pre-pregnancy BMI was associated with lower reporting accuracy (p<0.01) (Figure 2-5, Table 2-2). In a separate model, pre-pregnancy BMI was examined as a categorical variable and there was a significant main effect of weight status on reporting accuracy between participants with obesity (LS mean -47%±7) and without obesity (LS mean -25%±6) (p<0.05) (Figure 2-6). In two separate models, self-reported and back-calculated EI by pre-pregnancy weight status were examined. Mean self-reported EI did not significantly differ between women with pre-pregnancy obesity (LS mean 1689±80) and women without pre-pregnancy obesity (LS mean 1651±98). Back-calculated EI was significantly higher, on average, in women with pre-pregnancy obesity (LS mean 3384±151) compared to women without obesity (LS mean 2526±123; p<0.05) (Table 2-3).

Figure 2-5: Reporting Accuracy by Pre-Pregnancy BMI



*Trend line shown in blue

Figure 2-6: Self-Reported and Back-Calculated Energy Intake by Pre-Pregnancy BMI



Next, we tested the independent effects of perceived stress and eating behaviors on reporting accuracy. Eating behaviors were examined monthly and stress was examined weekly as time-varying predictors. Mean baseline value for perceived stress was 30±12 (range=10-55) and perceived stress increased significantly across gestation (<0.001). Mean baseline values were 2.79±0.47 for cognitive restraint (range = 2.00-3.67), 2.15±0.39 for uncontrolled eating (range = 1.33-3.00), and 2.14±0.59 for emotional eating (range = 1.00-3.33). Cognitive restraint significantly decreased across gestation ($p<0.001$), as did uncontrolled eating ($p<0.01$). Emotional eating did not significantly change across gestation. There was a significant main effect of total perceived stress on reporting accuracy, such that higher perceived stress was associated with lower reporting accuracy i.e., higher UR ($p<0.05$) (Table 2-2). Uncontrolled eating ($p<0.05$) was also negatively associated with reporting accuracy (i.e., positive relationship with UR). A similar trend emerged for cognitive restraint and emotional eating, but did not reach statistical significance. There were no significant relationships detected between GWG, treatment group, birth weight, maternal age, parity, income, or education and the extent of reporting accuracy. All variables except birthweight trended in the direction we had hypothesized (Table 2-2).

Table 2-2: Multilevel Model Parameter Estimates of Independent Predictors of Maternal Reporting Accuracy, each in a separate model (*n=25*)

Term	**Estimate**	**Standard Error**	***p-value***
Gestational Age (in days, continuous)	-0.05245	0.008971	**<0.0001**
Gestational Age (by trimester, categorical)			
Intercept	-39.0283	3.6650	**<0.0001**
Trimester (1)	8.0969	1.5065	
Trimester (2)	1.6986	1.0609	
Trimester (3)	0		
Pre-Pregnancy BMI (continuous)	-1.4014	0.4443	**0.0057**
Pre-Pregnancy BMI (categorical)			
Intercept	-47.5543	5.0196	
BMI = 24.5-29.9	17.8271	6.4866	**0.0114**
BMI ≥ 30	0		
Perceived Stress	-0.3009	0.1466	**0.0403**
Emotional Eating (TFEQ)	-1.7743	1.0421	0.1001
Cognitive Restraint (TFEQ)	-5.3817	2.6504	0.0523
Uncontrolled Eating (TFEQ)	-1.8853	0.8816	**0.0417**
GWG (in lb., continuous) (*n=23*)	-0.2500	0.3421	0.4734
GWG (meeting vs. exceeding IOM guidelines, categorical)			
Intercept	-27.6890	7.54293	
Exceeding	-12.2186	10.5818	0.2618
Not Exceeding	0		
Treatment group			
Intercept	-31.4899	6.6494	
Control	-5.3725	9.6311	0.5823
Intervention	0		
Birth Weight (g)	0.004412	0.008001	0.5866
Maternal Age (yrs.)	1.3586	1.6360	0.4148
Parity			
Intercept	-25.8394	7.7735	
Parity (0)	-12.9252	9.7569	0.1983
Parity (1)	0		
Household Income (yearly)			
Intercept	-31.0597	8.0424	0.5263
\$10000-\$20000	-33.8023	25.5669	
\$20000-\$40000	5.0010	14.6402	
\$40000-100000	-5.4857	10.8318	
>\$100000	0		
Maternal Education			
Intercept	-0.6490	24.2892	0.0958
College	-42.1062	25.0615	
Graduate School	-25.5884	25.2026	
High School	0		

Table 2-3. Self-Reported and Back-Calculated Energy Intake for Predictor Variables, reported as LS mean ± standard deviation			
	Self-reported EI, kcal/d	Back-Calculated EI, kcal/d	% Under-reporting (SD)
Overall *(n=25)*	1710±466	2900±812	36% (±26)
Gestational Age (Trimester)			
First Trimester	1685±65	2627±129	28% (±6)
Second Trimester	1670±61	2870±127	33% (±5)
Third Trimester	1676±62	2977±128	39% (±5)
Pre-Pregnancy BMI			
Not Obese *(n=15)*	1689±80	2526±123	25% (±6)
Obese *(n=10)*	1651±98	3384±151	47% (±7)
Total GWG Classified by IOM Guidelines			
Not Exceeding *(n=11)*	1763±93	2750±184	28% (±7)
Exceeding *(n=12)*	1552±94	2937±184	40% (±8)
Treatment Group Assignment			
Intervention *(n=13)*	1674±89	2812±179	31% (±7)
Control *(n=12)*	1673±89	2931±186	37% (±7)
Parity			
0 *(n=16)*	1637±76	2913±161	39% (±6)
1 *(n=9)*	1739±102	2790±215	26% (±8)
Annual Household Income			
$10000-$20000 (n=1)	1465±316	4342±590	65% (±24)
$20000-$40000 *(n=4)*	1691±158	2693±295	26% (±12)
$40000-$100000 *(n=11)*	1630±95	2796±178	37% (±7)
>$100000 *(n=9)*	1742±105	2873±197	31% (±8)

Chapter 3

Discussion

Misreporting in self-reported dietary records is a common and complex phenomenon. Adequate EI and energy balance are essential during pregnancy for optimizing maternal and fetal outcomes, including GWG. Inaccurate self-reported EI may result in difficulty for health professionals in providing nutrition counselling to pregnant patients. Yet, UR during pregnancy is poorly understood due to scant literature examining reporting accuracy during this life stage.

The overall objective of this project was to examine the trends, magnitude, and associated characteristics of energy reporting accuracy using intensive longitudinal data in a sample of pregnant women with overweight and obesity. Based on previous literature in pregnant and non-pregnant adults, we hypothesized that EI UR would be prevalent and that the following characteristics would be positively associated with UR: gestational age, pre-pregnancy BMI, GWG, control group assignment, perceived stress, dietary restraint, uncontrolled eating, emotional eating, and infant birth weight. This paper adds to the current body of literature by using intensive longitudinal data to evaluate reporting accuracy dynamically across pregnancy.

To address this objective, we conducted a post hoc analysis using secondary data from the *Healthy Mom Zone Study*, a randomized controlled feasibility trial which followed women with overweight and obesity from early pregnancy (8-12 weeks) to approximately 36 weeks gestation. Validated questionnaires were completed to assess perceived stress weekly and eating behaviors monthly. MHealth technology was used to measure daily weight (Wi-Fi Smart Scale) and physical activity (activity monitor), and tri-weekly self-reported EI (smartphone app). Back-calculated EI was calculated using a predictive equation with objective measures of weight and physical activity. Linear fixed effects modelling was used to test whether each predictor was associated with reporting accuracy.

Results suggest that EI UR is pervasive during pregnancy. Women in this sample under-reported EI by an average magnitude of 36%. These data also allowed us to examine UR by trimester, revealing a longitudinal increase with gestational age. Average EI UR increased throughout pregnancy from 28% in the first trimester, to 33% in the second trimester, and 39% in the third trimester. This study adds to the growing body of literature that show UR throughout pregnancy is associated with pre-pregnancy BMI.[113-115, 117] We also report perceived stress and uncontrolled eating as predictors of UR during pregnancy. We did not detect a significant effect of the following predictors: parity, age, education, income, total GWG, birth weight, restrained eating, emotional eating, or treatment group. Together these data suggest that UR during pregnancy has a multifaceted etiology and as pregnancy progresses UR may become more severe, despite increasing energy requirements.

The increase in UR over gestation appeared to be driven by an average increase in EI while reported kcal stayed stable. In other words, women were eating 350 more kcal on average in the third, compared with the first trimester, but reported they were eating the same amount, on average ~1670 kcal per day. Our findings are consistent with those of Moran et al. who found that prevalence of EI UR was higher at 36-weeks gestation than at study entry (early pregnancy) in a group of 945 Australian pregnant women with overweight or obesity.[114] This trend may indicate that self-reporting of EI is a habitual behavior. Pregnant women may perceive their EI to remain relatively stable, despite increases in EI. Another explanation is that women may tire of logging intake and thus reporting may become less accurate over time. Retention in health and fitness tracking tends to decrease rapidly over time.[133-135] Food logging and self-monitoring can be burdensome and time-consuming, and can result in noncompliance and underestimation as usual dietary intakes may be altered to avoid the inconvenience of recording,[136] potentially explaining the decrease in reporting accuracy across pregnancy.

Pregnant women have many unique characteristics which may contribute to misreporting including potential increases in psychological distress and body image concern, pregnancy-related health conditions and outcomes (e.g., preeclampsia, gestational diabetes, cesarean section delivery, infant birth weight), and GWG.[122, 123] We also found that stress and uncontrolled eating were significant positive predictors of UR during pregnancy, while cognitive restraint and uncontrolled eating exhibited similar trends. This is the first study, that we are aware of, to examine these associations in pregnant women. In the general population, both restraint and disinhibition have been associated with UR.[75] It is thought that disinhibition may affect a person's ability or motivation to accurately report intake and uncontrolled eating may result in embarrassment or shame, especially when paired with high social desirability.[99] Restrained eating is consistently associated with lower energy reporting, especially of certain nutrients such as dietary fat.[137] Restrained eaters may be hyper-aware of a perceived "normal" intake and therefore report EI towards that perceived norm.[99] Additionally, some individuals exhibit high restraint and disinhibition scores simultaneously, leading to cycles of binging and restricting,[138, 139] and so perhaps individuals with this phenotype also have high risk of UR. Moran reports that the number of times women reported limiting food intake in order to lose weight and self-reported dissatisfaction with weight and body shape were independent predictors of UR at 36-weeks' gestation.[114] Additionally, increased stress (measured with C-Reactive Protein and the PSS) has been positively associated with UR in postmenopausal women with overweight and obesity.[140]

Incomplete record-keeping is also a likely contributor to misreporting in this sample. Prior research in non-pregnant adults has found that certain types of foods, especially grains/starches, sauces, oils, and beverages are systematically under-reported.[81] Another study found that UR is more related to the eating occasion (i.e., snacks rather than main meals) than the type of foods consumed.[80] Based on single 24-hour recall data from NHANES, it has been estimated that snacks, desserts and beverages contribute 13.6-25.0%[141, 142] of reported calorie intake and snacking has been increasing in American women over the last 4 decades.[143] Common advice for pregnant women is to snack more often to meet additional calorie needs for pregnancy, thus higher snack and beverage intake may contribute to a greater extent of UR.[81]

In contrast to previous studies, we found no significant association of UR with the following variables: age, education, income, parity, gestational weight gain, treatment group, or birth weight. Prior studies with pregnant women have found positive associations between UR and infant birth weight, income, education, socioeconomic status, and younger age.[114, 117, 119] It is important to consider that these studies were cross-sectional while these findings suggest that UR may change throughout pregnancy. Another potential explanation for the lack of association reported in our study may be that unlike other studies, we had a small and homogenous sample, which may reduce our ability to detect significant relationships. Additionally, population differences between Australia and the US may explain some of these discrepancies. Surprisingly, no relationship was found between UR and treatment group or GWG. There are several possible explanations for these findings, including that the intervention may have had an effect in later but not early pregnancy. In regards to GWG, energy expenditure through physical activity or RMR may have had a greater influence on GWG in this sample, or perhaps women who under-reported were also more likely to decrease EI simultaneously. There was also notable variability both between- and within-person, though most of the variation was within-person. Future studies should explore additional factors that may influence within-person variation in reporting accuracy which may include day of the week (e.g., weekend vs. weekday), types of foods (e.g., snacks, beverages), selective misreporting of nutrients (e.g., fat or carbohydrates), frequency of consumption (e.g., unplanned eating, snacking), and other factors which may vary from day to day within the same person. Further research should continue to explore other characteristics that are associated with under-reporting across gestation.

Though not a main focus of this analysis, it is worth noting that in the present sample, daily back-calculated EI increased by an average of 243 kcal from the first to second trimester and 350 kcal total throughout pregnancy. The IOM guidelines for EER recommends that all pregnant women require an additional 340 kcal daily in the second trimester and 452 kcal daily in the third trimester.[33] Prior research indicates that the IOM kcal guidelines are likely too high for women with overweight and obesity[144, 145] and, combined with UR, this may exacerbate excess EI contributing to GWG. The reasons why more women with overweight and obesity are more likely to experience excessive GWG has yet to be determined, although women with overweight and obesity have lower GWG goals (than women with normal weight or underweight). Additionally, women with obesity may not require increased caloric intake during pregnancy,[144] contrary to current recommendations. These preliminary findings highlight the need for additional research on adequate energy needs for women with elevated BMI to meet recommended GWG.

While MyFitnessPal is not a validated method for collecting EI, it was chosen due to its usability and acceptability among participants as a tool for self-monitoring. The average magnitude of UR (36%) observed in this sample is comparable to the 24-33% that has been seen using DLW against FFQs in healthy, non-pregnant adults, and about three times higher than the 12-13% under-reporting comparing DLW to repeated 24-hour recalls.[89] Although we saw higher UR in this sample, this was expected in a sample of women with overweight and obesity. It is also important to consider that MyFitnessPal may over-estimate EI UR. MyFitnessPal and other mobile tracking tools are favored by participants for self-monitoring EI when compared to traditional paper records.[62] Rather than discarding mHealth EI data as unusable, apps such as this should be continually studied and improved upon as a feasible and cost-effective method for self-monitoring EI.

With known deficits in self-reported EI, the predictive equation we developed using weight changes, physical activity (using wrist-worn actigraphy), and RMR to back-calculate kcal may provide estimates of intake that are more reliable. As the use of mHealth technology for self-monitoring continues to increase, health care professionals may be able to use predictive equations to estimate EI and provide individualized counselling. Mathematical models that predict GWG and EI could provide a clinical tool for setting precise kcal goals and providing continuous objective feedback throughout pregnancy. This novel way of determining UR has practical implications of utilizing GWG, self-reported EI, and kcal recommendations in prenatal counselling. This method may give clinicians an alternative to self-reported EI to more accurately predict a patient's EI and guide women in making choices to promote energy balance and appropriate GWG.

Pregnant women need accurate information and clinical guidance on GWG recommendations, including nutrition education. National recommendations should include appropriate and specific information about energy needs for women with varying BMIs and training for clinicians must be made available to increase their confidence in communicating nutrition information to patients. Dietary tracking and monitoring, despite limitations in estimating EI, are still important tools for assessing diet quality and should continue to be used in the clinical setting. However, in order for clinicians to use self-reported EI appropriately they must know not to take these values at “face-value”. Clinicians should be aware of potential predictors of EI UR (e.g., elevated pre-pregnancy BMI, eating behaviors, perceived stress, advanced GA) to provide more tailored guidance for women who may be at higher risk of misreporting.[75, 146, 147] Additionally, clinicians can incorporate methods to improve reporting accuracy into practice, including the use of the multiple-pass 24-h recalls or “real-time” logging methods such as mobile apps[148] and training for at-risk patients on food-portion estimation skills using tools (e.g., food scales and measuring spoons/cups).[149] Finally, our findings may indicate that holistic treatment approaches, such as stress-management, may also have downstream impacts on UR in patients. Though, because this is an observational study, causality cannot be proved. Future research might test whether stress management interventions improve UR, using a randomized controlled trial study design.

Strengths and Limitations

Strengths of this study include intensive longitudinal data collected throughout pregnancy, using reporting accuracy as a continuous variable rather than with threshold cutoffs, as well as the use of measured physical activity to determine back-calculated EI. Limitations to this research include reliance on self-reported pre-pregnancy height and weight, which can lead to under-estimated BMI.[150, 151] Performing multiple statistical tests increases the risk of type I error, though careful selection of variables based on prior, evidence-based, findings was used to help reduce the Type I error rate. The small sample size precludes the ability to make assumptions at a population level. Lastly, the target population was a homogenous sample of women who were predominantly non-Hispanic, white, married, and middle to upper class, thus limiting the generalizability of the study findings to other populations of pregnant women. Analyses are exploratory in nature and do not propose any concrete associations. Future research may extend on these findings with a larger, more diverse sample. Research should also continue to explore interventions that promote reporting accuracy during pregnancy to improve patient adherence to the EI recommendations to manage GWG.

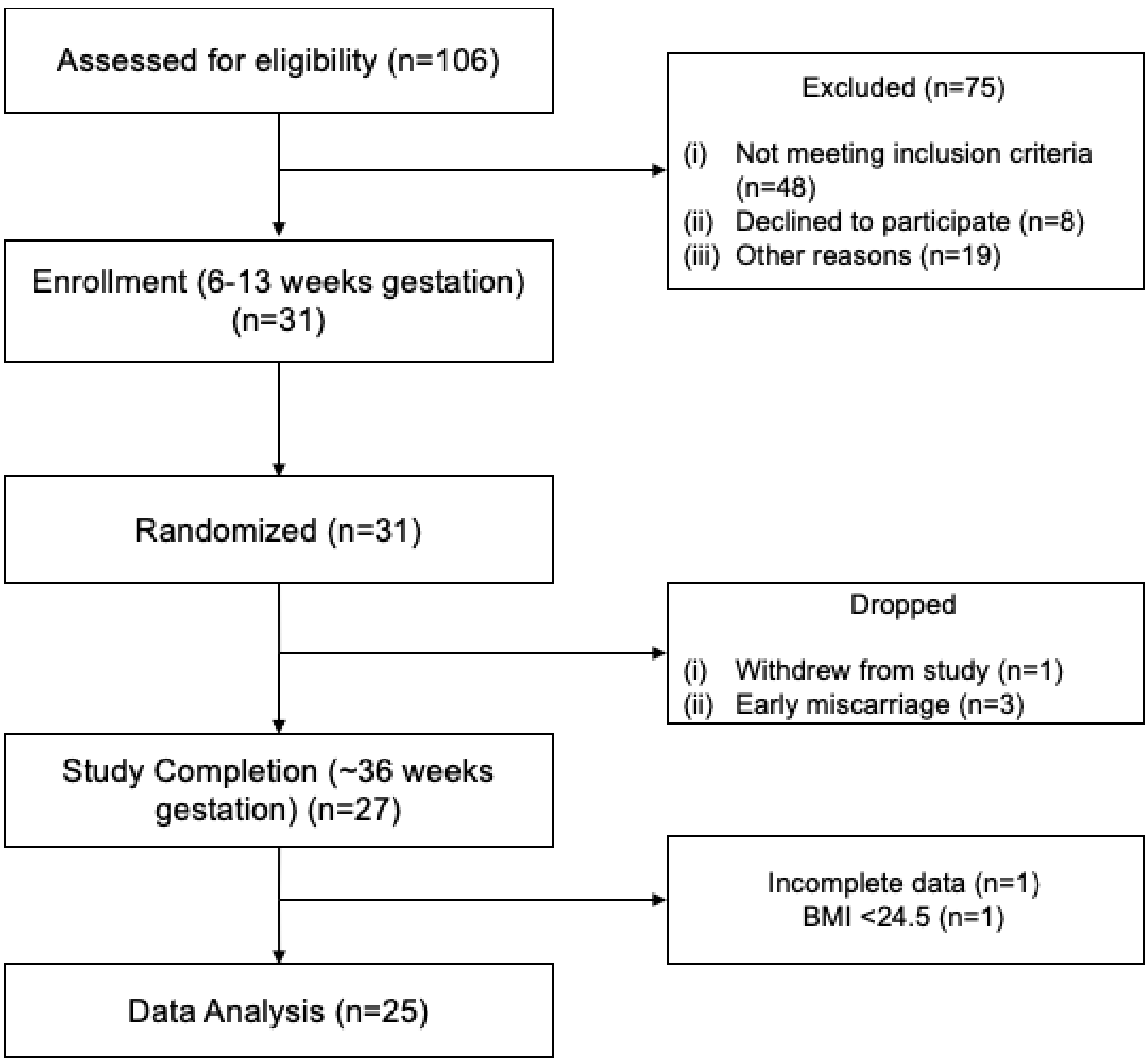
Conclusion

Energy balance is essential for weight management during pregnancy, though this is made difficult to monitor due to poor reporting of EI. Using a predictive equation to estimate EI, we found that UR was associated with pre-pregnancy BMI, perceived stress, uncontrolled eating, and gestational age across pregnancy. These findings are an important initial step in evaluating psychosocial and behavioral variables not previously assessed in relation to energy UR in pregnant women. The results have implications for prenatal nutrition counselling and there is a need to identify additional predictors of UR. Research should also continue to explore which tools are most effective in improving reporting accuracy to promote positive outcomes in pregnant women with overweight and obesity.

Appendices

Appendix A

CONSORT DIAGRAM



Appendix B

PERCEIVED STRESS SCALE

The questions in this scale ask you about your feelings and thoughts during the last week.

In each case, you will be asked to indicate *how often* you felt or thought a certain way.

1 = Never **2 = Almost Never** **3 = Sometimes** **4 = Fairly Often** **5= Very Often**

1.	In the last week, how often have you been upset because of something that happened unexpectedly?	1 2 3 4 5
2.	In the last week, how often have you felt that you were unable to control the important things in your life?	1 2 3 4 5
3.	In the last week, how often have you felt nervous and "stressed"?	1 2 3 4 5
4.	In the last week, how often have you felt confident about your ability to handle your personal problems?	1 2 3 4 5
5.	In the last week, how often have you felt that things were going your way?	1 2 3 4 5
6.	In the last week, how often have you found that you could not cope with all the things that you had to do?	1 2 3 4 5
7.	In the last week, how often have you been able to control irritations in your life?	1 2 3 4 5
8.	In the last week, how often have you felt that you were on top of things?	1 2 3 4 5
9.	In the last week, how often have you been angered because of things that were outside of your control?	1 2 3 4 5
10.	In the last week, how often have you felt difficulties were piling up so high that you could not overcome them?	1 2 3 4 5

From: Cohen S, Kamarck T, and Mermelstein R. (1983). A global measure of perceived stress. Journal of Health and Social Behavior. 24, 386-396.

Appendix C

Three-Factor Eating Questionnaire – Revised 21-Item (TFEQ-R21)

1 = Definitely True **2 = Mostly True** **3 = Mostly False** **4 = Definitely False**

1. I deliberately take small helpings to control my weight.	1	2	3	4
2. I start to eat when I feel anxious.	1	2	3	4
3. Sometimes when I start eating, I just can't seem to stop.	1	2	3	4
4. When I feel sad, I often eat too much.	1	2	3	4
5. I don't eat some foods because they make me fat.	1	2	3	4
6. Being with someone who is eating, often makes me want to also eat.	1	2	3	4
7. When I feel tense or "wound up", I often feel I need to eat.	1	2	3	4
8. I often get so hungry that my stomach feels like a bottomless pit.	1	2	3	4
9. I'm always so hungry that it's hard for me to stop eating before finishing all of the food on my plate.	1	2	3	4
10. When I feel lonely, I console myself by eating.	1	2	3	4
11. I consciously hold back on how much I eat at meals to keep myself from gaining weight.	1	2	3	4
12. When I smell a sizzling steak or see a juicy piece of meat, I find	1	2	3	4
it very difficult to keep from eating – even if I've just finished a meal.	1	2	3	4
13. I'm always hungry enough to eat at any time.	1	2	3	4
14. If I feel nervous, I try to calm down by eating.	1	2	3	4
15. When I see something that looks very delicious, I often get so hungry that I have to eat right away.	1	2	3	4
16. When I feel depressed, I want to eat.	1	2	3	4
17. How often do you avoid "stocking up" on tempting foods?	1	2	3	4
18. How likely are you to make an effort to eat less than you want?	1	2	3	4
19. Do you go on eating binges even though you're not hungry?	1	2	3	4
20. How often do you feel hungry?	1	2	3	4
21. On a scale from 1-8, where 1 means no restraint in eating and 8 means total restraint, what number would you give yourself?	5	6	7	8

From: Cappelleri JC, Bushmakin AG, Gerber RA, Leidy NK, Sexton CC, Lowe ME, Karlsson J (2009). International Journal of Obesity.33, 611-620.

Appendix D

Predictive Equations

Daily energy intake was estimated with a back-calculation method[8, 9, 127] as a function of maternal weight (W), physical activity (PA), and resting metabolic rate (RMR) as follows:

$$EI_{est}(k) = \frac{-W(k+2) + 8W(k+1) - 8W(k-1) + W(k-2)}{12TK_1} - \frac{K_2}{K_1}(PA(k) + RMR(k))$$

The variables are as follows: k = 1, 2, …, *N* corresponding to day 1-day *N*. T represents sampling time which in this case was T = 1 day. Maternal weight was measured by Aria Wi-Fit scale in kilograms and the Jawbone device was used to assess physical activity in kcals. Research investigators estimated daily RMR as a function of maternal weight using an established and validated empirical equation that was proposed[152] and fit using quadratic regression on data from Butte and colleagues, where W(t) is the maternal weight expressed in kg:[40, 153]

$$RMR(t) = 0.1976W(t)^2 - 13.424W(t) + 1457.6$$

Excerpt From: Downs DS, Savage JS, Rivera DE, Pauley AM, Leonard KS, Hohman E, Guo P, Stetter C, Kunselman A (2020). Healthy Mom Zone Adaptive Behavioral Intervention Impacts Prenatal Weight Gain and Components of Energy Balance in Pregnant Women with Overweight/Obesity. Under Review: Translational and Behavioral Medicine.

Appendix E

SAS Code for Analyses

```
*Healthy Mom Zone Study
*File name: Energy Intake & Reporting Accuracy Data
*Written by: Katie McNitt                    Created: 8/11/19
                                                   Last Modified: 3/25/20 KMM

****************
  IMPORT DATA
****************

*Import Perceived Stress Scale (PSS) data;
PROC IMPORT OUT= WORK.psych
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sets\study2_pyschosocial_construct_4_09_18.csv"
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   GETNAMES=YES;
   DATAROW=2;
RUN;
data psych;
set psych;
rename hmz_part_id=partid;
run;

PROC IMPORT OUT= WORK.pss
        DATAFILE= "L:\GWG and Fetal Studies\Healthy Mom Zone Ancillary Pieces\R56 Expansion of Fetal
Growth\Data\Analyses\Cortisol and fetal growth analyses\pss.csv"
        DBMS=CSV REPLACE;
   GETNAMES=YES;
   DATAROW=2;
RUN;
data pss;
set pss;
hmzid=partid;
keep partid week date;
run;

proc sort data=pss;
by partid week;

proc sort data=psych;
by partid week;
run;

data pss2;
merge pss psych;
by partid week;
keep partid week date psstot psstot_mr;
if psstot_mr=. then delete;
if hmzid=2046 and week=38 then delete; *This is a postpartum entry that was entered incorrectly as wk. 38;
          if partid=2004 then delete; *Remove participants not used in analysis;
          if partid=2016 then delete;
          if partid=2500 then delete;
          if partid=2504 then delete;
          if partid=2505 then delete;
          if partid=2506 then delete;
          if partid=2507 then delete;
```

```
run;

*Import Three-Factor Eating Questionnaire (TFEQ) Disinhibition/Restraint data;
libname gwg 'L:\GWG and Fetal Studies\Healthy Mom Zone Parent Study\2. Phase 2 Materials\Data\Data sets';
data tfeq;
set gwg.tfeq;
rename gestday=GA;
rename hmzid=partid;

data tfeq;
set tfeq;
        if partid=2004 then delete; *Remove participants not used in analysis;
        if partid=2016 then delete;
        if partid=2500 then delete;
        if partid=2504 then delete;
        if partid=2505 then delete;
        if partid=2506 then delete;
        if partid=2507 then delete;
run;

PROC IMPORT OUT= WORK.tfeq_i
       DATAFILE= "Q:\Manuscripts\IN PROGRESS\2017 HMZ Energy Intake\Data\Excel
Files\Raw\HealthyMomZoneStudyP-Tfeq_DATA_2020-03-01_1504.csv"
       DBMS=CSV REPLACE;
   GETNAMES=YES;
   DATAROW=2;
RUN;

data tfeq_i;
set tfeq_i;
rename hmz_part_id=partid;
        if partid=2004 then delete; *Remove participants not used in analysis;
        if partid=2016 then delete;
        if partid=2500 then delete;
        if partid=2504 then delete;
        if partid=2505 then delete;
        if partid=2506 then delete;
        if partid=2507 then delete;
run;

*Import Birth Weight data;

PROC IMPORT
      DATAFILE= "L:\GWG and Fetal Studies\Healthy Mom Zone Ancillary Pieces\R56 Expansion of Fetal
Growth\Data\birthweights 2.9.18.csv"
                OUT=birthwt
                DBMS=CSV REPLACE;
         GETNAMES=Y;
RUN;
data birthwt;
set birthwt;
        rename hmzid=partid;
        if partid=2004 then delete; *Remove participants not used in analysis;
        if partid=2016 then delete;
        if partid=2500 then delete;
        if partid=2504 then delete;
        if partid=2505 then delete;
        if partid=2506 then delete;
        if partid=2507 then delete;
run;

*Import demog data;
```

```
PROC IMPORT
	DATAFILE= "Q:\Manuscripts\IN PROGRESS\2017 HMZ Energy Intake\Data\Excel
Files\Cleaned\demog_cleaned_8.15.19.csv"
			OUT=demog
			DBMS=CSV REPLACE;
	 GETNAMES=Y;
RUN;

DATA demog;
	set demog;
*make gravidity and parity character variables;
	gravid = PUT (gravidity, 10. -L);
	parid = PUT (parity, 10. -L);
*Drop participants and variables from demographics that will not be used in analysis;
	drop gravidity parity;
	if partid=2004 then delete;
	if partid=2016 then delete;
	if partid=2500 then delete;
	if partid=2504 then delete;
	if partid=2505 then delete;
	if partid=2506 then delete;
	if partid=2507 then delete;
run;

*Import backcalculated EI data;
PROC IMPORT
	DATAFILE= "Q:\Manuscripts\IN PROGRESS\2017 HMZ Energy Intake\Data\Excel
Files\Cleaned\EI_Backcalculated_cleaned 8.2.19.csv"
			OUT=Backcalc
			DBMS=CSV REPLACE;
	 GETNAMES=Y;
run;

data backcalc;
set backcalc;
*drop participants that will not be used in the analysis;
	if partid=2016 then delete;
	if partid=2500 then delete;
	if partid=2504 then delete;
run;

*Import MFP EI data;
PROC IMPORT
	DATAFILE= "Q:\Manuscripts\IN PROGRESS\2017 HMZ Energy Intake\Data\Excel
Files\Cleaned\EI_MFP_cleaned_8.12.19.csv"
			OUT=MFP
			DBMS=CSV REPLACE;
			guessingrows=32767;
	 GETNAMES=Y;
RUN;

data mfp;
set mfp;
*drop participants that will not be used in the analysis;
	if partid=2016 then delete;
	if partid=2500 then delete;
	if partid=2504 then delete;
	if partid=2505 then delete;
	if partid=2506 then delete;
	if partid=2507 then delete;
run;
```

```
*Import GWG data;
PROC IMPORT
       DATAFILE= "Q:\Manuscripts\IN PROGRESS\2017 HMZ Energy Intake\Data\Excel
Files\Cleaned\GWGKatie_cleaned.csv"
                       OUT=GWG
                       DBMS=CSV REPLACE;
                       guessingrows=32767;
            GETNAMES=Y;
RUN;

data GWG;
           SET GWG;
*change the variable weight change (GWG) into a numeric variable;
           wtchange=wtchange+0;
*drop participants from the data set that will not be used in the analysis;
           if partid=2016 then delete;
           if partid=2500 then delete;
           if partid=2504 then delete;
           if partid=2505 then delete;
           if partid=2506 then delete;
           if partid=2507 then delete;
RUN;

*Import initial weight gain data - this is the difference in weight from pre-pregnancy report to baseline study visit at the
CRC;
PROC IMPORT
       DATAFILE= "Q:\Manuscripts\IN PROGRESS\2017 HMZ Energy Intake\Data\Excel Files\Raw\CRCweights
(1).csv"
                       OUT=Initial_wt
                       DBMS=CSV REPLACE;
            GETNAMES=Y;
RUN;

data initial_wt;
set initial_wt;
*keep only those variables that will be used in data analysis;
keep partid initial_wt;
run;


**************************
 MERGE DATA SETS TOGETHER
**************************;

*Sort each data set;

proc sort data=birthwt;
by partid;
run;

proc sort data=tfeq;
by partid;
run;

proc sort data = vesco;
by partid;
run;

proc sort data=MFP;
by partid ga;
run;
```

```
proc sort data = GWG;
by partid;
run;

proc sort data=demog;
by partid;
run;

proc sort data=initial_wt;
by partid;
run;

proc sort data=backcalc;
by partid ga;
run;

*Merge data sets with daily data together;
data daily;
	merge backcalc mfp tfeq;
	by partid ga;
	drop duedt;
run;

data daily;
	set daily;
*Create Trimester variable;
if ga gt 196 then trimester=3;
else if ga gt 98 then trimester=2;
else if ga ne . then trimester=1;
if ga gt 280 then delete;
if ga lt 0 then delete;
*Create Reporting Accuracy Variable;
UR=((mfp_kcal-EI)/EI)*100; *UR = reporting accuracy (flip sign for under-reporting)
if UR gt 150 then delete;
if EI lt 0 then delete;
if partid=2038 then delete;
run;

*Create Reporting Days and Not Reporting days variable to compare EI on days reported vs. not in new data set
	"EIrept";
data EIrept;
   set daily;
	if mfp_kcal = '.' then rept=0;
	if mfp_kcal ne '.' then rept=1;
	keep partid ga ei date mfp_kcal ur rept;
run;

*Merge data sets with single (non-repeated) measures data;
data one;
	merge vesco gwg demog initial_wt birthwt;
	by partid;
run;

data one;
set one;
/**Grouping GWG categ: meeting and exceeding IOM GWG guidelines;*/
if iomcateg='Above' then IOM='Exceed';
else if iomcateg in ('Below' 'Within') then IOM='Not Exceed';
*Create new variable 'obese' to classify obese and non-obese (overweight) participants;
if prepregbmi ge 30 then obese=1;
else obese=0;
*Drop participants not used in analysis;
```

```
if partid=2016 then delete; *missing mfp data;
if partid=2079 then delete; *early miscarriage;
if partid=2500 then delete; *R56;
if partid=2504 then delete; *R56;
if partid=2505 then delete; *R56;
if partid=2506 then delete; *R56;
if partid=2507 then delete; *R56;
if partid=2038 then delete; *BMI < 24.5;
run;

proc sort data=one;
by partid;
run;

proc sort data=daily;
by partid;
run;

*Create combined data set with all data together;
data final;
	merge daily one pss2;
	by partid;
	gacont=ga;
run;

*CREATE NEW VARIABLE WHICH IS AVG UR FOR EA PARTICIPANT;

proc sort data=final;
by partid;
run;

proc means data=final;
	var UR;
	by partid;
	output out=new mean(UR) = avgUR;
run;

data final;
merge final new;
by partid;
run;

*cross checked against the original data sets 9.22.19 and merge is successful -KM;
*FINISHED WITH DATA CLEANING;


********************************
    DATA ANALYSIS
********************************;

*Calculate Chronbach's Alpha for the TFEQ;

data tfeq_i;
set tfeq_i;
keep partid tfeq1-tfeq21;
run;

data tfeq_i;
set tfeq_i;
*Reverse coding - items 1-16;
tfeq1r = 5-tfeq1;
tfeq2r = 5-tfeq2;
```

```
tfeq3r = 5-tfeq3;
tfeq4r = 5-tfeq4;
tfeq5r = 5-tfeq5;
tfeq6r = 5-tfeq6;
tfeq7r = 5-tfeq7;
tfeq8r = 5-tfeq8;
tfeq9r = 5-tfeq9;
tfeq10r = 5-tfeq10;
tfeq11r = 5-tfeq11;
tfeq12r = 5-tfeq12;
tfeq13r = 5-tfeq13;
tfeq14r = 5-tfeq14;
tfeq15r = 5-tfeq15;
tfeq16r = 5-tfeq16;
if tfeq21 = 1 then tfeq21r = 1;
if tfeq21 = 2 then tfeq21r = 1;
if tfeq21 = 3 then tfeq21r = 2;
if tfeq21 = 4 then tfeq21r = 2;
if tfeq21 = 5 then tfeq21r = 3;
if tfeq21 = 6 then tfeq21r = 3;
if tfeq21 = 7 then tfeq21r = 4;
if tfeq21 = 8 then tfeq21r = 4;

*Calculate subscales;

tfeq_CR = mean (of tfeq1r, tfeq5r, tfeq11r, tfeq17, tfeq18,tfeq21r);
tfeq_EE = mean (of tfeq2r, tfeq4r, tfeq7r, tfeq10r, tfeq14r, tfeq16r);
tfeq_UE = mean (of tfeq3r, tfeq6r, tfeq8r, tfeq9r, tfeq12r, tfeq13r, tfeq15r, tfeq19, tfeq20);

run;

*Correlations and Cronbach alpha for Restraint subscale;
proc corr alpha nomiss data=tfeq_i;
var tfeq1r tfeq5r tfeq11r tfeq17 tfeq18 tfeq21r;
run;

*Correlations and Cronbach alpha for Emotional Eating subscale;
proc corr alpha nomiss data=tfeq_i;
var tfeq2r tfeq4r tfeq7r tfeq10r tfeq14r tfeq16r;
run;

*Correlations and Cronbach alpha for Uncontrolled Eating subscale;
proc corr alpha nomiss data=tfeq_i;
var tfeq3r tfeq6r tfeq8r tfeq9r tfeq12r tfeq13r tfeq15r tfeq19 tfeq20;
run;


*DEMOGRAPHIC DATA*;

*Calculate mean age and pre-pregnancy BMI for whole sample (n=25);
proc means data=one;
	var age prepregbmi wtchange;
run;


*Calculate frequencies and percentage for character variable demographics;
proc freq data=one;
	tables race ethnicity marital gravid parid employment educatio income obese;
run;

**Calculate frequencies and percentage for character variable demographics by UR category (adequate, moderate, high);
```

```
proc sort data=one;
by URcateg;
run;

*DESCRIPTIVE DATA*;

*UR Data;

*Percentage of UR observations <0;
data daily2;
set daily;
if UR gt 0 then UR2='N';
if UR le 0 then UR2='Y';
run;

proc freq data=daily2;
table UR2;
run;

*Calculate average UR in sample and for each participant;

proc means data=daily;
var UR;
run;

proc means data=daily;
by partid;
var UR;
run;

*CALCULATE OVERALL MEANS FOR PREDICTED AND REPORTED EI AND UR;
proc means data=final;
        var EI mfp_kcal UR;
run;

*frequencies ;
proc freq data=one;
tables obese group_assignment iom parid income;
run;

*ICC;
Proc mixed data=final;
class IOM partid GA group_assignment trimester prepregbmi tfeq_cogrest tfeq_unconeat tfeq_emoteat age educatio
income bwt wtchange psstot ;
model UR = gacont /solution cl ddfm=bw;
random intercept /subject=partid type=un g gcorr solution cl;
run;

****************************
   INDIVIDUAL MODELS
***************************;

*MAIN EFFECT OF TIME ON UR;

*UR as continuous variable;
proc mixed data=final;
class partid GA;
model UR=GAcont / solution ;
repeated GA/subject=partid type=cs;
run;

*UR as categorical variable;
```

```
proc mixed data=final;
class partid GA trimester;
model UR=trimester / solution ;
repeated GA/subject=partid type=cs;
lsmeans trimester/pdiff;
run;

*MFP;
proc mixed data=final;
class partid GA trimester;
model mfp_kcal=trimester / solution ;
repeated GA/subject=partid type=cs;
lsmeans trimester/pdiff;
run;

*EI;
proc mixed data=final;
class partid GA trimester;
model EI=trimester / solution ;
repeated GA/subject=partid type=cs;
lsmeans trimester/pdiff;
run;

*MAIN EFFECT OF PRE-PREG BMI ON UR;

*BMI as continuous variable;
proc mixed data=final;
class partid GA;
model UR=prepregbmi / solution ;
repeated GA/subject=partid type=cs;
run;

*BMI as categorical variable;
proc mixed data=final;
class partid GA obese;
model UR=obese / solution ;
repeated GA/subject=partid type=cs;
lsmeans obese/pdiff;
run;

*MFP;
proc mixed data=final;
class partid GA obese;
model mfp_kcal=obese / solution ;
repeated GA/subject=partid type=cs;
lsmeans obese/pdiff;
run;

*EI;
proc mixed data=final;
class partid GA obese;
model EI=obese / solution ;
repeated GA/subject=partid type=cs;
lsmeans obese/pdiff;
run;

*MAIN EFFECT OF STRESS ON UR;

*Individual Model - testing relationship b/w PSS and UR;

proc mixed data=final;
class partid GA;
```

```
model UR=psstot / solution ;
repeated GA/subject=partid type=cs;
run;

proc sgplot data=final;
reg x=psstot y=UR;
run;

*MAIN EFFECT OF TFEQ SUBSCALES ON UR;

*Individual Model - testing relationship b/w TFEQ and UR;
proc mixed data=final;
class partid GA;
model UR=tfeq_emoteat / solution ;
repeated GA/subject=partid type=cs;
run;

proc sgplot data=final;
reg x=tfeq_emoteat y=UR;
run;

proc mixed data=final;
class partid GA;
model UR=tfeq_cogrest / solution ;
repeated GA/subject=partid type=cs;
run;

proc sgplot data=final;
reg x=tfeq_cogrest y=UR;
run;

proc mixed data=final;
class partid GA;
model UR=tfeq_unconeat / solution ;
repeated GA/subject=partid type=cs;
run;

proc sgplot data=final;
reg x=tfeq_unconeat y=UR;
run;


*MAIN EFFECT OF GWG ON UR;

*GWG as continuous variable;
data GWGmodel;
set final;
*remove participants with no weight within 10 days of delivery;
        if partid=2005 then delete;
        if partid=2015 then delete;
        if partid=2040 then delete;
run;

proc mixed data=GWGmodel;
class partid GA;
model UR=wtchange / solution ;
repeated GA/subject=partid type=cs;
run;


*GWG as categorical variable - IOM Guidelines (Meet/Exceed);
proc mixed data=GWGmodel;
```

```
class partid GA IOM;
model UR=IOM / solution ;
repeated GA/subject=partid type=cs;
lsmeans IOM/pdiff;
run;

*MFP;
proc mixed data=GWGmodel;
class partid GA IOM;
model mfp_kcal=IOM / solution ;
repeated GA/subject=partid type=cs;
lsmeans IOM/pdiff;
run;

*EI;
proc mixed data=GWGmodel;
class partid GA IOM;
model EI=IOM / solution ;
repeated GA/subject=partid type=cs;
lsmeans IOM/pdiff;
run;

*Get counts of n in ea IOM grouping;
proc sort data=GWGmodel;
by IOM;
run;

proc freq data=GWGmodel;
table partid;
by IOM;
run;


*MAIN EFFECT OF STUDY GROUP ON UR;

*Study Group as Categorical Variable;
proc mixed data=final;
class partid GA group_assignment;
model UR=group_assignment / solution ;
repeated GA/subject=partid type=cs;
lsmeans group_assignment/pdiff;
run;

*MFP;
proc mixed data=final;
class partid GA group_assignment;
model mfp_kcal=group_assignment / solution ;
repeated GA/subject=partid type=cs;
lsmeans group_assignment/pdiff;
run;

*EI;
proc mixed data=final;
class partid GA group_assignment;
model EI=group_assignment / solution ;
repeated GA/subject=partid type=cs;
lsmeans group_assignment/pdiff;
run;

*Run n frequency for study groups;
proc sort data=final;
by group_assignment;
```

```
run;

proc freq data=final;
table partid;
by group_assignment;
run;

*MAIN EFFECT OF BIRTH WT ON UR;

proc mixed data=final;
class partid GA;
model UR=bwt / solution ;
repeated GA/subject=partid type=cs;
run;

proc sgplot data=final;
reg x=bwt y=UR;
run;


*MAIN EFFECT OF MATERNAL AGE ON UR;

proc mixed data=final;
class partid GA;
model UR=age / solution ;
repeated GA/subject=partid type=cs;
run;

proc sgplot data=final;
reg x=age y=UR;
run;

*MAIN EFFECT OF PARITY ON UR;

proc mixed data=final;
class partid GA parid;
model UR=parid / solution ;
repeated GA/subject=partid type=cs;
lsmeans parid/pdiff;
run;

*MFP;
proc mixed data=final;
class partid GA parid;
model mfp_kcal=parid / solution ;
repeated GA/subject=partid type=cs;
lsmeans parid/pdiff;
run;

*EI;
proc mixed data=final;
class partid GA parid;
model EI=parid / solution ;
repeated GA/subject=partid type=cs;
lsmeans parid/pdiff;
run;

*Run n frequency;

proc freq data=final;
table partid;
by parid;
```

```
run;


*MAIN EFFECT OF INCOME ON UR;

proc mixed data=final;
class partid GA income;
model UR=income / solution ;
repeated GA/subject=partid type=cs;
lsmeans income/pdiff;
run;

*MFP;
proc mixed data=final;
class partid GA income;
model mfp_kcal=income / solution ;
repeated GA/subject=partid type=cs;
lsmeans income/pdiff;
run;

*EI;
proc mixed data=final;
class partid GA income;
model EI=income / solution ;
repeated GA/subject=partid type=cs;
lsmeans income/pdiff;
run;

*Run n frequency for study groups;
proc sort data=final;
by income;
run;

proc freq data=final;
table partid;
by income;
run;


*MAIN EFFECT OF EDUCATION ON UR;

proc mixed data=final;
class partid GA educatio;
model UR=educatio / solution ;
repeated GA/subject=partid type=cs;
lsmeans educatio/pdiff;
run;

*MFP;
proc mixed data=final;
class partid GA educatio;
model mfp_kcal=educatio / solution ;
repeated GA/subject=partid type=cs;
lsmeans educatio/pdiff;
run;

*EI;
proc mixed data=final;
class partid GA educatio;
model EI=educatio / solution ;
repeated GA/subject=partid type=cs;
lsmeans educatio/pdiff;
```

```
run;

*Run n frequency for study groups;
proc sort data=final;
by educatio;
run;

proc freq data=final;
table partid;
by educatio;
run;
```

Appendix F

Journal Manuscript

Energy Intake Under-Reporting Increases Over Pregnancy: An Intensive Longitudinal Study of Women with Overweight and Obesity

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Abstract

Background: Energy intake (EI) under-reporting (UR) is widespread, yet UR during pregnancy is poorly understood. Adequate EI and energy balance are essential for optimizing maternal and fetal outcomes, including gestational weight gain (GWG). Inaccurate self-reported EI may result in erroneous nutrition education from health professionals during pregnancy.

Objective: This study aimed to examine the trends, magnitude, and associated characteristics (i.e., time, anthropometrics, demographics, and psychological measures) of EI UR using intensive longitudinal data in a sample of pregnant women in the US.

Methods: This is a post hoc analysis using secondary data from *the Healthy Mom Zone Study (HMZ)*, a randomized controlled feasibility trial which followed women with overweight and obesity from early pregnancy to approximately 36 weeks gestation. Pre-pregnancy weight and demographics were reported at study enrollment. Validated questionnaires were completed monthly to assess perceived stress, uncontrolled eating, emotional eating, and cognitive restraint. Mobile health (mHealth) technology was used to measure daily weight (Wi-Fi Smart Scale) and physical activity (activity monitor) and tri-weekly self-reported EI (Smartphone App). Back-calculated EI was calculated using a predictive equation. UR was defined as: [(self-reported EI – back-calculated EI) / back-calculated EI] * 100%. Linear fixed effects modelling was used to test whether each predictor was associated with UR.

Results: Women were, on average, 30.7 years old, married, well-educated, with overweight or obesity (mean BMI=31.5), and pregnant with their first child (64%). On average, women under-reported by 36% of their estimated EI. UR increased significantly from the 1^{st} to 2^{nd} to 3^{rd} trimester from 28% to 33% to 39%, respectively (p<0.001). We also found a significant positive association between UR and gestational age (in days) (p<0.001), pre-pregnancy BMI (p<0.01), perceived stress (p<0.05), and uncontrolled eating (p<0.05). The following characteristics were not significantly associated with reporting accuracy: age, education, income, parity, gestational weight gain, treatment group, birth weight, cognitive restraint, and emotional overeating.

Conclusions: EI UR increases across pregnancy and is higher in women with higher BMI and later in gestation. Women may need guidance during pregnancy to improve the accuracy of reporting food intake. These findings may inform prenatal nutrition counselling, and future interventions which identify or improve reporting accuracy during pregnancy.

Introduction

Two-thirds of women in the United States enter pregnancy with overweight or obesity.[10] The Institute of Medicine (IOM) recommends that optimal gestational weight gain (GWG) is 15-25 pounds (lb.) for women with overweight and 11-20 lb. for those with obesity.[154] In the U.S. over 60% of these women exceed these recommendations.[155, 156] This is problematic because elevated pre-pregnancy BMI and excess maternal gestational weight gain (GWG) are associated with higher risk of pregnancy complications and adverse outcomes in both the mother and child.[12-15] Women who enter pregnancy with elevated BMI and/or exceed the GWG recommendations are at higher risk of gestational diabetes, preeclampsia, complications during delivery, unsuccessful breastfeeding, and both short- and long-term post-partum weight retention.[16-24] In the offspring, risks of high pre-pregnancy BMI and GWG include macrosomia (birth weight >4000 grams),[25-27] large for gestational age (birth weight >90th percentile),[25] higher child BMI z-scores,[28] increased body fat and elevated systolic blood pressure in children at age 3 years,[28] and overweight during adolescence.[29, 30] Self-monitoring of food intake is one strategy that has effectively reduced excessive GWG,[63] yet the accuracy of self-reported EI is questionable.[64-68]

The IOM recommends clinical dietary assessment for all pregnant women in the United States[43] and this may be especially beneficial for those at risk of excessive GWG or with other risk factors.[44] In order to counsel patients to meet nutritional needs clinicians are instructed to obtain information on the usual EI of the patient.[43, 63] While self-reported EI is a commonly used tool in management of GWG and gestational diabetes, under-reporting (UR) of EI is widespread[64-68] and is positively associated with BMI.[64-66, 80, 88-90] Studies show psychosocial influences, including weight concern and cognitive restraint, are associated with inaccurate self-reported intake in women across the lifespan,[64, 102, 114, 120, 121] though these studies are lacking in pregnant women. Misreporting of EI makes it difficult for health care providers to accurately interpret and monitor self-reported dietary information to provide optimal nutrition counselling. Estimated prevalence of UR among pregnant women has ranged from 13-50%, with the highest prevalence among women with pre-pregnancy overweight and obesity.[111-117]

Studies of reporting accuracy of EI in pregnant women have largely relied on cross-sectional data, with a lack of research in American samples.[119] Further, the majority of these studies calculate and report the prevalence of under-reporters using a variety of methods to estimate reporting accuracy (e.g., threshold cutoffs) for the sole purpose of excluding "implausible" reporters from analyses of interest. In sum, the estimated magnitude of misreporting in pregnant women is unknown. In response to these limitations, we expanded an energy balance model developed by Thomas and colleagues to calculate EI from GWG in pregnant women [119] using additional input variables: measured weight, physical activity, and resting metabolic rate (RMR).[8, 9] A more accurate prediction of EI using this predictive equation is a viable alternative to self-reported EI in pregnant women.

Because there is scant literature examining reporting accuracy throughout pregnancy, the aims of this study are to describe the trends and magnitude of reporting accuracy of EI among pregnant women in the *Healthy Mom Zone study*, and to examine potential group-level differences in reporting accuracy by time (i.e., gestational age), anthropometric measures (i.e., pre-pregnancy BMI, GWG), treatment group assignment (i.e., intervention or control), demographics (i.e., maternal age, education, parity, household income), perceived stress, eating behaviors (i.e., dietary restraint, uncontrolled eating, and emotional overeating), and infant birth weight. This paper adds to the current body of literature by using a predictive equation to estimate kcal and evaluate the accuracy of self-reported kcal using intensive longitudinal data in a sample of pregnant women with overweight and obesity in the United States.

Methods

Study Subjects

Participants are a convenience sample of pregnant women from *the Healthy Mom Zone Study*, a randomized controlled feasibility trial testing an individually tailored, adaptive intervention for managing GWG in pregnant women in State College, PA (ClinicalTrials.gov identifier #NCT03945266).[126] This was an optimization trial within the multiphase optimization strategy (MOST) framework,[157] and full details of the design of the HMZ intervention have been published previously.[127] Study participants were recruited from 2016 to 2017 through referrals by local obstetricians at the first prenatal appointment. Inclusion criteria were 8-12 weeks gestation and within the BMI range of 24.5 and 45.0 (BMI=40-45 were enrolled with physician consent) at time of enrollment. Including individuals with BMI ≥ 24.5 is clinically relevant as lower cutoffs for overweight are often used in clinical screening.[128] Exclusion criteria included pre-existing diabetes and other conditions known to impact fetal growth or GWG, severe allergies or dietary restrictions, contraindications to prenatal physical activity, and not residing in the area for duration of the study. Thirty-one participants were randomized to the intervention or a standard of care control group. All participants received usual prenatal health care and the intervention offered nutrition and physical activity guidance beyond what was offered in standard care. Participants (n=31) were followed from study enrollment to approximately 36 weeks gestation. From this initial group, one participant was missing all EI data, one participant dropped out of the study, one participant had BMI below 24.5, and three participants had a miscarriage in the first trimester, resulting in a sample size of 25 for this analysis. The study was approved by the Pennsylvania State University Institutional Review Board and all participants provided written informed consent prior to participation.

Measures

Demographic data and pre-pregnancy height and weight (self-reported) was collected from participants at the baseline visit using questionnaires. Height and weight at study entry were obtained by trained nurses. Gestational age was defined as the first day of the last menstrual cycle. Participants were instructed to weigh themselves daily from home using a Fitbit Aria Wi-Fi Smart Scale (Fitbit Inc., San Francisco, CA, USA) throughout the study. Final maternal weights within 10 days of delivery were abstracted from medical records or using Aria Wi-Fi Smart Scale data if medical record data was not available. GWG was calculated for participants with a final maternal weight ($n=23$) by subtracting the last available weight of the participant (within 10 days of delivery) from self-reported pre-pregnancy weight. Infant birth weight was extracted from the medical record.

At study enrollment and every four weeks thereafter, women completed the 10-Item Perceived Stress Scale (PSS)[4] and the 21-Item Three Factor Eating Questionnaire (TFEQ)[5] via online surveys through Research Electronic Database Capture (REDCap).[129]. The TFEQ, which has a four point response scale ranging from (1) definitely true to (4) definitely false, measures three subscales: cognitive restraint (e.g., "I consciously hold back on how much I eat at meals to keep from gaining weight."), uncontrolled eating (e.g., "Sometimes when I start eating, I just can't seem to stop."), and emotional eating (e.g., "I start to eat when I feel anxious."). Scores for each subscale were calculated by averaging respective items. Internal consistencies ranged from acceptable to excellent with a standardized Cronbach alpha of 0.66 for the restrained eating subscale, 0.85 for the uncontrolled eating subscale, and 0.91 for the emotional eating subscale.

Participant self-reported EI was obtained using a dietary intake phone application (app; MyFitnessPal), which was used for the purpose of participant self-monitoring of food intake during the study. Participants were trained on use of the app and instructed to record all foods and drinks consumed over 24-hours on three days per week (two weekdays and one weekend day) on the app for the duration of the study. RMR was estimated daily using the quadratic formula: $RMR=0.1976(\text{weight in kg})^2 - 13.424(\text{weight in kg}) + 1457.6$ to account for increase in RMR across gestation.[40] Measurements of physical activity were assessed at baseline and throughout the study using data from wrist-worn actigraphy (Jawbone UP 4, Jawbone Inc., San Francisco, CA, USA) to extract daily activity time and estimated energy expenditure data.[130]

Calculating reporting accuracy of energy intake

Back-calculated kcal intake was determined daily for each participant using a predictive equation developed by the HMZ research team with the inputs of daily weights measured from home using Aria Wi-Fi Scale, estimated RMR, and kcal expended from physical activity assessed from the Jawbone activity monitor.[8, 9] To calculate reporting accuracy, self-reported and back-calculated EI data were matched by date. Unmatched data were excluded from analyses. A reporting accuracy variable was created using the following equation: *Reporting accuracy = [(self-reported EI – back-calculated EI) / back-calculated EI] * 100%*.[121, 131] This continuous variable represents reporting accuracy of EI or the discrepancy between self-reported and back-calculated kcal. Positive values indicate over-reporting, and negative values indicate EI UR.

Statistical analysis

Statistical analysis was performed in SAS version 9.4 (SAS Institute Inc., Cary, NC). Sample means were calculated for continuous demographic variables (pre-pregnancy BMI, GWG, and age). Frequencies and percentages were calculated for categorical demographic variables (pre-pregnancy BMI category, race, ethnicity, marital status, employment status, education, income, gravidity, and parity). Means were also determined for self-reported EI, back-calculated EI, and daily reporting accuracy.

Linear mixed effects models, which accommodate multilevel data structures and unevenly spaced longitudinal data,[132] were used to test whether reporting accuracy and kcal (self-reported and back-calculated) were associated with the following predictors: time (i.e., gestational age), anthropometric measures (i.e., pre-pregnancy BMI, GWG), treatment group assignment (i.e., intervention or control), demographics (i.e., maternal age, education, parity, household income), perceived stress, eating behaviors (i.e., dietary restraint, uncontrolled eating, and emotional overeating), and infant birth weight. Change in reporting accuracy across pregnancy was assessed using multilevel modeling (PROC MIXED). Reporting accuracy was tested against each predictor in an individual two-level model in which time points were nested within individual. Each model used the restricted maximum likelihood and compound symmetry covariance structure (CS). Determination of model fit was based on several criteria including model convergence, a positive definite G matrix, and Akaike information criteria. Intraclass correlation coefficients (ICCs) were calculated as the ratio of between-subjects variance to total variance. The alpha level was set at 0.05.

Results

Demographic Data

Participant demographics can be found in Table 1. Age of women at study entry ranged from 24-37 years of age (M=30.7±3.0). Women in this sample were predominantly overweight or obese with a mean pre-pregnancy BMI of 31.5±6.9. Forty percent of participants reported a pre-pregnancy weight that was classified as obese (BMI>30 kg/m^2) and 60% reported a weight that was not classified as obese (BMI 24.5-29.9) . The majority (92%) of participants were married and pregnant with their first baby (64% no prior live births, 36% had 1 previous live birth). Participants were, on average, well-educated and fairly affluent. Moreover, the majority (84%) of women were employed full-time. Mean GWG was 24.1±15.5 pounds (lb.) [Intervention: *M*=23.9±17.6 lb., Control: *M*=24.3±14.1 lb.].

Energy Intake Under-Reporting

EI UR was pervasive in this sample with mean of all reporting accuracy observations of -36%±26 (range: -97% to 134%), representing an approximately 1044 kcal underestimation. Ninety-seven percent of reporting accuracy observations were negative values, indicating UR. There was considerable variation both between and within participants. The ICC indicates that about 89% of the variation in the UR variable was within-person, rather than between-person.

Change in under-reporting across pregnancy

Linear mixed modelling shows a main effect of gestational age (in days) as a continuous variable on reporting accuracy such that reporting accuracy decreases as pregnancy progresses ($p<0.0001$) (Table 2). In a separate model, gestational age was examined as a categorical variable and there was a main effect of trimester on reporting accuracy ($p<0.0001$), whereas reporting accuracy in the first trimester (LS mean -28%±6) was significantly lower than in the second (-33%±5) and third trimesters (-39±5%). Differences in self-reported and back-calculated EI by trimester were each examined in separate models. Mean self-reported kcal intake did not significantly differ between the first (*M*=1685±65), second (*M*=1670±61), and third trimesters (*M*=1676±62). Meanwhile, as expected, back-calculated EI increased by an average of 243 kcal from the first (*M*=2627±129) to the second trimester (*M*=2870±127;

$p<0.0001$) and 107 kcal from the second to the third trimester ($M=2977\pm128$; $p<0.0001$) (Table 3).

Other predictors of under-reporting

Linear mixed modelling results show a main effect of pre-pregnancy BMI as a continuous variable on reporting accuracy such that a higher pre-pregnancy BMI was associated with lower reporting accuracy ($p<0.01$) (Table 2). In a separate model, pre-pregnancy BMI was examined as a categorical variable and there was a significant main effect of weight status on reporting accuracy between participants with obesity (LS mean -47%±7) and without obesity (LS mean -25%±6) ($p<0.05$). In two separate models, self-reported and back-calculated EI by pre-pregnancy weight status were examined. Mean self-reported EI did not significantly differ between women with pre-pregnancy obesity (LS mean 1689±80) and women without pre-pregnancy obesity (LS mean 1651±98; $p>0.05$). Back-calculated EI was significantly higher on average in women with pre-pregnancy obesity (LS mean 3384±151) compared to women without obesity (LS mean 2526±123; $p<0.05$) (Table 3).

Next, we tested the independent effects of perceived stress and eating behaviors on reporting accuracy. Eating behaviors were examined monthly and stress was examined weekly as time-varying predictors. Mean baseline value for perceived stress was 30±12 (range=10-55) and perceived stress increased significantly across gestation (<0.0001). Mean baseline values were 2.79±0.47 for cognitive restraint (range = 2.00-3.67), 2.15±0.39 for uncontrolled eating (range = 1.33-3.00), and 2.14±0.59 for emotional eating (range = 1.00-3.33). Cognitive restraint significantly decreased across gestation ($p<0.001$), as did uncontrolled eating ($p<0.01$). Emotional eating did not significantly change across gestation. There was a significant main effect of total perceived stress on reporting accuracy, such that higher perceived stress was associated with lower reporting accuracy or higher UR (p<0.05) (Table 2). Uncontrolled eating (p<0.05) was also negatively associated with reporting accuracy (positive relationship with UR). A similar trend emerged for cognitive restraint and emotional eating, but did not reach statistical significance. There were no significant relationships detected between GWG, treatment group, birth weight, maternal age, parity, income, or education and the extent of reporting accuracy. All variables except birthweight, which had almost no relationship to reporting accuracy, trended in the direction we had hypothesized (Table 2).

Discussion

This is the first study, to our knowledge, to show that average EI UR increases throughout pregnancy using intensive longitudinal data in a sample of U.S. pregnant women with overweight and obesity. These data also allowed us to examine UR by trimester, revealing a longitudinal increase with gestational age. This was the first study of our knowledge to also report that pre-pregnancy BMI is positively associated with UR in the second trimester, while adding to the growing body of research indicating that UR in the first and third trimesters of pregnancy is associated with pre-pregnancy BMI.[113-115, 117] We also report perceived stress, and uncontrolled eating as predictors of UR during pregnancy. Factors that were not related to reporting accuracy include: parity, age, education, income, GWG, birth weight, emotional eating, or treatment group. Together these data suggest that UR has a variety of drivers and as pregnancy progresses UR may become more severe, despite increasing energy requirements in pregnant women.

Increases in UR over gestation appeared to be driven by an average increase in EI while reported kcal stayed stable. In other words, women were eating 350 more kcal on average in the third, compared with the first trimester, but reported they were eating the same amount, on average ~1670 kcal per day. Our findings are consistent with those in a group of 945 Australian pregnant women with overweight or obesity, which showed that prevalence of EI UR was higher at 36 weeks gestation than at study entry (early pregnancy).[114] This trend may indicate that self-reporting of EI is a habitual behavior. Pregnant women may perceive their EI to remain relatively stable, despite increases in EI. Another explanation is that women may tire of logging intake and thus reporting may become less accurate over time. Retention in health and fitness tracking tends to decrease rapidly over time.[133-135] Food logging and self-monitoring can be burdensome and time-consuming, and can result in noncompliance and underestimation as usual EI may be altered to avoid the inconvenience of recording,[136] potentially explaining the increasing UR across pregnancy. Regardless, UR of intake is common during this life stage, with 96% of women in this sample UR to some extent. There was also notable variability between and within person. Most of the variation we observed was within-person. Future studies should explore additional factors that may influence within-person variation in reporting accuracy which may include day of the week (e.g., weekend vs. weekday), types of foods (e.g., snacks, beverages), selective misreporting of nutrients (e.g., fat or carbohydrates), frequency of consumption (e.g., unplanned eating, snacking), and other factors which may vary from day to day within the same person.

This study supports prior research suggesting that UR has a complex etiology. A variety of factors have been attributed to poor reporting of EI, including: incomplete recordkeeping (e.g., recording fatigue, memory disturbances, misrepresentation of portion size, unconscious omission of eating occasion or item), conscious misreporting (e.g., social desirability bias, denial of consumption), changes in eating behavior from the reporting process itself, and training and quality control.[75] There is strong evidence that psychological factors such as social desirability, eating restraint, and history of dieting are associated with UR.[75] For many women, pregnancy is a time of increased psychological distress and body image concern which may contribute to conscious misreporting among pregnant women with overweight and obesity.[122, 123] Moran reports that the number of times women reported limiting food intake in order to lose weight and self-reported dissatisfaction with weight and body shape were independent predictors of UR at 36-weeks' gestation.[114] Incomplete record-keeping is also a likely contributor to misreporting in this sample. Certain types of foods (e.g., sauces, oils, and beverages) and eating occasions (e.g., snacks) are systematically under-reported.[80, 81] Common advice for pregnant women is to snack more often to meet additional kcal needs, and this may contribute to UR.[81]

Prior research indicates that the IOM kcal guidelines are likely too high for women with overweight and obesity[144, 145] and, combined with UR, this may exacerbate excess EI contributing to GWG. The 2005 IOM guidelines for estimated energy requirement (EER) recommend that all pregnant women require an additional 340 kcal in the second trimester and 452 kcal in the third trimester.[33] This estimate was based on energy deposition calculations using longitudinal maternal body composition data collected in well-nourished, normal weight (pre-pregnancy BMI from 18.5 up to 25 kg/m^2) pregnant women.[38] In the present sample, back-calculated EI increased by an average of 243 kcal from the first to second trimester and 107 kcal from the second to the third trimester. This highlights the need for additional research on adequate energy needs for women with elevated BMI to meet recommended GWG.

While MyFitnessPal is not a validated method for collecting EI, it was chosen due to its usability and acceptability among participants as a tool for self-monitoring. The use of mHealth technologies are increasingly popular among both healthcare providers and patients.[56] Using dietary and weight-tracking mobile apps, including MyFitnessPal, for self-monitoring of EI and weight have produced clinically significant weight loss in randomized controlled trials of non-pregnant women.[57, 58] While the nutrient-content of many of the foods within the app have not been verified, MyFitnessPal has been shown to provide estimates of EI that are comparable to 24-hour weighted food records and have nutrient profiles similar to United States Department of Agriculture (USDA) Food Composition Databases.[59, 60] Apps such as MyFitnessPal are favored by participants for the self-monitoring of EI when compared to traditional paper records,[62] and mobile tools such as this should be continually studied and improved upon as a method for self-monitoring EI.

Our data reinforce that EI UR is pervasive during pregnancy, especially in women with obesity. Women in this sample under-reported by an average of 736 kcal in the first trimester, 947 kcal in the second trimester, and 1161 kcal in the third trimester. Training for prenatal dietitians, nurses, and physicians might incorporate methods to improve reporting accuracy, including the use of the multiple-pass 24-h recall method or "real-time" logging methods such as mobile apps to reduce "forgotten foods".[148] Another way to improve reporting accuracy is to train patients on food-portion estimation skills using tools (e.g., food scales and measuring spoons/cups) and to encourage patients to use these tools to more accurately self-monitor intake, especially of foods that are commonly under-estimated.[149] Clinicians should be aware of social desirability bias in misreporting, which can result in conscious omission of foods and may be higher in participants with higher BMI, cognitive restraint, and uncontrolled eating.[75] Holistic treatment approaches, such as stress-management and weight bias training for prenatal clinicians may have downstream impacts on UR. Finally, clinicians should be trained on potential predictors of EI UR (e.g., elevated pre-pregnancy BMI, perceived stress, later GA) to provide more tailored guidance for women who may be at higher risk of misreporting.[146, 147]

With known deficits in self-reported EI, the predictive equation we developed using weight changes, physical activity (using wrist-worn actigraphy), and RMR to back-calculate kcal may provide estimates of intake that are more reliable. As the use of mHealth technology for self-monitoring continues to increase, health care professionals may be able to use predictive equations to estimate EI and provide individualized counselling. Mathematical models that predict GWG and EI could provide a clinical tool for setting precise kcal goals and continuous objective feedback throughout pregnancy. This novel way of determining underreporting has practical implications of utilizing GWG, self-reported EI, and kcal goals in prenatal counselling. This method gives clinicians an alternative to self-reported intake to more accurately predict a patient's EI and guide women in making choices to promote energy balance and appropriate GWG.

In contrast to previous studies, we found no significant association of underreporting with the following variables: age, education, income, parity, GWG, treatment group, or birth weight. Moran found that socioeconomic status was an independent predictor at 36 weeks of EI UR.[114] Another study found that young women were more likely to under-report than older women during pregnancy.[117] Thomas found that birth weight, higher income, and education predicted higher UR.[119] One potential explanation for the lack of association reported in our study may be that unlike the studies reported above, we had a relatively small sample size, which may reduce our ability to detect a significant relationship. Additionally, population differences between Australia and the US may explain some of these discrepancies. Further research should explore characteristics that are associated with UR across gestation.

Strengths of this study include intensive longitudinal data collected throughout pregnancy, using UR as a continuous variable rather than with threshold cutoffs, as well as the use of measured weight and physical activity to determine back-calculated EI. Limitations to this research include reliance on self-reported pre-pregnancy height and weight, which can lead to under-estimated BMI.[150, 151] The small sample size precludes the ability to make assumptions at a population level. Additionally, the target population was a homogenous sample of women who were predominantly non-Hispanic, white, married, and middle to upper class, thus limiting the generalizability of the study findings to other populations of pregnant women. Future research may extend on these findings with a larger, more diverse sample. Research should also continue to explore interventions that promote reporting accuracy during pregnancy to improve patient adherence to the EI recommendations to manage GWG.

Conclusion

Energy balance is essential for weight management during pregnancy, though this is made difficult to monitor due to poor reporting of EI. Using a predictive equation to estimate EI, we found that UR was associated with pre-pregnancy BMI, perceived stress, restrained eating, uncontrolled eating, and gestational age across pregnancy. These findings have implications for prenatal nutrition counselling and there is a need to identify and implement efficacious interventions which identify or improve reporting accuracy. Research should also continue to explore which tools are most effective in improving reporting accuracy to promote positive outcomes in pregnant women with overweight and obesity.

Table 1: Baseline Descriptive Characteristics (*n=25*)	
Characteristic	n (%)*
Maternal Age, years	30.7±3.0
Preconception BMI, kg/m^2	31.5±6.9
% BMI = 24.5-29.9	15 (60%)
% Obese (BMI ≥ 30)	10 (40%)
Gestational Weight Gain, lb.	24.1±15.5
Race	
White	24 (96%)
Asian	1 (4%)
Ethnicity	
Non-Hispanic	25 (100%)
Marital Status	
Divorced	1 (4%)
Married	23 (92%)
Single	1 (4%)
Maternal Education	
High School	1 (4%)
College	13 (52%)
Graduate prof	11 (44%)
Gravidity	
1	12 (48%)
2	10 (40%)
3	2 (8%)
No response	1 (4%)
Parity	
0	16 (64%)
1	9 (36%)
Employment	
Full-Time	21 (84%)
Part-Time	2 (8%)
Self-Employed	1 (4%)
Other	1 (4%)
Income	
<$20,000	1 (4%)
$20,000-$40,000	4 (16%)
$40,000-100,000	11 (44%)
≥$100,000	9 (36%)

*Continuous variables (maternal age and BMI: body mass index) data presented as mean plus/minus SD.

Table 2: Multilevel model parameter estimates showing independent predictors of maternal under-reporting, each in a separate model (*n=25*)

Variable	**Mean (difference in estimated vs. self-reported energy) kcals**	**Standard Error**	***p-value***
Gestational Age (in days, continuous)	-0.05245	0.008971	**<0.0001**
Gestational Age (by trimester, categorical)			
Intercept	-39.0283	3.6650	**<0.0001**
Trimester (1)	8.0969	1.5065	
Trimester (2)	1.6986	1.0609	
Trimester (3)	0		
Pre-Pregnancy BMI (continuous)	-1.4014	0.4443	**0.0057**
Pre-Pregnancy BMI (categorical)			
Intercept	-47.5543	5.0196	
BMI = 24.5-29.9	17.8271	6.4866	**0.0114**
BMI ≥ 30	0		
Perceived Stress	-0.3009	0.1466	**0.0403**
Emotional Eating (TFEQ)	-1.7743	1.0421	0.1001
Cognitive Restraint (TFEQ)	-5.3817	2.6504	0.0523
Uncontrolled Eating (TFEQ)	-1.8853	0.8816	**0.0417**
GWG (in lb., continuous) (*n=23*)	-0.2500	0.3421	0.4734
GWG (meeting vs. exceeding IOM guidelines, categorical)			
Intercept	-27.6890	7.54293	
Exceeding	-12.2186	10.5818	0.2618
Not Exceeding	0		
Treatment group			
Intercept	-31.4899	6.6494	
Control	-5.3725	9.6311	0.5823
Intervention	0		
Birth Weight (g)	0.004412	0.008001	0.5866
Maternal Age (yrs)	1.3586	1.6360	0.4148
Parity			
Intercept	-25.8394	7.7735	
Parity (0)	-12.9252	9.7569	0.1983
Parity (1)	0		
Household Income (yearly)			
Intercept	-31.0597	8.0424	0.5263
\$10000-\$20000	-33.8023	25.5669	
\$20000-\$40000	5.0010	14.6402	
\$40000-100000	-5.4857	10.8318	
>\$100000	0		
Maternal Education			
Intercept	-0.6490	24.2892	0.0958
College	-42.1062	25.0615	
Graduate School	-25.5884	25.2026	
High School	0		

Table 3. Energy Intake and Under-Reporting During Pregnancy by Maternal Characteristics and Treatment Group.			
Characteristic	Self-reported EI, kcal/d	Back-Calculated EI, kcal/d	% Under-reporting (SD)
Overall *(n=25)*	1710±466	2900±812	36% (±26)
Gestational Age (Trimester)			
First Trimester	1685±65	2627±129	28% (±6)
Second Trimester	1670±61	2870±127	33% (±5)
Third Trimester	1676±62	2977±128	39% (±5)
Pre-Pregnancy BMI			
Not Obese *(n=15)*	1689±80	2526±123	25% (±6)
Obese *(n=10)*	1651±98	3384±151	47% (±7)
Total GWG Classified by IOM Guidelines			
Not Exceeding *(n=11)*	1763±93	2750±184	28% (±7)
Exceeding *(n=12)*	1552±94	2937±184	40% (±8)
Treatment Group Assignment			
Intervention *(n=13)*	1674±89	2812±179	31% (±7)
Control *(n=12)*	1673±89	2931±186	37% (±7)
Parity			
0 *(n=16)*	1637±76	2913±161	39% (±6)
1 *(n=9)*	1739±102	2790±215	26% (±8)
Annual Household Income			
$10000-$20000 *(n=1)*	1465±316	4342±590	65% (±24)
$20000-$40000 *(n=4)*	1691±158	2693±295	26% (±12)
$40000-$100000 *(n=11)*	1630±95	2796±178	37% (±7)
>$100000 *(n=9)*	1742±105	2873±197	31% (±8)

*Variables reported as mean plus/minus SE (PROC MEANS)

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