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Original Research

Anthropometric Changes During Pregnancy and Their Association with Adequacy of Gestational Weight Gain

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A B S T R A C T

Background: Gestational weight gain (GWG) is an expected component of a healthy pregnancy. Gaining weight within the recommended range helps support the mother's health by providing energy reserves and nutrients to meet the increased metabolic demands during pregnancy. Too much or too little GWG has been associated with adverse health outcomes for the mother and child.
Objective: The objective of the study was to examine how changes in anthropometric indicators during pregnancy, including fat gain, vary, compare changes among body mass index (BMI) (kg/m^2) groups, and examine how the changes were associated with adequacy of GWG defined using the 2009 Institute of Medicine guidelines.
Methods: Data came from a cohort of 360 pregnant women with measured anthropometric indicators (weight, midupper arm circumference, and skin folds of the triceps, thigh, and upper iliac) at <12-, 16 to 22-, and 28 to 32-wks of gestation. Fat gain was calculated using a formula. Analysis of variance was used to test for differences in anthropometric changes by BMI and adequacy of GWG in the third trimester. Multiple logistic regression was used to examine associations between changes in anthropometric indicators and GWG recommendations.
Results: Women with normal weight had greater increases in all anthropometric indicators, which differed from women with obesity, who had negative changes and gained less weight. Women who gained inadequately (21%) had negative changes that were all less, compared with women who gained adequately (46%) (except in upper iliac) or excessively (34%). Women with BMI of >25 who gained adequately also had negative changes. Logistic regression results indicated that changes in midupper arm circumference, triceps, and thigh skin folds, and fat gain were all inversely associated with inadequate GWG, whereas all indicators were positively associated with excessive GWG.
Conclusions: Anthropometric changes during pregnancy differ by BMI and are associated with adequacy of GWG. Women who gained adequately had minimal fat gain, lending support for current GWG guidelines.

Keywords: Pregnancy, gestational weight gain, BMI, anthropometrics, women

Introduction

Gestational weight gain (GWG) is a normal and expected component of a healthy pregnancy because it reflects the increasing size and weight of the fetus and placenta, as well as maternal tissues, blood, extracellular fluid, and maternal fat stores [1]. In 2009, the Institute of Medicine (IOM) committee believed that this last component, maternal fat stores, was the only malleable component and as such, concluded that all women, including those with obesity, should gain some weight during pregnancy, with varying target ranges specific to pregravid weight status [1]. It has been well documented that 40%–

Abbreviations: BMI, body mass index; GWG, gestational weight gain; IOM, Institute of Medicine.

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60% of pregnant women, regardless of pregravid body mass index (BMI) (kg/m^2), gain too much weight during pregnancy and subsequently are left with more maternal fat stores in the postpartum period [2–4]. Excessive gestational weight gain and high-postpartum weight retention are associated with immediate and long-term health outcomes for the mother and child [5,6]. Excessive weight gain during pregnancy is associated with an increased risk of complications, such as gestational diabetes, high blood pressure, and cesarean delivery [6]. On the other hand, insufficient weight gain can increase the risk of preterm birth and low-birth weight [7]. Staying within the recommended range helps minimize these risks. Appropriate weight gain during pregnancy can also contribute to a smoother postpartum recovery by providing the body with sufficient energy stores for breastfeeding and physical healing after childbirth [8].

There has been a paucity of data relating adequacy of weight gain with anthropometric changes, including an estimate of the amount of fat gained during pregnancy, the one malleable component. Lederman et al. [9] showed that women who gained within the 1990 IOM guidelines retained the least amount of fat, supporting the weight gain recommendations that existed at that time. A United Kingdom study examining anthropometric changes from pregnancy to postpartum found that women with overweight and obesity had the greatest variability. Furthermore, they noted that the obese group had different anthropometric patterns than women of normal and overweight status for skinfold thickness, waist-to-hip ratio, and fat mass in the postpartum period [10]. Berggren et al. [11] showed greater maternal fat mass accrual among women with overweight or obese BMI with excessive gestational weight gains compared with those who gained adequately using the 2009 IOM recommendations. Additionally, a study by Most et al. [12] that examined body composition of women within the 3 classes of obesity concluded that the 2009 IOM recommendations for this group may be too high.

There are differences between the 1990 and 2009 recommendations, with the most notable being that the cut points used to group women into weight classifications were updated to be consistent with those used in the nonpregnancy state, and women with obesity were given a target range of 5–9 kg [1]. Given that the BMI of women entering pregnancy has increased over time, further examination is warranted to understand if the current recommended GWG for women who are overweight and obese is associated with lower maternal fat stores over the course of pregnancy. Although theoretically, these fat stores serve the purpose of aiding in the production of breast milk for the infant, the prevalence and duration of breastfeeding among women with a higher BMI remains lower than that of women with BMI in the normal range [13–15] making high weight gains a risk factor for increased severity of BMI comorbidities for future pregnancies and long-term health of the mother if not intervened upon [16].

There exist multiple methods to measure body composition, including dual energy x-ray absorptiometry, magnetic resonance, isotope dilution, air displacement plethysmograph (also known as Bod Pod), and bioelectrical impedance. The strengths and weaknesses of each have been previously published [17]. However, body composition assessments during pregnancy are challenging due to some methods being contraindicated, methods being unable to differentiate maternal and fetal tissues, or methods being cumbersome and costly, resulting in small sample sizes. Anthropometric measurements, such as weight, height, skin folds, and circumferences continue to be the easiest to collect and, when conducted by well-trained staff, can be used in formulas to estimate body composition during pregnancy, making these measurements useful in a clinical setting.

The purpose of this paper was to address several gaps related to the soundness of the 2009 GWG recommendations using data from a contemporary pregnancy cohort. Specifically, our objectives were to examine how weight, midupper arm circumference, skin folds, and fat gain change over the course of pregnancy, compare these changes by BMI groupings and assess whether changes in anthropometric measurements (including fat gain) are associated with adequacy of GWG and whether BMI modifies this relationship.

Methods

This paper is a secondary analysis of data from a study conducted to examine the role of reward-related eating in the maternal diet and weight change during pregnancy and postpartum [18]. Participants were recruited from women obtaining prenatal care at the obstetrics clinics at the University of North Carolina at Chapel Hill Hospitals with 2 locations, one in the hospital and the other in the community. Inclusion criteria encompass the following: confirmed uncomplicated singleton pregnancy ≤12 wks of gestation at enrollment; age ≥18 and <45 y at screening; BMI of ≥18.5; able to complete self-report assessments in English; access to Internet with email; willingness to undergo study procedures and provide informed consent for herself and assent for the infant's participation; plan to deliver at the Women's Hospital; and plan to remain in the geographic vicinity of the clinical site for 1 y following delivery. Assessments occurred once during each trimester of pregnancy, and in postpartum at 4–8 wk, 6 mo, and 12 mo. Figure 1 illustrates the flow of participants through the study and inclusion in the current analysis. Protocols were approved by the Institutional Review Board at the University of North Carolina.

Anthropometrics

Maternal height was measured at baseline (<12 wk) using a stadiometer and recorded to the nearest 0.1 cm. Weight, skin folds (triceps, thigh, and upper iliac), and midupper arm circumference were measured at baseline, 16–22 wks of gestation (second visit), and at 26–32 wks of gestation (third visit) during pregnancy by trained research staff using established protocols [19]. Each measurement was taken twice, and if not within specified range, a third measure was taken, and the 2 closest were entered into the database. For this analysis, GWG was calculated using the measured weight at baseline subtracted from the weight at visit 3. Measured early pregnancy weight was used because self-reported prepregnancy weight is prone to bias, especially in women with overweight and obesity [20].

Fat gain was estimated using the formula by Paxton et al., [21] where fat gain (kg) = 0.77 (weight change, kg) + 0.07 (change in thigh skinfold thickness, mm) – 6.13. The 2009 IOM assumes a first trimester total weight gain of 0.5–2.0 kg and a mean and range of incremental weight gain recommendations during the second and third trimesters of 0.42 kg/wk (0.35–0.50) for normal

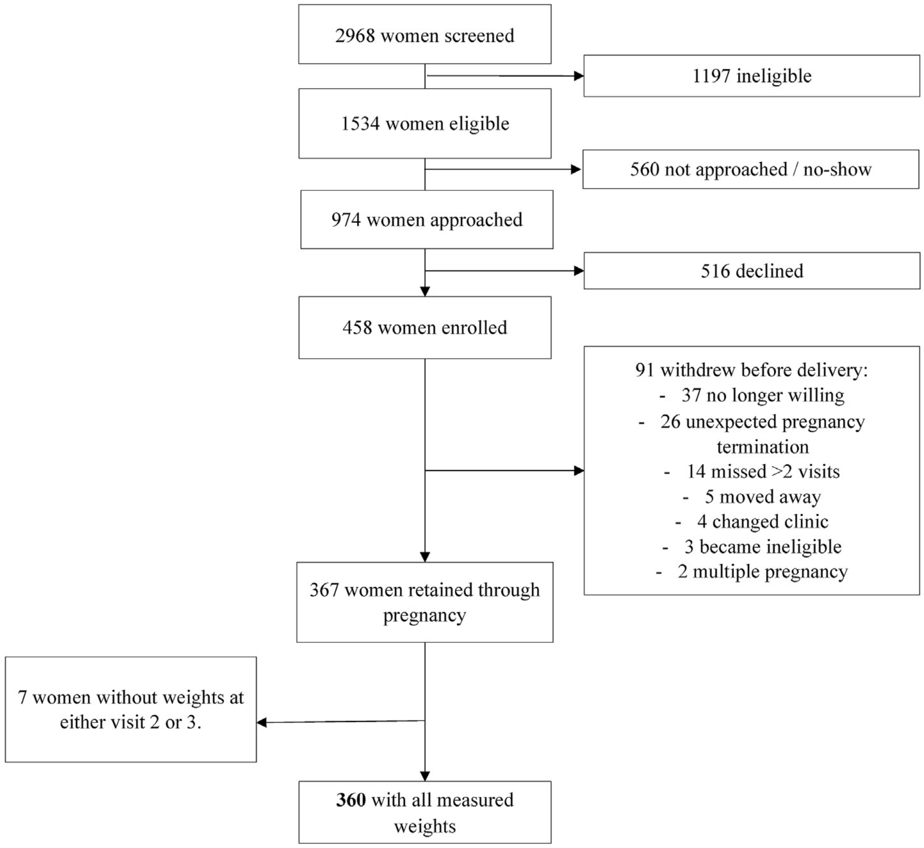

FIGURE 1. Flow chart of Pregnancy Eating Attributes Study individuals included in the analysis.

weight, 0.28 kg/wk (0.23–0.33) for overweight, and 0.22 kg/wk (0.17–0.27) for women with obesity [1]. The lower and upper bound of the range of recommended weight to be gained at any point in gestation was calculated as follows: lower or upper estimate of recommended first trimester GWG + [(GA at weight measurement – 13 wk) × (lower or upper recommended rate of weekly GWG for the second and third trimesters)] specific for pregravid BMI [1]. Weight gain was inadequate when observed weight was less than the lower estimate and excessive if it exceeded the higher limit. This calculation allows controls for the wks in gestation, which is highly correlated with weight gain [1].

Statistical analysis

Descriptive statistics including the mean and standard deviations (SDs) were calculated for each of the anthropometric indicators by visit and for change from baseline to visit 3. Unadjusted differences in mean change of each anthropometric indicator, including fat gain, by baseline BMI (18.5–<25 normal weight, 25–<30 overweight, and ≥30 obese) and adequacy of GWG were analyzed by analysis of variance using a *P* value of <0.05 to denote statistical significance. Multivariate logistic regression models were employed to assess the association between change in each anthropometric indicator, including fat gain, and adequacy of GWG at visit 3. Separate models were built for each anthropometric indicator using adequate weight gain as the referent group. Confounders considered, based on a priori literature review as cited in the 2009 IOM report, included maternal age, height, race/ethnicity, marital status, education, employment, and baseline BMI [1]. Variables kept in the model were those that changed the β-coefficient of the independent variable by >10% in any of the models, and then one standard set of confounders was used to create a parsimoniousness set that was applied in all models. Baseline BMI was also considered as an effect modifier based on the work of Berggren et al. [11] and Most et al. [12] that showed differences in body composition by weight status and adequacy of GWG. All analyses were conducted in STATA version 15 [22].

Results

At baseline (mean 9.8 ± SD 1.7 wks of gestation), mean maternal age was 30.6 ± SD 4.5 y. Baseline BMI classification was 48% normal weight, 27% overweight, and 25% obese. The racial/ethnic composition of the sample was as follows: 8% Hispanic, 67% non-Hispanic White, 16% non-Hispanic Black, 5% Asian, and the remainder other/unknown. Most of the women were married (91%) and employed (63%), with 14% employed part-time, 5% reported not working because they were students, and 13% reported not working by choice. The sample was highly educated, with 19% having some college or an associate degree, 30% having completed college, 24% having a master's degree, 18% having completed an advanced doctoral degree, and <10% having only completed high school. Thirty percent of women reported an annual household income <$50,000, whereas 31% reported their income as >$100,000. Thirteen percent of women reported receiving benefits from The Special Supplemental Nutrition Program for Women, Infants, and Children, and ~11% reported being on the Supplemental Nutrition Assistance Program.

Table 1 presents the mean anthropometric measurements at each visit (baseline 9.8 ± SD 1.7, visit 2 19.0 ± SD 1.7, and visit 3

TABLE 1
Mean and standard deviation of anthropometric measurements taken at each prenatal study visit and change from baseline to visit 3 ($n = 360$)

Anthropometric indicator	Visit 1 (baseline) (mean 9.8 ±SD 1.7 gestational wks)	Visit 2 (mean 19.0 ± SD 1.7 gestational wks)	Visit 3 (mean 30.0 ± SD 1.5 gestational wks)	Change (visit 3–1)
Weight (kg)	73.7 (19.1)	75.5 (17.6)	81.1 (16.8)	8.4 (4.0)
Circumference (cm)				
Midupper arm	30.8 (5.2)	30.7 (5.1)	30.8 (4.6)	0.2 (1.7)
Skinfolds (mm)				
Triceps	26.6 (8.7)	26.8 (8.3)	26.9 (7.7)	0.5 (6.2)
Thigh	39.9 (13.7)	40.5 (13.2)	42.3 (12.4)	2.5 (12.2)
Upper iliac	34.2 (12.0)	36.7 (11.8)	36.6 (10.2)	2.4 (10.4)

Abbreviations: BMI, body mass index; SD, standard deviation

TABLE 2
Mean change in anthropometrics by baseline body mass index*

Anthropometric indicators (change from baseline to visit 3)	BMI 18.5–<25 $n = 172$ mean (SD)	BMI 25–<30 $n = 98$ mean (SD)	BMI ≥ 30 $n = 90$ mean (SD)
Weight (kg)	9.4 (2.8)	8.9 (3.8)[b]	5.8 (5.0)[a,b]
Midupper arm circumference(cm)	0.7 (1.6)	0.1 (1.7)[a,b]	-0.7 (1.7)[a,b]
Triceps skinfold (mm)	1.5 (6.4)	0.5 (5.3)	-1.2 (6.3)[a]
Thigh skinfold (mm)	3.9 (13.2)	2.8 (11.1)	-0.4 (11.0)[a]
Upper iliac skinfold (mm)	3.6 (10.2)	3.6 (9.5)[b]	-1.3 (10.8)[a,b]
Fat gain (kg)[c]	1.3 (2.6)	0.9 (3.3)[b]	-1.7 (4.2)[a,b]

Abbreviations: BMI, body mass index; SD, standard deviation
* Statistical differences noted when P value of <0.05
a Different from normal weight.
b Differences between overweight and obese.
c Fat gain = 0.77 (weight change, kg) + 0.07 (change in thigh skinfold thickness, mm) – 6.13. (Paxton et al. 1998) [21]

30.0 ± SD 1.5 wks of gestation) and the change from baseline to visit 3. On average, weight gain was 8.4 kg over the observed period of ~20 wk. Modest changes were observed for midupper arm circumference and triceps skinfolds and of about the same magnitude for skinfolds of the thigh and upper iliac. Anthropometric changes by BMI category are shown in Table 2. Normal weight women had greater increases in all anthropometric indicators, which were different from women with obesity, who showed a mean decrease in all skinfolds and fat gain. Women with overweight had a smaller increase in midupper arm circumference compared with women who were normal weight, and they had greater increases in weight, skinfolds of the upper iliac, and fat gain than women with obesity.

Changes in the anthropometric indicators, including fat gain by adequacy of GWG at visit 3 for all and stratified by BMI are shown in Table 3. Overall, 46% gained within the IOM weight gain guidelines, whereas 20.5% gained inadequately, and 33.7 % gained excessively. Adequacy of weight gain varied by baseline BMI (Pearson chi2(4) = 47.5 $P < 0.0001$). Women who gained inadequately gained less weight from baseline to visit 3 and had negative changes that were all less, compared with women who gained adequately (except for upper iliac skin folds) or excessively. Similar patterns were seen in analysis stratified by BMI, except that women with a BMI of >25 who gained adequately also had negative anthropometric changes (not seen in upper iliac skin folds of women with BMI 25–29).

Results of the multivariate logistic regression models to assess the association between change in the anthropometric indicator and adequacy of GWG at visit 3 are shown in Table 4. The only confounding variable was baseline maternal weight status used as a categorical variable (BMI <25 normal or ≥25 overweight and obese), and it did not modify the associations in any model. Compared with the referent category of adequate weight gain, changes in midupper arm circumference, triceps and thigh skin folds, and fat gain were all inversely associated with inadequate GWG. All indicators were positively associated with excessive GWG, implying that the greater the change in these anthropometric indicators including fat gain, the higher likelihood of being in the excessive compared with adequate category.

Discussion

Pregnancy is a physically demanding period, and the body undergoes significant changes. Gaining weight within the recommended range helps support both the mother's and infant's health [15]. In this cohort, differences in patterns of anthropometric changes by early pregnancy weight status were observed. Specifically, women with obesity had negative anthropometric changes across pregnancy, gained the least amount of weight, and had greater variability in the measurements compared to women with a normal or overweight BMI. Women who gained adequately had

TABLE 3

Mean change in anthropometrics by adequacy of gestational weight gain (GWG)[c] at visit 3[*]

Anthropometric indicators (change from visit 1 to 3)	Adequate GWG $n = 165$ mean (SD)	Inadequate GWG $n = 74$ mean (SD)	Excessive GWG $n = 121$ mean (SD)
All women			
Weight (kg)	8.0 (2.1)	3.4 (3.0)[a,b]	11.9 (2.9)[a,b]
Midupper arm circumference(cm)	0.3 (1.6)	-0.9 (1.9)[a,b]	0.7 (1.5)[b]
Triceps skinfold (mm)	0.7 (6.3)	-2.4 (5.5)[a,b]	2.2 (5.8)[b]
Thigh skinfold (mm)	2.8 (13.0)	-3.5 (9.7)[a,b]	5.9 (11.2)[b]
Upper iliac skinfold (mm)	2.0 (9.2)	-1.3 (11.3)[b]	5.1 (10.6)[a,b]
Fat gain (kg)[d]	0.2 (2.0)	-3.8 (2.4)[a,b]	3.5 (2.5)[a,b]
Normal weight	$N = 105$	$N = 34$	$N = 33$
Weight (kg)	9.3 (1.3)	5.8 (1.2)[a,b]	13.3 (2.0)[a,b]
Midupper arm circumference(cm)	0.8 (1.7)	-0.2 (1.3)[a,b]	1.4 (1.2)[b]
Triceps skinfold (mm)	1.7 (6.1)	-2.0 (6.3)[a,b]	4.5 (5.7)[b]
Thigh skinfold (mm)	4.7 (13.3)	-3.8 (9.5)[a,b]	9.2 (13.3)[b]
Upper iliac skinfold (mm)	3.1 (9.0)	0.3 (11.6)[b]	8.5 (11.0)[a,b]
Fat gain (kg)[d]	1.3 (1.4)	-2.0 (1.2)[a,b]	4.8 (1.9)[a,b]
Overweight	$N = 29$	$N = 14$	$N = 55$
Weight (kg)	6.8 (0.9)	3.1 (1.7)[a,b]	11.6 (2.4)[a,b]
Midupper arm circumference(cm)	-0.5 (1.3)	-1.2 (2.2)[b]	0.8 (1.3)[a,b]
Triceps skinfold (mm)	-1.1 (5.4)	-2.5 (2.9)[b]	2.0 (5.1)[a,b]
Thigh skinfold (mm)	-0.02 (12.5)	-2.7 (7.8)[a]	5.8 (10.2)[b]
Upper iliac skinfold (mm)	2.6 (6.6)	1.45 (10.2)	4.7 (10.5)
Fat gain (kg)[d]	-0.9 (1.3)	-4.0 (1.3)[a,b]	3.2 (2.2)[a,b]
Obese	$N = 31$	$N = 26$	$N = 33$
Weight (kg)	4.9 (0.9)	0.5 (2.3)[a,b]	10.9 (3.7)[a,b]
Midupper arm circumference(cm)	-0.5 (1.1)	-1.6 (2.2)[a,b]	-0.3 (1.5)[b]
Triceps skinfold (mm)	-1.2 (7.0)	-2.9 (5.4)	0.02 (6.2)
Thigh skinfold (mm)	-1.2 (11.5)	-3.6 (11.0)	2.8 (9.9)
Upper iliac skinfold (mm)	-2.2 (11.0)	-4.8 (11.1)[b]	2.2 (9.5)[b]
Fat gain (kg)[d]	-2.4 (1.2)	-6.0 (2.2)[a,b]	2.6 (3.0)[a,b]

[*] Statistical differences noted when P value <0.05.
[a] Different from adequate.
[b] Differences between inadequate and excessive.
[c] GWG (Based on third visit weight minus first measured weight using 2009 IOM guidelines).
[d] Fat gain = 0.77 (weight change, kg) + 0.07 (change in thigh skinfold thickness, mm) – 6.13. (Paxton et al. 1998) [21]

minimal fat gain and small positive anthropometric changes, whereas women who gained inadequately had negative anthropometric changes. Higher positive changes in skin folds, midupper arm circumference, weight, and fat gain were all associated with excessive GWG compared with adequate GWG.

The proportion of women who gained outside of the IOM guidelines by 32 wk (54%) in this study is somewhat lower than that reported using national data from women who delivered term but suggestive of a similar pattern by the end of pregnancy (68%) [2,4]. Our observation of women with obesity gaining the least amount of weight and having greater variability in the measurements compared to women with a normal or overweight BMI has been shown previously [10]. Findings of negative skinfold and fat changes for women with obesity in this study suggest they may be mobilizing fat stores to meet the energy needs of pregnancy, whereas, for women with normal weight and overweight, the net positive changes appear to be reflective of building up stores [11,12]. The majority of studies recording

TABLE 4

Results of the multivariable logistic regression model for the association between change in anthropometric indicator from baseline to visit 3 and adequacy of gestational weight gain at visit 3 (GWG)[a,b]

Change in anthropometric indicator from baseline to visit 3	Inadequate GWG β-coefficient (95% CI)	Excessive GWG β-coefficient (95% CI)
Midupper arm circumference (cm) ($n = 352$)	-0.96 (-1.39, -0.53)	0.73 (0.34, 1.12)
Triceps skinfold (mm) ($n = 352$)	-2.58 (-4.2, -1.0)	2.32 (0.86, 3.8)
Thigh skinfold (mm) ($n = 348$)	-5.50 (-8.8, -2.2)	4.33 (1.4, 7.3)
Upper iliac skinfold (mm) ($n = 353$)	-2.40 (-5.2, 0.4)	3.93 (1.4, 6.4)
Fat gain (kg) ($n = 348$)	-3.41 (-3.9, -2.9)	4.08 (3.6, 4.5)

Abbreviations:GWG, gestational weight gain; CI, confidence interval
[a] Based on 2009 IOM guidelines; Adjusted for maternal baseline overweight and obesity status
[b] Referent category is adequate GWG.

changes in anthropometric indicators during pregnancy were conducted in developing countries years ago, where the primary health concern was related to undernutrition, inadequate weight gain, and low birthweight outcomes [23,24]. Similar to these studies, we observed that women who gain inadequately have negative anthropometric changes compared to those who gain adequately. Regardless of country setting (e.g., high income or low income), anthropometric changes have consistently been shown to be predictive of pregnancy complications and infant birthweight and are thus useful in clinical settings [25,26].

Because fat accumulation could not be directly measured, we used the formula by Paxton et al. (1998) [21] that was validated against measured fat gain to calculate fat gain from baseline (entry into prenatal care) to the third visit (on average a 20-wk span). Consistent with Lederman et al.'s (1997) [9] study, we observed that fat gain varied by adequacy of gestational weight gain and that women who gained adequately had minimal fat gain, providing anthropometric evidence supporting the 2009 IOM weight gain recommendations. Updated analysis of the cohort by Lederman et al., [9] using 2009 IOM guidelines, found that both pattern and rate of GWG were associated with fat gain [27]. Differences in their cohort's pattern were that gaining below the guidelines was not associated with fat mass changes [27]. Our study differed from the UK study by Soltani and Fraser (2010) [10] in that we observed differences in the anthropometric indicators during pregnancy, including estimated fat gain by weight status and adequacy of weight gain. The latter outcome was not included in the UK study. It is important to note that we are unable to directly compare the estimates of fat gain between their study and ours due to the different methodology used to calculate fat gain.

There are several limitations to consider when interpreting the findings. First, if weight change occurred between conception and the first weight measurement (collected at 9.8 wks of gestation on average), our calculation may have misclassified adequacy of weight gain. However, because weight and body composition were collected simultaneously, the relationship of changes in these variables should not be impacted by lack of weight measurements earlier in pregnancy. Second, fat gain was not directly measured because current methods for assessing body composition during pregnancy, such as dual energy x-ray absorptiometry or bioelectrical impedance, are not well accepted in pregnancy. More studies using these direct measures are needed to understand how and to what degree women are redistributing fat stores during pregnancy. Our sample size is not large; however, it is larger than previously published studies that have collected similar anthropometric measurements during pregnancy [11,12]. Lastly the generalizability of this study may be limited, as the women were recruited from one clinic, and due to the demographics of the region, resulted in a study sample of highly educated women. However, when examining associations of weight change with anthropometric change, differences by sociocultural variables are less likely to influence findings.

Despite these limitations, our study contributes to the existing literature by addressing several important questions related to the soundness of the 2009 IOM weight gain recommendations [1] using measured weights and other anthropometric indicators across pregnancy in a contemporary cohort. Additional strengths of this study include the prospective cohort design, access to medical records, and information on several potential covariates.

In conclusion, these data illustrate that anthropometric changes over the course of pregnancy differ by maternal early pregnancy BMI and are associated with adequacy of GWG. Women who gained adequately had minimal fat gain while avoiding negative anthropometric changes, lending support for the current weight gain guidelines. More studies are warranted to corroborate our findings and to explore the relationships between these anthropometric changes and metabolic profiles during pregnancy.

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Author contributions

The authors responsibilities were as follows – AMSR, MF, WN, AS: were involved in overseeing the data collection; AMSR: developed the analytical plan and wrote the manuscript; all authors: involved in the design of the study, the interpretation of results, reading of the various drafts, and approved of the final manuscript.

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Data availability

Data described in the manuscript, code book, and analytic code will be available from Dr. Tonja Nansel at NICHD upon request, pending application and approval.

Conflict of interests

The authors report no conflict of interest. Anna Maria Siega-Riz is an Editorial Board Member of Current Developments in Nutrition.

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