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Physical Activity in Pregnancy and Neonatal Body Composition: The Healthy Start Study

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Abstract

Objective—To examine associations between pregnancy physical activity and neonatal fat mass and fat-free mass, birth weight and small for gestational age (SGA).

Methods—We analyzed 826 mother-neonate pairs (term births) participating in the longitudinal Healthy Start study. The Pregnancy Physical Activity Questionnaire was used to assess total energy expenditure and meeting American College of Obstetricians and Gynecologists (the College) guidelines for physical activity during early pregnancy, mid-pregnancy and late pregnancy. Models were adjusted for maternal and neonatal characteristics.

Results—Neonates had mean fat mass of 292.9 grams, fat-free mass of 2,849.8 g, and birth weight of 3,290.7 g. We observed 107 (12.9%) SGA and 30 (3.6%) large-for-gestational age (LGA) births. A significant inverse linear trend between total energy expenditure during late pregnancy and neonatal fat mass ($P_{trend} = 0.04$) was detected. Neonates of mothers in the highest compared to lowest quartile of total energy expenditure during late pregnancy had 41.1 g less fat mass (249.4 vs. 290.5 g; $P = 0.03$). No significant trend was found with total energy expenditure and neonatal fat-free mass or birth weight. Early-pregnancy and mid-pregnancy total energy expenditure were not associated with neonatal outcomes. No significant trend was observed between late-pregnancy total energy expenditure and SGA ($P_{trend} = 0.07$), but neonates of mothers in the highest compared to the lowest quartile had a 3.0 (95% CI 1.4–6.7) higher likelihood of SGA. Meeting the College's physical activity guidelines during pregnancy was not associated with differences in neonatal outcomes.

Conclusions—Increasing levels of late-pregnancy total energy expenditure are associated with decreased neonatal adiposity without significantly reduced neonatal fat-free mass.

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Mrs. Martinez contributed to the development and management of the Healthy Start study.

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Study personnel contributed to data collection, entry and management and development of datasets.

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Introduction

The current American College of Obstetricians and Gynecologists guidelines for physical activity during pregnancy recommend 30 minutes of moderate activity on most days of the week (1). Nevertheless, the role of pregnancy physical activity on neonatal body composition [i.e. fat mass and fat-free mass] is not fully elucidated. Understanding these effects may contribute to developing better guidelines for pregnancy physical activity.

Pregnancy physical activity likely benefits offspring of women across the body mass index (BMI) spectrum, as exercise during pregnancy may result in better blood flow and oxygenation to the fetus (2). Further, in mothers with pre-pregnancy overweight/obesity, physical activity may reduce the availability and delivery of glucose and free fatty acids, potentially reducing the risk of large-for-gestational age (LGA) or macrosomia (3-5) in the offspring and in turn, reduce the risk of future obesity (6-8) and metabolic syndrome (9-11).

There are limited data on the effects of pregnancy physical activity on neonatal body composition in large observational studies. Small randomized controlled trials (RCT) have indicated that neonatal body composition is affected by physical activity (12-14) and may be time-specific, particularly during late pregnancy (13).

We aimed to examine associations between total energy expenditure and meeting physical activity guidelines during early pregnancy, mid-pregnancy, and late pregnancy and neonatal fat mass, fat-free mass, birth weight and small for gestational age (SGA).

We hypothesized that increasing levels of total energy expenditure and meeting guidelines for physical activity during late pregnancy would be significantly associated with reduced neonatal fat mass, but not fat-free mass, birth weight, or SGA.

Materials and Methods

We explored our hypotheses using data from the Healthy Start study, an ongoing longitudinal, prebirth cohort in Colorado that follows ethnically-diverse pregnant women.

The Healthy Start study recruited pregnant women from prenatal obstetrics clinics located at the University of Colorado Hospital Outpatient Pavilion within the Anschutz Medical Campus of the University of Colorado - Denver. Women were not eligible if multiple births were expected or they had a previous stillbirth, if they were less than 16 years of age at consent or had a gestational age at the time of baseline research visit greater than 24 weeks. Of 1,135 mother-neonates pairs with delivery date at or before November 1st, 2013, participants were excluded from analyses if they withdrew consent before delivery (n = 8) or if their index pregnancy resulted in fetal death (n = 16) or a preterm birth (i.e. less than 37 weeks) (n = 80). After exclusion, 1,031 mother-neonates pairs were eligible for this analysis and 826 met criteria for the analytic cohort (i.e. complete data and measured by air displacement plethysmography [PEA POD; Cosmed, USA, Concord, CA] within 72 hours of birth) (Figure 1). Pregnant women enrolled in the study were invited to participate in three research visits. The first visit occurred during early pregnancy (median = 17 weeks; SD: 3.1), followed by a second visit during mid-pregnancy (median = 27 weeks; SD: 2.3)

and a third visit after delivery during hospitalization stay (median = 1 day; SD: 0.5). A total of 1,031 mother-neonate pairs that enrolled in the study and delivered between March 30, 2010 and November 1, 2013 were eligible for this analysis. During recruitment, all mothers provided written informed consent. The Healthy Start study protocol and procedures were approved by the Colorado Multiple Institutional Review Board. Mothers received a monetary incentive for participating in each prenatal research visit.

All data were entered by trained research assistants and verified by the database manager in REDCap (Research Electronic Data Capture) (15), a secure, web-based application designed to support data capture for research studies with validated data entry and features audit trails for tracking data manipulation (15).

Physical activity levels were ascertained through a validated (16) Pregnancy Physical Activity Questionnaire during each research visit assessing a general week of activity during early-, mid- and late pregnancy. The Pregnancy Physical Activity Questionnaire is a semi-quantitative questionnaire consisting of 33 questions, two of which are open-ended, that query the frequency and duration of time spent in 4 domains of activity: household/care giving, occupational, sports/exercise, and transportation activities. Activities were assigned MET values according to the compendium of physical activities (17) and where possible, pregnancy-specific MET values (18). MET intensity values are energy expenditure parameters that are assigned to specific activities through objective measures of physical activity (e.g. actigraph). Reported duration of activity was multiplied by the respective MET value to estimate total energy expenditure (MET-hrs/wk). For analyses, we estimated total energy expenditure for early-, mid- and late pregnancy and analyzed these variables as quartiles (i.e. 25th percentile or below [referent], indicates the lowest level of MET-hrs/wk and 75th percentile or above, indicates the highest level of MET-hrs/wk). Women were categorized by meeting guidelines for physical activity if they did or did not have 7.5 MET-hrs/wk in sports/exercise activities of moderate-intensity or greater (i.e. 30-minutes per day of activity at 3 METs multiplied by 5 days per week) (1) during early pregnancy, mid-pregnancy and late pregnancy.

Neonatal body composition was measured by air displacement plethysmography. The infant body composition system is a 2-compartment model measuring fat mass (i.e. adipose tissue) and fat-free mass (i.e. water, bone, and non-bone mineral and protein) in both absolute and proportionate terms. The system measures neonatal body composition parameters using densitometric techniques based on air displacement plethysmography, (19) which has been shown to be reliable and valid in multiple studies (19-22) with the mean percentage error in volume measurements as low as < 0.05% (20). Trained clinical personnel measured each neonate by air displacement plethysmography up to 3 times following delivery (median = 1 day). The mean of the two closest measures were used for each outcome. Birth weight was ascertained through medical record abstraction (n = 819) and maternal self-report (n = 7). Using United States national reference data (23), SGA was indicated as a birth weight below the 10th percentile for gestational age, given sex of the offspring.

Data on covariates were collected on mother-neonate pairs during research visits and through medical record abstraction. Maternal age at delivery was calculated based on the

difference between offspring delivery date and maternal date of birth. Data on education, gravidity, household income, prenatal smoking and race/ethnicity were collected through research questionnaires. Data on Apgar scores and gestational hypertension were obtained through medical records. Gestational diabetes mellitus (GDM) status was collected through medical records (n = 777) and research visits (n = 49). Maternal pre-pregnancy weight, obtained from research visits (n = 80) and medical records (n = 746), and maternal height, measured at the baseline research visit, were used to calculate pre-pregnancy BMI. Gestational age at delivery was estimated using ultrasound data (n = 211), self-reported last menstrual period (n = 77) or both (n = 538). Neonatal chronological age when measured by air displacement plethysmography was calculated by taking the difference between the date of birth and research visit. Neonatal anthropometric measures (i.e. skinfolds and circumferences) and birth length were obtained during the delivery visit. Using the previously described reference data (23), LGA was indicated as a birth weight above the 90th percentile for gestational age, given sex of the offspring.

All statistical analyses were conducted in SAS 9.3 (SAS Institute, Cary, NC). Covariates were individually entered into models. A variable remained in the model if a Partial F-test showed that the covariate meaningfully contributed to predicting the outcome of interest ($P < 0.10$) or if the adjusted effect size of physical activity was meaningfully altered (i.e.

10% change). Using neonatal fat mass and fat-free mass and birth weight as outcomes, individual multiple linear regression models (PROC GLM) were tested and adjusted means were computed using the LSMEANS function, adjusted for gestational age at birth, chronological age at body composition exam, offspring sex, gravidity, maternal age, race or ethnicity, educational status, household income, pre-pregnancy BMI, and prenatal smoking status. With SGA as an outcome, logistic regression models (PROC LOGISTIC) were used and odds ratios were estimated, adjusted for gravidity, maternal age, race or ethnicity, educational status, household income, pre-pregnancy BMI and prenatal smoking status. Models testing quartiles of total energy expenditure were further adjusted for overall mean total energy expenditure during pregnancy. Pre-pregnancy overweight/obesity was explored as an effect modifier. Linear trend for quartiles of physical activity were tested using contrast statements for 4-level nominal variables.

Results

Of the 1,031 mothers who were eligible to participate, 826 mother-neonate pairs had complete exposure and outcome data and were included in final analyses. There were no clinically relevant differences in mean maternal age (27.7 vs. 27.7 years), previous number of pregnancies (1.3 vs. 1.4), pre-pregnancy BMI (25.8 vs. 25.8 kg/m²), mean total energy expenditure during pregnancy (196.4 vs. 195.8 MET-hrs/wk), gestational age (277.0 vs. 277.1 days), birth weight (3,281.4 vs. 3,290.7 g) or length (49.3 vs. 49.3 cm), or distribution of offspring sex, maternal race or ethnicity, prenatal smoking status, educational attainment, and household income between those who were eligible compared to those included in final analyses.

Among the final sample of 826 mothers, 825 completed the Pregnancy Physical Activity Questionnaire during early pregnancy; 747 completed it during mid-pregnancy and 823

completed it during late pregnancy (Figure 1). All participants completed the questionnaire at least twice during pregnancy with 743 completing it at each research visit. Further, during early pregnancy, mid-pregnancy and late pregnancy, 421; 349 and 311 women met physical activity guidelines, respectively.

The study occurred in Colorado, which varies in altitude and may affect fetal growth (24). Nevertheless, no significant differences were found between neonates who gestated at an elevation greater than 6,000 feet ($n = 12$) compared to at or below 6,000 feet ($n = 814$) in body mass (3,171.0 vs. 3,142.3 grams; $P = 0.81$), fat mass (292.1 vs. 293.0 g; $P = 0.98$) or fat-free mass (2,878.8 vs. 2,849.4 g; $P = 0.76$).

In our analytic cohort ($N = 826$), on average, mothers were 27.7 (95% CI 27.3-28.2) years old, with a pre-pregnancy BMI of 25.8 (95% CI 25.4-26.2) (kg/m^2) and multi-ethnic (16.7% non-Hispanic black; 23.7% Hispanic; 53.4% non-Hispanic white and 6.2% other). Of note, 44.9% were overweight or obese and 17.4% of mothers met guidelines for physical activity throughout pregnancy. Neonates had mean body mass when measured by air displacement plethysmography of 3,142.7 (95% CI 3,114.4-3,171.1) g with 292.9 (95% CI 282.7-303.2) g of fat mass and 2,849.8 (95% CI 2,827.4-2,872.1) g of fat-free mass. Of offspring births, 12.9% ($n = 107$) were SGA and 3.6% ($n = 30$) were LGA (Table 1).

Adjusted associations of early- and mid-pregnancy total energy expenditure with neonatal fat mass and fat-free mass and birth weight were not statistically significant for both linear trend and quartile comparisons (Table 2). Further, pre-pregnancy overweight/obesity did not statistically significantly modify any of these associations.

A statistically significant inverse linear trend was observed with late-pregnancy total energy expenditure and fat mass ($P_{\text{trend}} = 0.04$). Mothers in the highest quartile of late-pregnancy total energy expenditure compared to those in the lowest quartile had neonates with 41.1 grams less fat mass (249.4 vs. 290.5 g; $P = 0.03$). Further, a non-significant inverse trend was detected between late-pregnancy total energy expenditure and offspring birth weight ($P_{\text{trend}} = 0.10$). Compared to neonates of mothers in the lowest quartile of late-pregnancy total energy expenditure, neonates of mothers in the highest quartile had 97.0 g lower birth weight (3,142.9 vs. 3,239.9 g; $P = 0.04$) (Table 2). Pre-pregnancy overweight/obesity was not an effect modifier of the above associations.

There were no statistically significant associations between meeting physical activity guidelines during early-, mid- or late-pregnancy and birth weight, neonatal fat mass or fat-free mass (Table 2) and pre-pregnant overweight or obesity did not modify these relationships.

Linear trend and quartile comparisons of total energy expenditure during early- and mid-pregnancy were not significantly associated with SGA births (Table 3). We did not find a significant linear trend between increasing levels of late-pregnancy energy expenditure and SGA ($P_{\text{trend}} = 0.07$). However, when comparing mothers in the highest quartile of late-pregnancy total energy expenditure to the lowest, the likelihood of having an SGA birth was three times greater (OR 3.0, 95% CI 1.4-6.7; $P = 0.007$). Additionally, mothers in the second quartile of late-pregnancy energy expenditure relative to the lowest quartile were 2.2 times

more likely to have an SGA birth [2.2 (1.1, 4.3); $P = 0.02$]. Meeting guidelines for physical activity during early pregnancy, mid-pregnancy or late pregnancy was not associated with SGA (Table 3).

Discussion

We found that increasing levels of late-pregnancy total energy expenditure were associated with reduced neonatal adiposity. Although we did not find a significant linear trend, we found an increased likelihood of SGA births among mothers with higher levels of total energy expenditure during late pregnancy. Moreover, we found no association between late-pregnancy energy expenditure and neonatal fat-free mass. These findings suggest that the increased likelihood of SGA with increased levels of total energy expenditure during late pregnancy may be due to reduced neonatal adiposity, rather than systematic growth restriction.

SGA is generally assumed to be as a result of systematic growth restriction in the offspring, which is associated with later chronic diseases (25-28). However, if the reduction in offspring birth weight is attributable to reduction in adiposity, as opposed to fat-free mass, which is related to organ development, then the risk of subsequent morbidities may actually be attenuated.

Existing evidence for associations between pregnancy physical activity and SGA and LGA appear to favor protective or null relationships (4, 5, 14). The Danish National Birth Cohort examined close to 80,000 pregnant women and found that exercise at any level had protective effects on the risk of SGA and LGA births relative to no exercise (4). In an RCT (14) of 84 pregnant women randomly assigned to home-based stationary cycling or no exercise, Hopkins et. al found no significant association between exercise and risk of SGA births. In an observational study, Mudd et al. found a significant protective association with physical activity during pregnancy and LGA and no association with SGA (5). Nevertheless, in an older observational study in lean, active pregnant women who continued endurance exercise during pregnancy displayed an increased risk of SGA (29).

Our findings of late-pregnancy physical activity reducing neonatal adiposity appear to be supported by previous experimental studies. A study by Clapp et al. (12) randomized 46 pregnant women to weight-bearing activities or no exercise and found that maternal physical activity improves fetal growth, without increasing infant adiposity (12). In another RCT, Clapp et al. (13) randomized 75 pregnant women to one of three varying weight-bearing physical activity regimens. Mothers who were active during late pregnancy compared to those who were not had offspring with reduced neonatal fat mass (13).

Potential biologic mechanisms for the association between physical activity and neonatal adiposity may include effects on maternal fuels and insulin sensitivity. Physical activity during late pregnancy reduces maternal glucose and insulin levels, (30) and increases maternal insulin sensitivity (31). Lower levels of insulin-like growth factor-1 were found in cord serum among offspring of exercising mothers relative to controls (14). In another study (32), exercise increased maternal leptin levels during late pregnancy and marginally

decreased free fatty acids. Overall, these data suggest potential mechanisms by which maternal physical activity may result in reduced offspring adiposity.

We found that meeting physical activity guidelines during early pregnancy, mid-pregnancy or late pregnancy was not significantly associated with neonatal fat mass, fat-free mass, SGA or birth weight. Furthermore, a large proportion (82.57%) did not meet guidelines throughout pregnancy.

Our study has some limitations. Although we adjusted for several confounders, our findings may be biased by residual confounding. Since we conducted several statistical tests, by chance, we may have falsely rejected a null hypothesis (i.e. type I error), which is why more emphasis was put on tests of linear trend. Pregnancy physical activity was assessed by self-report, but the Pregnancy Physical Activity Questionnaire has been shown to be a valid measure of energy expenditure during pregnancy (16). To mitigate potential concerns related to over reporting physical activity during pregnancy, we analyzed total energy expenditure data as quartiles. In our cohort based in Colorado, we observed a negative mean birth weight z-score. Additionally, 107 (12.9%) births were SGA and only 30 (3.6%) were LGA. Therefore, our results may not be completely generalizable to other populations.

In summary, in a large cohort, increasing levels of total energy expenditure during late pregnancy was associated with reduced neonatal adiposity. We found that women with high levels of late-pregnancy activity had the suggestion of an increased likelihood of SGA as compared to women with low levels. However, our data indicate that such an effect may be attributable to decreases in neonatal fat mass as opposed to fat-free mass. Further study is needed to more comprehensively explore associations of meeting the American College of Obstetricians and Gynecologists guidelines during pregnancy and neonatal body composition, which may lead to more appropriate guidelines for pregnancy physical activity.

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Figure 1.

Study flow diagram for Healthy Start among enrolled participants with a delivery date at or before November 1st, 2013. PEA POD, air displacement plethysmography.

Table 1

Characteristics of Healthy Start Mother-Neonate Pairs Delivered Between March 2010 and November 2013
(N = 826)

Characteristics	Mean (95% CI)
Maternal age (years)	27.7 (27.3, 28.2)
Gravidity ^a	1.4 (1.3, 1.5)
Pre-pregnancy BMI (kg/m ²)	25.8 (25.4, 26.2)
Total energy expenditure (MET-hours/week) ^b	195.8 (189.5, 202.0)
Gestational age (days)	277.1 (276.6, 277.7)
Chronological age (days) ^c	1.1 (1.1, 1.1)
5-minute Apgar score (Out of 10)	8.8 (8.7, 8.8)
Abdominal circumference (cm)	29.4 (29.3, 29.6)
Head circumference (cm)	34.2 (34.1, 34.3)
Mid-thigh circumference (cm)	13.9 (13.8, 14.0)
Mid-thigh skinfold (mm)	6.4 (6.3, 6.5)
Subscapular skinfold (mm)	4.3 (4.2, 4.4)
Triceps skinfold (mm)	4.4 (4.3, 4.4)
Birth length (cm)	49.3 (49.2, 49.5)
Birth weight (g)	3,290.7 (3,261.5, 3,319.9)
Birth weight z-score	-0.4 (-0.4, -0.3)
Total body mass (g) ^d	3,142.7 (3,114.4, 3,171.1)
Neonatal fat mass (g)	292.9 (282.7, 303.2)
Neonatal fat-free mass (g)	2,849.8 (2,827.4, 2,872.1)
Neonatal fat mass (%)	9.0 (8.8, 9.3)
Neonatal fat-free mass (%)	90.9 (90.7, 91.2)
Characteristics	n (%)
Prepregnancy BMI categories (kg/m ²)	
Obese (≥ 30)	165 (20.0)
Overweight (25-29.9)	206 (24.9)
Normal (18.5-24.9)	428 (51.8)
Underweight (<18.5)	27 (3.3)
Race or ethnicity	
Non-Hispanic black	138 (16.7)
Hispanic	196 (23.7)
Non-Hispanic white	441 (53.4)
Other	51 (6.2)
Met College guidelines ^e	
Yes	144 (17.4)
No	682 (82.6)
Prenatal smoking ^f	
Yes	72 (8.7)

Characteristics	Mean (95% CI)
No	754 (91.3)
Gestational diabetes mellitus	
Yes	32 (3.9)
No	794 (96.1)
Preeclampsia	
Yes	26 (3.2)
No	786 (96.8)
Education	
High school degree/high school equivalency certificate or less	269 (32.6)
More than high school	557 (67.4)
Household income ^g	
\$10,000	66 (8.0)
\$10,001 to \$20,000	61 (7.4)
\$20,001 to \$40,000	117 (14.2)
\$40,001 to \$70,000	144 (17.4)
>\$70,000	272 (32.9)
Don't Know	166 (20.1)
Large for gestational age ^h	
Yes	30 (3.6)
No	796 (96.4)
Small for gestational age ⁱ	
Yes	107 (12.9)
No	719 (87.0)
Sex	
Male	425 (51.4)
Female	401 (48.5)

^aTotal number of previous pregnancies.

^bMean total energy expenditure during pregnancy.

^cAge of neonate when measured by air displacement plethysmography.

^dTotal body mass measured by air displacement plethysmography.

^eMeeting American College of Obstetricians and Gynecologists guidelines of 7.5 MET-hrs/wk in sports/exercise activities of moderate-intensity or greater throughout pregnancy.

^fSelf-reported smoking at any study specific research visit.

^gTotal household income before taxes during the past year.

^hBirth weight greater than 90th percentile, given gestational age and sex.

ⁱBirth weight less than 10th percentile, given gestational age and sex.

CI, confidence interval; BMI, body mass index; MET, metabolic equivalent task; College, American College of Obstetricians and Gynecologists;

Table 2

Adjusted Means and Standard Errors for Birth Weight, Neonatal Fat Mass and Fat-Free Mass, by Quartiles of Total Energy Expenditure and Meeting American College of Obstetricians and Gynecologists Guidelines During Early Pregnancy, Mid-pregnancy, and Late Pregnancy

Variables	Fat Mass (g)		Fat-Free Mass (g)		Birth weight (g) ^d	
	Adjusted Means (SE)	P	Adjusted Means (SE)	P	Adjusted Means (SE)	P
<i>Early-pregnancy</i>						
<i>Total energy expenditure (MET-hrs/wk)^{a,c}</i>						
1st quartile	273.9 (14.5)	Ref	2,752.4 (27.3)	Ref	3,172.8 (37.0)	Ref
2nd quartile	279.9 (14.1)	0.68	2,794.4 (26.5)	0.13	3,208.3 (35.9)	0.34
3rd quartile	257.2 (14.0)	0.28	2,774.1 (26.4)	0.46	3,175.6 (35.7)	0.94
4th quartile	281.5 (15.7)	0.70	2,803.8 (29.6)	0.17	3,220.4 (40.0)	0.35
P-trend	0.99		0.26		0.49	
<i>Met College guidelines^{a,b}</i>						
Yes	273.1 (12.1)	0.88	2,765.6 (22.9)	0.20	3,180.9 (30.9)	0.38
No	274.7 (11.4)	Ref	2,791.5 (21.5)	Ref	3,204.7 (29.0)	Ref
<i>Mid-pregnancy</i>						
<i>Total energy expenditure (MET-hrs/wk)^{a,c}</i>						
1st quartile	282.60 (15.2)	Ref	2,783.5 (28.5)	Ref	3,212.7 (38.7)	Ref
2nd quartile	277.46 (15.5)	0.74	2,785.5 (29.1)	0.94	3,200.6 (39.5)	0.76
3rd quartile	262.9 (15.0)	0.23	2,806.1 (28.0)	0.46	3,206.3 (38.1)	0.88
4th quartile	267.9 (17.5)	0.49	2,768.0 (32.9)	0.70	3,178.4 (44.7)	0.53
P-trend	0.39		0.84		0.58	
<i>Met College guidelines^{a,b}</i>						
Yes	271.4 (13.7)	0.77	2,795.1 (25.7)	0.48	3,205.5 (34.9)	0.80
No	274.6 (12.0)	Ref	2,780.5 (22.5)	Ref	3,198.2 (30.5)	Ref
<i>Late-pregnancy</i>						
<i>Total energy expenditure (MET-hrs/wk)^{a,c}</i>						
1st quartile	290.5 (14.2)	Ref	2,801.4 (26.9)	Ref	3,239.9 (36.3)	Ref
2nd quartile	277.4 (14.2)	0.37	2,762.6 (26.8)	0.16	3,173.0 (36.1)	0.07
3rd quartile	277.5 (13.5)	0.38	2,802.4 (25.7)	0.97	3,212.4 (34.6)	0.47

Variables	Fat Mass (g)		Fat-Free Mass (g)		Birth weight (g) [†]	
	Adjusted Means (SE)	P	Adjusted Means (SE)	P	Adjusted Means (SE)	P
4th quartile	249.4 (15.1)	0.03	2,749.8 (28.6)	0.14	3,142.9 (38.6)	0.04
P-trend	0.04		0.30		0.10	
Late-pregnancy						
Met College guidelines ^{a,b}						
Yes	275.0 (12.4)	0.81	2,789.7 (23.4)	0.42	3,204.2 (31.6)	0.51
No	272.6 (11.0)	Ref	2,773.9 (20.9)	Ref	3,186.7 (28.2)	Ref

[†] Birth weight may not equal fat mass and fat-free mass, given neonatal body composition was measured within 72-hours of delivery.

^a Adjusted for gestational and chronological age at body composition exam, offspring sex, gravidity, maternal age, race or ethnicity, educational status, household income, pre-pregnancy BMI, prenatal smoking status, and mean total energy expenditure during pregnancy.

^b Meeting American College of Obstetricians and Gynecologists' guidelines of 7.5-MET-hrs/week in sports and exercise activities of moderate intensity or greater during periods of pregnancy.

^c Medians of MET-hrs/wk by period of pregnancy and quartile: Early pregnancy - 110.9 (1st quartile); 161.0 (2nd quartile); 217.4 (3rd quartile); 337.8 (4th quartile). Mid-pregnancy: 97.9 (1st quartile); 144.0 (2nd quartile); 191.2 (3rd quartile); 286.6 (4th quartile). Late pregnancy: 85.8 (1st quartile); 135.0 (2nd quartile); 180.3 (3rd quartile); 270.2 (4th quartile).

MET, metabolic equivalent task; SE, standard error, College, American College of Obstetricians and Gynecologists.

Table 3

Adjusted Odds Ratios for the Associations Between Total Energy Expenditure and Meeting American College of Obstetricians and Gynecologists' Guidelines During Early Pregnancy, Mid-pregnancy, and Late Pregnancy and Small for Gestational Age

Variables	SGA [†]					
	Early Pregnancy		Mid-pregnancy		Late Pregnancy	
	Odds Ratio (95% CI)	P	Odds Ratio (95% CI)	P	Odds Ratio (95% CI)	P
<i>Total energy expenditure (MET-hrs/wk)^{a,c}</i>						
1st quartile	Referent		Referent		Referent	
2nd quartile	0.8 (0.4, 1.5)	0.51	0.8 (0.42, 1.59)	0.56	2.2 (1.1, 4.3)	0.02
3rd quartile	1.0 (0.5, 1.8)	0.89	0.9 (0.46, 1.66)	0.75	1.8 (0.9, 3.5)	0.11
4th quartile	0.8 (0.3, 1.7)	0.53	1.2 (0.50, 2.70)	0.73	3.0 (1.4, 6.7)	0.007
P-trend	0.66		0.42		0.07	
<i>Met College guidelines^{a,b}</i>						
Yes	1.2 (0.8, 1.9)	0.35	0.8 (0.5, 1.2)	0.29	0.9 (0.6, 1.4)	0.61
No	Referent		Referent		Referent	

[†] Birth weight less than 10th percentile given gestational age and sex.²³

^a Adjusted for gravidity, maternal age, race or ethnicity, educational status, household income, prepregnancy BMI, and prenatal smoking status and mean total energy expenditure during pregnancy.

^b Meeting American College of Obstetricians and Gynecologists' guidelines of 7.5 MET-hrs/week in sports/exercise activities of moderate-intensity or greater during periods of pregnancy.

^c Medians of MET-hrs/wk by period of pregnancy and quartile: Early pregnancy - 110.9 (1st quartile); 161.0 (2nd quartile); 217.4 (3rd quartile); 337.8 (4th quartile). Mid-pregnancy: 97.9 (1st quartile); 144.0 (2nd quartile); 191.2 (3rd quartile); 286.6 (4th quartile). Late pregnancy: 85.8 (1st quartile); 135.0 (2nd quartile); 180.3 (3rd quartile); 270.2 (4th quartile).

SGA, small for gestational age; CI, confidence interval; MET, metabolic equivalent task; College, American College of Obstetricians and Gynecologists.