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Leisure time physical activity before and during mid-pregnancy and offspring adiposity in mid-childhood

Kai Ling Kong, PhD., MS.[1], **Matthew W. Gillman, MD., SM.**[2,3], **Sheryl L. Rifas-Shiman, MPH**[2], and **Xiaozhong Wen, PhD**[1]

[1]Division of Behavioral Medicine, Department of Pediatric, School of Medicine and Biomedical Sciences, State University of New York at Buffalo, Buffalo, NY

[2]Obesity Prevention Program, Department of Population Medicine, Harvard Medical School and Harvard Pilgrim Health Care Institute, Boston MA

[3]Department of Nutrition, Harvard School of Public Health, Boston MA

Abstract

Background—Effects of maternal leisure time physical activity (LTPA) on pediatric obesity are unknown. The objective of this study was to examine associations of maternal LTPA with offspring overall and central adiposity in mid-childhood.

Methods—We analyzed data from 802 mother-child dyads from Project Viva, a prospective pre-birth cohort study. Women reported average weekly LTPA before and during mid-pregnancy. At age 7-10 y, we measured fat, truncal fat, and lean mass with dual-energy X-ray absorptiometry. Using multivariable linear regression, we examined associations of maternal LTPA with offspring adiposity, adjusting for child age and sex, maternal race/ethnicity, education, age, pre-pregnancy BMI, marital status, and smoking status.

Results—Mean (SD) of LTPA before and during mid-pregnancy were 9.5 (8.1) and 7.1 (7.0) h/week. At mean age 7.8 (0.8) y, childhood fat, truncal fat and lean mass indices were 4.3 (1.8), 1.4 (0.8) and 12.9 (1.4) kg/m^2. We did not find that higher maternal LTPA was associated with lower child adiposity outcomes. For example, compared with 0-3 h/week of LTPA during mid-pregnancy, children of mothers with 8+ h/week had fat mass index 0.07 kg/m^2 (95% CI: −0.22, 0.36). In analyses of within-person LTPA change from before to mid-pregnancy, compared with 2+ h/week decrease in LTPA, increased LTPA (2 ± h/week) was associated with a 0.09 kg/m^2 fat mass index (−0.25, 0.43).

Conclusions—Contrary to our hypothesis, higher LTPA before and during mid-pregnancy, and the change between them, were not associated with lower adiposity in mid-childhood.

CORRESPONDENCE TO, Kai Ling Kong, PhD, MS, Division of Behavioral Medicine, Department of Pediatrics, School of Medicine and Biomedical Sciences, State University of New York at Buffalo, 3435 Main St., G56M Farber Hall, Buffalo, NY 14214-3000, Office phone: 1-716-829-6815, Fax number: 1-716-829-3993, kailingkong@gmail.com.

CONFLICT OF INTEREST

Kai Ling Kong, Matthew W. Gillman, Sheryl L. Rifas-Shiman and Xiaozhong Wen declare no conflicts of interest.

Keywords

Leisure time physical activity; Gestation; Adiposity; Childhood obesity

INTRODUCTION

Pediatric obesity is only partly the result of genetic inheritance and unhealthful lifestyles. Early developmental exposures likely play roles in the programming of pediatric obesity and its chronic disease sequela later in life (1, 2). Women are often motivated to modify their behavior during pregnancy for their developing babies as robust evidences show that pre-pregnancy weight and excessive gestational weight gain are associated with offspring risk of being overweight and obese (3–5). Therefore, pregnancy or the pre-conception period may be advantageous times to promote healthful behaviors that could influence offspring health. One of these healthful behaviors is physical activity (PA). Maternal PA can improve insulin sensitivity, which may reduce excess nutrient delivery to the fetus (6). Observational studies and some randomized control trials show that higher amounts of leisure time PA may reduce the risk of excessive gestational weight gain and gestational diabetes, which are both risk factors for offspring obesity (7–10). Observational studies also consistently show that higher amounts of activity during pregnancy are associated with increased likelihood of giving birth to appropriate-for-gestational age versus large-for-gestational age infants (11–13), and lower infant body fat mass (6, 14, 15). Larger infant size is associated with higher body mass index (BMI) later in life (16–18). Therefore, it is possible that children of mothers who participated in more PA during pregnancy have lower adiposity in childhood.

However, limited research examines the long-term impact of mothers' PA during pregnancy on the post-natal adiposity outcomes of their offspring. To our knowledge, only 4 small studies (n = 23 – 104) have examined such associations (14, 15, 19, 20). In sum these studies, which have reliable PA assessment at various time points throughout their pregnancy, raise the possibility of a small inverse association; however, they are limited not only by small sample size, but also by relatively short follow-up periods (1 study to 5 years, the others to less than 2 years), and lack of gold standard adiposity outcome measures.

The objectives of this study were 1) to examine the associations of leisure time physical activity (LTPA) before and during mid-pregnancy with offspring adiposity outcomes in mid-childhood (age 7-10 y); 2) to examine the associations of the change in LTPA from pre-pregnancy to mid-pregnancy with offspring adiposity outcomes. We hypothesized that LTPA before and during mid-pregnancy, and an increase in LTPA during mid-pregnancy from pre-pregnancy are associated with lower offspring overall and central adiposity. At enrollment in the first trimester, we asked women to report LTPA "during the 12 months before this pregnancy". At the mid-pregnancy visit, we asked women to report LTPA "in the past 3 months". We measured children's adiposity with dual-energy X-ray absorptiometry (DXA), a gold standard measure (21).

METHODS

Subjects

Project Viva is an ongoing pre-birth cohort study of pregnant women enrolled between April 1999 and July 2002 from Harvard Vanguard Medical Associates, a multi-site group medical practice in eastern Massachusetts. All pregnant women in the study signed informed consent, and the study protocols were approved by the Institutional Review Board of Harvard Pilgrim Health Care. Details of recruitment and data collection have been published elsewhere (22). Exclusion criteria include non-singleton pregnancy, planning to relocate before delivery, unable to answer questions in English, and gestational age >22 completed weeks at initial prenatal visit. Please refer to Figure S1 for participant flow chart. Briefly, among 2,128 women with live births, 1,683 completed self-reported pre-pregnancy LTPA questions, and 1,620 completed the mid-pregnancy LTPA questions. At mid-childhood visits (age 7-10 y), we obtained DXA measurements of 802 children born to mothers who completed either the pre-pregnancy or mid-pregnancy LTPA questionnaires (n = 735 with pre-pregnancy LTPA and child DXA measurements; n = 718 with mid-pregnancy LTPA and child DXA measurements; n = 651 with pre- and mid-pregnancy LTPA and child DXA measurements).

Compared with the 1,326 women who did not meet these criteria, the 802 women in our analytic sample were slightly older [mean, 32.2 vs. 31.6 y], and their children had slightly longer gestation lengths [39.6 vs. 39.3 weeks] and were heavier at birth [3505 vs. 3434 g]. Our analytic sample also showed a higher proportion of maternal white race (69.8% vs. 64.5%), graduate education (34.5 % vs. 26.2 %), and household income exceeding $70,000 (64.8% vs. 58.7%) and lower smoking rates during pregnancy (9.4% vs. 14.6%). However included vs. excluded participants did not differ on mean self-reported LTPA before and during pregnancy (Table S2). Participants who reported to have higher LTPA were non-married women, and women with low social economic status (Table S3).

Measures

Exposures – Leisure Time Physical activity before pregnancy and during mid-pregnancy—The PA questionnaire used in Project Viva was a modification of the leisure time activity section of the Physical Activity Scale for the Elderly (PASE) (23). Modifications included: 1) instead of using the previous 7 days as a referent time period, we asked women to average their weekly LTPA participation; 2) we combined light and moderate activities. We asked women to report h/week in integer values for each of the 3 classes of LTPA: 1) walking (for fun or exercise, including to or from work, but not at work), 2) light-to-moderate LTPA (for example, yoga, bowling, stretching classes and skating—not including walking), 3) vigorous LTPA (for example, jogging, swimming, cycling, aerobics class, skiing, or other similar activities). The examples in each class are common among women in the northeastern United States. This modified PA questionnaire has been shown to be associated with abnormal glucose tolerance and excessive gestational weight gain during pregnancy (7, 10).

At the initial study visit (mean 10.4 weeks of gestation), women reported LTPA participation for the 12 months before pregnancy. At 26-28 weeks of gestation they completed the same questionnaire for the preceding 3 months, the mid-pregnancy visit (mean 27.9 weeks of gestation).

Outcomes – DXA measurement of overall and central adiposity—At the mid-childhood visit, we performed whole-body DXA scans using Hologic model Discovery A (Hologic, Bedford, MA). The research staff calibrated the instrument for quality control on visit days. A single trained research assistant used Hologic software version 12.6 for scan analysis. The trained DXA analyst checked all scans for positioning, movement, and artifacts. The analyst also defined body regions of the scans for analysis. The intra-rater reliability for body compartments was very high (r = 0.99). We calculated DXA total fat mass index (FMI), truncal fat mass index (TFMI) and total lean mass index (LMI) (mass in kg/(height in meters)^2) (24). These DXA measurements have been shown associated with cardiometabolic biomarker among children of our sample population (25).

Covariates – confounders and effect modifiers—In Project Viva, we have collected data on a range of variables from early pregnancy through mid-childhood. At the initial study visit, we collected information on height from the electronic medical records, self-reported pre-pregnancy weight, demographic and socioeconomic information, dietary intake from a semi-quantitative Food Frequency Questionnaire calibrated for use in pregnancy (26), and medical and reproductive history. For this study, we considered the following variables as potential confounders: child age and sex; maternal race/ethnicity (white, black, other), education (less than college, college grad, graduate studies), age at enrollment, pre-pregnancy BMI, marital status (single, divorced, or widowed vs. married or living with a partner), smoking status (never smoked, former smoker, smoked during pregnancy), mid-pregnancy total energy intake, annual household income (less than $40,000, $40,000 to $70,000, more than $70,000); and paternal BMI. We also considered pre-pregnancy BMI and child sex as potential effect modifiers.

Data analysis

We calculated weekly LTPA as the sum of walking, light-to-moderate and vigorous LTPA. Our main exposures were pre-pregnancy LTPA, mid-pregnancy LTPA, and change from pre-pregnancy to mid-pregnancy LTPA. In addition to using LTPA as a continuous variable (h/week), we further classified LTPA into tertiles based on the distribution (pre-pregnancy LTPA: 0-5 h/week, 6-10 h/week and 11 or more h/week; mid-pregnancy LTPA: 0-3 h/week, 4-7 h/week and 8 or more h/week). For change in LTPA from pre- to mid-pregnancy, we categorized women into the following groups: “decrease” (decrease of 2+ h/week), “maintenance” (change of 0 ± 1 h/week), and “increase” (increase of 2+ h/week).

We used multivariable linear regression models to examine associations of LTPA before and during mid-pregnancy, and change in LTPA with continuous childhood adiposity outcomes. We built two models: Model 1, adjusted for child age at DXA measures and sex; and Model 2 utilized Model 1 plus additional adjustment for confounders. We included confounders if the changed effect estimates by at least 10%. We added each potential confounder to the basic model, one at a time, to examine its influence. In the final model, we included child age and sex; maternal race/ethnicity, education, age, pre-pregnancy BMI, marital status, and smoking status. We addressed effect modification or interaction by pre-pregnancy BMI and child sex. We performed statistical analyses using SAS version 9.3 (Cary, NC).

RESULTS

Table S1 shows the characteristics of eligible mother-child dyads in our analytic samples. Overall, participants in the study were predominantly married women or women living with a partner (~ 92%), educated with at least a college degree (~ 70%), and white (~70%). The women's mean (standard deviation [SD]) age was 32.3 (5.2) y, and pre-pregnancy BMI was 24.7 (5.0) kg/m^2.

Overall, women in our analytic sample were relatively active based on their self-reported LTPA. Only 13.9% of women had 2 h or less of LTPA per week, and it increased to 23.4% at mid-pregnancy assessment. The mean pre-pregnancy LTPA was 9.5 (8.1) h/week, and in mid-pregnancy it dropped to 7.1 (7.0) h/week. On average, women decreased LTPA by 2.6 (7.5) h/week from pre-pregnancy to mid-pregnancy: 53.0% of women decreased by 2+ h/week; 27.3% maintained 0 ± 1 h/week; and 19.7% increased by 2+ h/week. The mean age at which we performed DXA measurements was 7.8 (0.8) years. In mid-childhood, mean offspring FMI was 4.3 (1.8) kg/m^2, TFMI was 1.4 (0.8) kg/m^2, and LMI was 12.9 (1.4) kg/m^2 for the mid-pregnancy analytic sample.

The associations between categorical and continuous variables for LTPA with offspring overall and central adiposity are shown in Table 1. There were no substantial differences in estimated associations between Model 1 and Model 2, suggesting non-significant evidence of confounding. The confounder-adjusted model (Model 2) showed that compared with 0-5 h/week of pre-pregnancy LTPA, FMI of children of mothers with 6-10 h/week was 0.12 kg/m^2 (95% CI: −0.17, 0.40), TFMI was 0.05 kg/m^2 (−0.07, 0.18) and LMI was 0.04 kg/m^2 (−0.17, 0.24); for 11+ h/week, FMI was 0.10 kg/m^2 (−0.19, 0.39), TFMI was 0.07 kg/m^2 (−0.06, 0.20), and LMI was 0.11 kg/m^2 (−0.10, 0.32). We observed similar null results for the associations of LTPA during mid-pregnancy with offspring overall and central adiposity. Please refer to Table 1 for detailed results.

The association of three different categories (decrease, maintenance, increase) and continuous change in LTPA with offspring overall and central adiposity are shown in Table 2. Likewise, we did not observe substantial differences in estimated associations across models 1, 2, and 3, suggesting non-significant evidence of confounding. Overall, the results were null. For example, in Model 3 (confounders and pre-pregnancy leisure time PA adjusted model) when compared to offspring of mothers who decreased their LTPA during mid-pregnancy, FMI of offspring of mothers who increased 2 or more h/week of LTPA was 0.09 kg/m^2 (−0.25, 0.43), TFMI was 0.03 kg/m^2 (−0.12, 0.18) and LMI was 0.08 kg/m^2 (−0.16, 0.33). The results were null for the continuous variable of change in LTPA.

Additionally, we analyzed effect modification by pre-pregnancy BMI and child sex between the relationships of maternal LTPA (pre-pregnancy, mid-pregnancy and change in LTPA) and offspring adiposity outcomes in mid-childhood. Overall, there were no differences in the stratum-specific estimates between the relationships (data not shown). We also evaluated associations of walking, light-to-moderate and vigorous LTPA separately with mid-childhood adiposity. The results were similar to LTPA, thus, they did not provide additional information.

DISCUSSION

In a prospective U.S. pre-birth cohort, we examined the associations of LTPA before and during mid-pregnancy with offspring adiposity outcomes in mid-childhood (age 7-10 y). Contrary to our hypothesis, LTPA before and during mid-pregnancy were not associated with offspring overall and central adiposity, or with lean mass, in mid-childhood. Similarly, increases in LTPA from pre-pregnancy to mid-pregnancy were not associated with lower mid-childhood adiposity. The lower limits of the confidence intervals of the estimates of our analysis effectively rule out substantial protective effects, that is, we found meaningfully null results.

Preventing pediatric obesity through maternal lifestyle before birth is a relatively new paradigm in conquering the public-health consequences that manifest as a result of obesity. Observational studies, including our own unpublished data, consistently provide evidence that maternal LTPA participation decreases the likelihood of giving birth to large-for-gestational age infants (11–13). However, the existing evidence of long-term benefits of maternal LTPA on child adiposity outcomes later in life is scarce and inconsistent. Among the four small studies in the literature, Clapp and colleagues' case-control study showed that 5-year-old offspring of women who exercised during mid-pregnancy weighed less (18.0 ± 0.5 vs. 19.5 ± 0.6 kg) and were leaner (Ponderal Index: 1.40 ± 0.02 vs. 1.47 ± 0.03; sum of skinfolds: 37 ± 1 vs. 44 ± 2 mm; arm fat area: 7.89 ± 0.35 vs. 9.23 ± 0.36 cm^2) compared to the offspring of women who discontinued exercise during mid-pregnancy (15). However, a second case-control study by Clapp and colleagues did not show the same results. At 1 year assessment, the anthropometric measurements of the offspring of mothers who exercised during pregnancy were not significantly different than the control group (weight: 9.68 ± 0.15 vs. 9.75 ± 0.18 kg; percent body fat: 25.8 ± 0.7 vs. 26.0 ± 1.1; abdominal circumference: 46.8 ± 0.5 vs. 48.3 ± 0.5 cm) (14). Two other studies suggested small beneficial effects of maternal PA on offspring anthropometric outcomes (19, 20). Mattran et al showed that recall, at 16 to 22 months post-partum, of 3rd trimester LTPA was marginally associated with lower toddler weight ($r_s = -0.39$, $p = 0.06$) and weight-for-length z-score ($r_s = -0.40$, $p = 0.06$) between 18 to 24 months of age (19). In a randomized-controlled trial of walking intervention among 37 overweight and obese women, Kong et al showed a trend towards significance in lower weight-for-length z-score among offspring of obese women in the intervention (0.17 ± 0.71) versus control group (1.04 ± 1.26) at 6 months post-partum (20).

In our study, the impact of maternal LTPA on offspring long-term health outcomes may have been masked by the relatively stronger effects of the child's own lifestyle factors. Another possibility for the null associations is that maternal self-reported LTPA is subject to under- or over-reporting and recall bias (27). This potentially led to considerable misclassification when we used it as a categorical exposure. However, in our previous publications using the same measures, vigorous LTPA before pregnancy and light-to-moderate LTPA during mid-pregnancy were associated with abnormal glucose tolerance during pregnancy (10). Mid-pregnancy walking and vigorous LTPA were inversely associated with excessive gestational weight gain (7). In addition, the decreases we observed in Project Viva in term of the amount of moderate and vigorous LTPA from pre-pregnancy to mid- and post-pregnancy, with relative sparing of walking, offer face validity to our measure (28). Additionally, we did not collect data on 1st trimester LTPA. It is possible that we failed to capture this critical period, but it is more likely that assessing activity in later pregnancy, which is the time of maximum fetal growth, would have longer-term effects on childhood adiposity. We also did not include occupational PA. In a non-pregnant population, occupational PA could potentially decrease the participation in recreational PA (29, 30). Lastly, given that Project Viva represents a non-low-income population in eastern Massachusetts; our results might not be generalizable to other populations. Additionally, there might be selection bias in our data set since women included in this present analytic sample were slightly older and had higher social economic status compared to those excluded.

Strengths of our study include a large number of potential confounders collected from pregnancy through mid-pregnancy. Secondly, because we collected data on pre-pregnancy activity we were able to examine change in LTPA from before to during mid-pregnancy. Thirdly, we obtained outcome measures—with DXA, a reference standard for adiposity in epidemiologic studies, in which intensive gold standard measures like 4-compartment models are infeasible (31). In conclusion, despite evidence that LTPA reduces pregnancy outcomes that are themselves related to childhood obesity, we did not observe associations between LTPA participation, during and before pregnancy, with offspring mid-childhood adiposity.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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Kai Ling Kong initiated and developed the research question, led the analytic plan, conducted all data analyses, drafted the manuscript, and approved the final manuscript as submitted. Matthew W. Gillman and Xiaozhong Wen contributed to the development of research question and the analytic plan, interpreted the results, made major contributions to revising the manuscript, and approved the final manuscript as submitted. Sheryl L. Rifas-Shiman contributed to the data analyses, result interpretation, and revision of the manuscript; and approved the final manuscript as submitted.

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WHAT'S KNOWN ON THIS SUBJECT

Increasing evidence suggests fetal origins of pediatric obesity. High amount of maternal leisure time physical activity is associated with lower risk of macrosomia. However, limited research has examined the long-term impact of maternal physical activity on child adiposity outcomes later in life.

WHAT THIS STUDY ADDS

Prospectively, we found that leisure time physical activity before and during pregnancy, or change in leisure time physical activity was neither associated with offspring overall adiposity nor with offspring central adiposity in mid-childhood (7-10 yo), measured using dual-energy X-ray absorptiometry.

Table 1

Associations of pre-pregnancy and mid-pregnancy leisure time physical activity with offspring adiposity outcomes in mid-childhood

		Fat mass index (kg/m^2)		Truncal fat mass index (kg/m^2)		Lean mass index (kg/m^2)	
		Model 1	Model 2	Model 1	Model 2	Model 1	Model 2
	n (%)	Mean Difference (95% CI)					
Pre-pregnancy LTPA (categorical)							
0-5 h/week	247 (33.6)	0.0 (ref)	0.0 (ref)	0.0 (ref)	0.0 (ref)	0.0 (ref)	0.0 (ref)
6-10 h/week	239 (32.5)	−0.02 (−0.31, 0.28)	0.12 (−0.17, 0.40)	0.00 (−0.13, 0.13)	0.05 (−0.07, 0.18)	−0.08 (−0.30, 0.14)	0.04 (−0.17, 0.24)
11+ h/week	249 (33.9)	0.01 (−0.28, 0.30)	0.10 (−0.19, 0.39)	0.03 (−0.10, 0.17)	0.07 (−0.06, 0.20)	0.08 (−0.14, 0.30)	0.11 (−0.10, 0.32)
Pre-pregnancy LTPA, per 2 h/week	735 (100)	−0.02 (−0.05, 0.01)	−0.02 (−0.05, 0.01)	0.00 (−0.02, 0.01)	0.00 (−0.02, 0.01)	0.00 (−0.03, 0.02)	−0.01 (−0.03, 0.02)
Mid-pregnancy LTPA (categorical)							
0-3 h/week	236 (32.9)	0.0 (ref)	0.0 (ref)	0.0 (ref)	0.0 (ref)	0.0 (ref)	0.0 (ref)
4-7 h/week	246 (34.3)	0.13 (−0.18, 0.43)	0.20 (−0.09, 0.49)	0.06 (−0.08, 0.20)	0.10 (−0.04, 0.23)	0.07 (−0.15, 0.30)	0.16 (−0.05, 0.37)
8+ h/week	236 (32.9)	−0.01 (−0.32, 0.30)	0.07 (−0.22, 0.36)	0.00 (−0.14, 0.14)	0.03 (−0.10, 0.17)	−0.01 (−0.24, 0.22)	0.03 (−0.18, 0.25)
Mid-pregnancy LTPA, per 2 h/week	718 (100)	0.01 (−0.03, 0.05)	0.02 (−0.02, 0.05)	0.01 (−0.01, 0.02)	0.01 (−0.01, 0.02)	0.00 (−0.03, 0.03)	0.00 (−0.03, 0.02)

Model 1: Adjusted for child's sex and age at DXA measures

Model 2: Additionally adjusted for maternal race/ethnicity, education, age, pre-pregnancy BMI, marital status, and smoking status

LTPA = leisure time physical activity, derived by adding self-reported walking, light/moderate and vigorous physical activity; SD = standard deviation;

CI = confident interval

Table 2

Associations of change in leisure time physical activity from pre-pregnancy to mid-pregnancy with offspring adiposity outcomes in mid-childhood

		Fat mass index (kg/m^2)			Truncal fat mass index (kg/m^2)			Lean mass index (kg/m^2)		
		Model 1	**Model 2**	**Model 3**	**Model 1**	**Model 2**	**Model 3**	**Model 1**	**Model 2**	**Model 3**
	n (%)	**Mean Difference (95% CI)**								
Change in LTPA (categorical)										
Decrease (−2+ h/week)	345 (53.0)	0.0 (ref)	0.0 (ref)	0.0 (ref)	0.0 (ref)	0.0 (ref)	0.0 (ref)	0.0 (ref)	0.0 (ref)	0.0 (ref)
Maintenance (0 ± 1 h/week)	178 (27.3)	−0.11 (−0.41, 0.19)	−0.13 (−0.41, 0.16)	−0.24 (−0.55, 0.07)	−0.08 (−0.22, 0.05)	−0.08 (−0.21, 0.05)	−0.12 (−0.26, 0.02)	−0.11 (−0.34, 0.11)	−0.11 (−0.32, 0.10)	−0.13 (−0.36, 0.10)
Increase (2+ h/week)	128 (19.7)	0.11 (−0.23, 0.45)	0.18 (−0.15, 0.50)	0.09 (−0.25, 0.43)	0.03 (−0.12, 0.18)	0.06 (−0.08, 0.21)	0.03 (−0.12, 0.18)	0.11 (−0.14, 0.36)	0.10 (−0.14, 0.34)	0.08 (−0.16, 0.33)
Change in LTPA, per 2 h/week	651 (100)	0.01 (−0.02, 0.05)	0.03 (−0.01, 0.06)	0.02 (−0.02, 0.06)	0.00 (−0.01, 0.02)	0.01 (−0.01, 0.02)	0.01 (−0.01, 0.03)	−0.01 (−0.04, 0.01)	0.00 (−0.03, 0.02)	−0.01 (−0.04, 0.02)

Model 1: Adjusted for child’s sex and age at DXA measures

Model 2: Additionally adjusted for maternal race/ethnicity, education, age, pre-pregnancy BMI, marital status and smoking status

Model 3: Additionally adjusted for pre-pregnancy LTPA

LTPA = leisure time physical activity, derived by adding self-reported walking, light/moderate and vigorous physical activity; SD = standard deviation;

CI = confident interval

Change in LTPA = pre-pregnancy LTPA - mid-pregnancy LTPA