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A prospective study of the association between vigorous physical activity during pregnancy and length of gestation and birthweight

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Summary

Current U.S. pregnancy-related physical activity recommendations do not provide specific guidance for vigorous intensity activity. Our objective was to examine the associations between vigorous physical activity during pregnancy and length of gestation and birthweight. Women were recruited before 10 weeks gestation. At 13-16 weeks gestation, participants reported the type, frequency, and duration of their typical weekly vigorous physical activities. Activity domains included recreational, occupational, household, and child/adult care. Infant birth date was obtained from medical or vital records; if unavailable, self-report was used. Birthweight (from vital records) was studied among term births. We analyzed gestational age among 1,647 births using discrete-time survival analysis. We used logistic and linear regression to analyze preterm birth (birth at <37 weeks) and birthweight, respectively. Vigorous recreational activity was associated with longer gestation (any vs. none, hazard ratio (HR) [95% CI]: 0.85 [0.70, 1.05]) and we did not detect any dose-response association. Higher frequency of vigorous recreational activity sessions (adjusted for total volume of activity) was associated with a decreased odds of preterm birth (≥ 4 sessions/week vs. 0 or 1, OR [95% CI]: 0.08 (0.006, 1.0). Birthweight was not associated with physical activity measures. In summary, vigorous physical activity does not appear to be detrimental to the timing of birth or birthweight. Our data support a reduced risk of preterm birth with vigorous recreational activity, particularly with increased frequency of recreational activity sessions. Future studies should investigate the components of physical activity (i.e. intensity, duration, and frequency) in relation to birth outcomes.

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Introduction

In the United States (U.S.), the prevalence of preterm birth has risen over the last two decades to approximately 12%.(1) This increase is of pressing public health concern because preterm birth is a leading cause of morbidity and mortality in U.S. infants.(2-4) Physical activity is one hypothesized risk factor for preterm birth or growth restriction.

Animal studies suggest decreased uterine blood flow during physical activity (5-8), but studies in women are inconclusive (9-11). Several studies have reported an increase in fetal heart rate during maternal physical activity (12-16), although changes in fetal heart rate may occur in response to maternal epinephrine and may not reflect a decrease in oxygen (12-15). Physical activity has been associated with decreased maternal blood glucose during (17) or after (18-21) physical activity. Physical activity during pregnancy lowers insulin levels and it is unclear how long the decrement lasts.(18, 19, 21) Relative insulin resistance is a normal adaptation of pregnancy, and is thought to increase glucose availability to the fetus.(22) Decreasing insulin resistance may leave the fetus to compete with its mother for glucose.(18)

The epidemiologic literature relating physical activity to risk of preterm birth or growth restriction is growing, but inconclusive. Physical activity encompasses several types or modes including recreational, household, child care and occupational activity. These modes of physical activity may differ in their associations with preterm birth and growth restriction. The literature examining the association between physical activity and preterm birth or birthweight is limited by assessments that do not include multiple modes of physical activity.(23) Few studies have examined household and child care activities as distinct exposures in relation to preterm birth or birthweight. A large literature relates occupational physical activities to both preterm birth and birthweight (reviewed by Bonzini et al.(24)); however, the measures of occupational activity in these studies are limited. Some studies focus on specific occupational activities (e.g., lifting only or standing only); others involve environmental stressors, like chemical exposures or noise.

Recreational physical activity has been studied as a distinct exposure, but the literature is still inconclusive. A recent Cochrane review of eleven randomized trials with 472 total participants suggested that the risk of preterm birth may be higher in women who perform recreational physical activity during pregnancy, although no association was detected with gestational age.(25) They concluded that the data are insufficient to draw firm conclusions.

The physical activity literature is also limited by studies that have not measured frequency and duration of activity. This limits their ability to assess either dose-response or the independent associations of these components of physical activity with pregnancy outcomes.

Current physical activity recommendations from the American College of Obstetricians and Gynecologists (26) and the U.S. Department of Health and Human Services (27) do not specifically address vigorous intensity activity, suggesting that studies of the associations of vigorous activity may be informative to those who make recommendations about physical activity, as well as for women and their health care providers.

From a summary of this literature several research questions remain. First, what is the association of each mode of physical activity (recreational, household, child care, occupational) with preterm birth or birthweight? And, is there a dose-response association? Second, how are frequency and duration of physical activity related to preterm birth or birthweight? Third, what is the association between vigorous physical activity and preterm birth or birthweight? Our objective was to address these questions in a large pregnancy cohort, *Right From the Start* (RFTS).

Methods

RFTS is an ongoing investigation of early pregnancy health. The study includes three waves of enrollment (RFTS1, 2 and 3). The physical activity questions differed slightly between waves 1 and 2/3, and thus only RFTS2/3 are included in this analysis. RFTS2/3 enrolled women from central North Carolina from 2004 to 2007.

RFTS invited women to participate through advertisements and community outreach. Study materials encouraged women planning a pregnancy or in early pregnancy to contact study staff through a toll free phone number. The recruitment methodology of RFTS2/3 is similar to that of RFTS1 and has been described previously.(28) The study was approved by the Institutional Review Boards of the University of North Carolina and Vanderbilt University.

When women called to volunteer, study staff screened them to determine eligibility and, if eligible, collected the woman's age and pre-pregnancy weight. Women were eligible if they were currently trying to conceive or had been pregnant less than ten weeks based on self-report of their last menstrual period. Women also had to be at least 18 years of age, conceiving without assisted reproductive technology, willing to have a first trimester ultrasound at one of the study's ultrasound locations, intending to remain in the area for the next 18 months, intending to carry the pregnancy to term, able to access a telephone for the first trimester interview, fluent in either English or Spanish, and able to identify a prenatal or primary care provider at the time of screening. This portion of the study included 1,861 live births beyond 20 completed weeks of gestation. We further restricted eligibility to the first pregnancy among women who participated in RFTS2/3 more than once (N=1,735), singleton gestations (N=1,708), and women who completed the first trimester interview (N=1,647). Compared to women who completed the first trimester interview (N=1,647), women who did not complete the interview (N=61) were more likely to be under 30 years of age (67% vs 48%), Black Non-Hispanic (30% vs. 12%), unmarried (39% vs 6%), obese (21% vs 16%), and have less than a college education (56% vs 24%).

Outcomes

Multiple data sources were used to obtain and confirm infant date of birth. The hierarchy of the sources was hospital discharge summaries and prenatal care records (51%), birth and fetal death records (32%), and participant self-report (17%). Birthweight was obtained from vital record linkage for all participants. Gestational age at birth was estimated based on last menstrual period and corrected to the first trimester ultrasound estimate only if the difference between the two was more than seven days. The ultrasound was performed between six and twelve weeks of gestation.

Physical activity

In a telephone interview targeted for 14 weeks gestation (mean and median: 14 weeks, range: 7-20 weeks), women were asked to describe their physical activities by mode (recreational, occupational, indoor/outdoor household and child/adult care). This questionnaire was based on a modified version of a structured seven day recall, with evidence for validity and reliability among pregnant women.(29) Women were asked to report if they do any “hard” or “very hard” recreational physical activities in a typical week. The description “hard or very hard” is a measure of vigorous intensity based on the Borg perceived exertion scale which has been found to correlate strongly with heart rate and oxygen uptake.(30) Participants were then asked to describe the type of activity and how often and for how long they performed the activity. Women who reported engaging in recreational activity but did not describe it as “hard” or “very hard” were considered to engage in non-vigorous recreational activity.

Occupational, indoor/outdoor household, and child/adult care physical activities were assessed with analogous questions and coded similarly. Occupational activities included lifting or carrying boxes and lifting and transporting patients. Examples of household activities include washing, folding, and carrying laundry, vacuuming, washing floors, and gardening. Examples of child/adult care activities include lifting and carrying children, bathing children, and lifting or transporting adults.

We summed the minutes per week of each recreational activity (i.e., jogging + swimming + walking) to obtain the total minutes per week of vigorous recreational activity. Similarly, we summed the minutes per week of each activity, within each of the other modes, to obtain the total minutes of vigorous occupational, household, and child/adult care activity, respectively. Finally, we summed over all modes to obtain the total minutes of vigorous physical activity.

Metabolic equivalent (MET) values were assigned to recreational activities only, based on the Compendium of Physical Activities.(31) The Compendium (originally published in 1993,(32) updated in 2000(31)) was developed to compare the intensities of different physical activities across participants. We multiplied the MET value for a given activity by the minutes per week of that activity and summed across activities to obtain total MET-minutes per week. METs were assigned by the first author (AMZJ) and reviewed by the second author (KRE). MET values are a measure of absolute intensity while the participants' categorization of an activity as "hard or very hard" is a measure of perceived or relative intensity. Thus our analysis contained two assessments of intensity. MET values have not been measured in pregnant populations and thus may not be accurate for pregnant women. Given the numerous physiologic and metabolic changes that occur during pregnancy it is possible that the woman's characterization of the intensity of the activity is more accurate than MET values assigned to a given activity. Therefore, our presentation of results focused on perceived intensity and we present the results based on absolute intensity (MET values) only where they differed from the perceived intensity results.

The cumulative frequency of vigorous recreational activity sessions per week was calculated as the sum of the individual frequencies reported for each activity. For example, if she reported walking three times per week and swimming two times per week her cumulative frequency would be five sessions per week. The average duration of a recreational activity session was calculated by dividing the total reported minutes per week of vigorous recreational activity by the cumulative frequency of vigorous activity sessions. From the previous example, if she reported 60 minutes of walking per week and 40 minutes of swimming per week she would be assigned an average duration of 100/5 = 20 minutes/session.

Women were also asked to report if their overall current physical activity had increased, decreased or stayed the same compared with pre-pregnancy activity. They were also asked if they changed their behaviors in preparation for becoming pregnant. If she answered affirmatively she was asked what she changed. The interviewer did not read a list of responses, but some women responded that they started exercising and these responses were coded. A woman could give multiple responses.

Covariates

The screening interview and the telephone interview collected information on important covariates including sociodemographics, reproductive history, presence of nausea and vomiting in early pregnancy, and lifestyle factors. Weight and height were measured at the first trimester ultrasound. If this measure was missing, then her self-reported weight and height from the first trimester questionnaire were used.

Covariates for these analyses were chosen if they were considered to be potential confounders based on directed acyclic graphs (33) constructed for each outcome. In all models, we considered adjustment for maternal age, race/ethnicity, education, income, marital status, alcohol consumption, body mass index, cigarette smoking, illicit drug use, history of miscarriage, history of preterm birth, parity, vaginal bleeding, nausea/vomiting, and history of any type of diabetes. These variables were included in the models if their removal changed the estimates by more than 10% for preterm birth and 20% for birthweight.

Behavioral characteristics were reported in the first trimester questionnaire. Current smokers include women who were smoking at the time of interview and who reported quitting in the previous four months. Former smokers were women who reported quitting at least four months prior to the questionnaire. Alcohol use was categorized into women who have never used alcohol, current users, those who stopped drinking within four months of interview and those who stopped drinking more than four months from the interview.

Statistical analysis

Analyses were performed with SAS software, version 9.1. We used a standard multivariable logistic regression to examine the association between physical activity and preterm birth as a dichotomous variable (<37 completed weeks of gestation). For comparison with previous studies we also evaluated the association between physical activity and length of gestation using a discrete time survival model.(34)

Among term births, we used a linear regression model to examine physical activity and birthweight, adjusted for gestational week at birth. Birthweight in preterm infants can reflect either their prematurity or growth restriction or both. Because the outcome is heterogeneous in preterm infants, we limited our analysis of birthweight to term infants. To improve the precision of our birthweight model, we included two strong predictors, maternal height and infant gender. The other outcomes were not modeled with linear regression, and thus adjustment for non-confounders is not warranted.(35)

Continuous variables, including our exposures of interest, were finely categorized and examined with each outcome variable in an unadjusted analysis. The shape of the crude association of each variable with each outcome was visually inspected to determine the appropriate structure (linear, quadratic, categorical) and, if categorical, the number and location of cutpoints. More parsimonious models with fewer parameters were compared to the full model containing the highly categorized variable. Fewer parameters were used if information was not lost when compared to the highly parameterized model (likelihood ratio test p-value >0.05). For each mode of vigorous physical activity (recreational, occupational, household and child/adult care) the minutes of activity were categorized into tertiles resulting in five categories: no activity, non-vigorous activity, and tertiles of the minutes of vigorous activity. The total minutes of vigorous physical activity was divided into five categories: no physical activity reported or only non-vigorous activity reported, and four categories of the total minutes of vigorous activity. We combined the “none” and “non-vigorous” categories because the number of women who reported no physical activity in any mode was small (2%).

For vigorous recreational physical activity only, we conducted separate multivariable analyses for perceived intensity (minutes per week) and absolute intensity (MET-minutes per week), duration of vigorous recreational activity session, and frequency of vigorous recreational activity sessions. Duration and frequency were modeled separately and both were adjusted for the total minutes of recreational activity (as recommended by Lee and Skerret(36)), the previously described covariates, and the other modes of physical activity (household, occupational, child/adult care). Women who perform zero minutes of recreational activity also had a frequency of zero recreational activity sessions per week. To avoid collinearity, women with a frequency of zero or one were combined to form the lowest frequency category. A similar strategy was employed with duration of recreational activity.

Results

Of the 1,647 live births, 108 (7%) were born preterm. The majority of this cohort was 25-34 years of age (71%), white non-Hispanic (78%), college graduates (76%), married (94%), non-smokers (76%), and non-drug users (97%) (Table 1).

Vigorous physical activity typically corresponds to a MET value of at least six.(27). The median MET value assigned to the recreational activities using absolute intensity measures from the compendium (31) was 5.5 (interquartile range (IQR): 3.3, 7), suggesting that the median perceived intensity of the activities was higher than the corresponding median MET value of the activity.

Only 35% of the women in this cohort performed first-trimester vigorous physical activity. The average total vigorous activity reported was 76 minutes/week (Table 1). Recreational activity was the most common mode of physical activity accounting for 38% of the total minutes of vigorous activity in the cohort, followed by child/adult care activity (29%).

Length of gestation

Preterm births were more frequent among black, non-Hispanic women (15%) compared with white non-Hispanic women (6%), Hispanic women (7%) and women grouped in "Other" racial groups (1%). Women who performed first-trimester vigorous recreational activity tended to have lower odds of preterm birth (Table 2). This was also true when considering absolute intensity (MET-minutes per week) (data not shown). The results of the survival analysis were similar, the hazard ratio for any vigorous recreational activity compared with none was 0.85 (95% confidence interval (CI) 0.70, 1.05) (data not shown). We did not find any dose-response association (Appendix 1). The odds of preterm birth were also lower with increasing frequency of first-trimester vigorous recreational activity sessions. This association persisted despite adjustment for total volume of recreational activity (Table 2). None of the other modes of first-trimester physical activity (occupational, household, child/adult care), nor total first-trimester physical activity were associated with length of gestation or preterm birth.

Birthweight

Birthweight was obtained from vital records and examined among term births (N=1,539). A confirmed match could not be found for 23% of these births. Compared with women who had birthweight information (N=1,184), women missing birthweight (N=355) were more likely to be Hispanic (11% vs 4%), to report an income ≤ \$40,000 (29% vs 21%), to report never using alcohol (21% vs 13%), and to report their physical activity stayed the same (37% vs 32%) or increased (5% vs 3%) relative to pre-pregnancy. Women missing birthweight information did not differ by any of our first-trimester physical activity measures.

Of the 1,184 term births with birthweight information, 14 (1%) were low birthweight (<2500 g). White non-Hispanic women had the heaviest infants (mean birthweight = 3,549g) followed by Hispanic women, 3,488g, and other race women, 3,387g. Black non-Hispanic women gave birth to the lightest infants, 3,310g. Women who performed first-trimester vigorous recreational activity tended to have lighter babies, but this was not statistically significant (p = 0.08) (Table 3). We did not see a dose-response association (Appendix 2).

None of the other first-trimester physical activity measures were associated with birthweight (Table 3).

Sensitivity analyses

A woman's physical activity in the first pregnancy may have influenced her first pregnancy outcome. If the woman tended to perform the same physical activities across pregnancies, controlling for previous pregnancy outcome would, in effect, be controlling for the exposure. To address this, we examined our multivariable results without pregnancy history variables (history of miscarriage or preterm birth and parity). When we did this, child and adult care activity estimates were generally strengthened possibly because care activity was confounded by parity. Because none of the other estimates meaningfully changed when pregnancy history variables were excluded, we retained them in the final models, which were presented in Tables 2 and 3. Similarly, we examined our results without controlling for nausea/vomiting and vaginal bleeding; estimates were unchanged and these variables were retained.

Women could have reported their physical activities in an unexpected category (i.e., she reported laundry as a recreational activity instead of a household activity). If this is the case, controlling for other modes of physical activity (i.e., controlling household activity for recreational activity) may be an over-adjustment. We examined each mode of activity without controlling for the other modes and results did not meaningfully change.

Discussion

We found no evidence that first-trimester vigorous recreational physical activity was associated with adverse changes in length of gestation. Previous studies suggest that recreational physical activity is either not associated(37-50) or associated with lower risk of preterm birth.(51-57) When limited to studies that have measured frequency, intensity, duration, and type of activity the results suggest reduced risk of preterm birth.(50, 53, 54, 56-61) Of these studies, the most precise estimate was from a survival analysis (hazard ratio: 0.82 [95% CI: 0.76, 0.88] for any exercise versus none) and the authors found no dose-response association.(60) Our survival analysis results were nearly identical (0.85 [0.70, 1.05]).

We found that frequency of first-trimester recreational activity sessions was associated with reduced risk of preterm birth. We did not find any studies that have examined the associations between components of recreational activity (duration and frequency) with preterm birth while controlling for total volume of recreational activity, as we have done.

Recreational activity may benefit pregnancy through placental development. Continuing to exercise during pregnancy has been associated with greater placental villous vascular volume and a higher proliferation index.(62) Moreover, intermittent changes in oxygen or nutrient delivery to the placenta may stimulate placental growth.(63) A recreational activity session could be associated with a decrease in nutrient delivery to the placenta, which would be followed by an increase as the woman recovers. The more frequent recreational activity sessions are, the more fluctuation there will be in nutrient delivery to the placenta, which may stimulate placental growth. This is intriguing given that frequency of vigorous activity sessions was associated with lower odds of preterm birth in our analysis.

Women who performed recreational activity tended to have lighter babies. Several previous studies reported no association(38, 39, 42, 46, 47, 64) or an increase in birthweight with recreational activity;(41, 65) however, these studies did not account for gestational age. We restricted our analysis of birthweight to term infants and also adjusted for gestational week.

Of the earlier studies that adjusted for gestational age, three reported higher birthweight for babies of mothers who perform recreational activity,(43, 55, 66) four others reported a decrease(67-70) and three reported no association.(71-73) These studies include mostly recreational activities, although some have combined recreational with occupational, child care, or housework activities(47, 55, 69, 73) A recent randomized trial found that women who participated in a stationary bicycling program from 20 weeks of gestation to delivery gave birth to babies that were lighter (about 140 g) than babies of control women(50).

We did not find convincing associations of vigorous first-trimester occupational, household, or child/adult care activities with any of the birth outcomes. These modes of physical activity may differ from recreational activity because they may not be volitional. One study examined household or child/adult care activities as separate exposures and suggested no association with preterm birth.(52) A recent Brazilian study suggested a reduced risk of preterm birth with increasing hours per day of domestic activity (61). Point estimates from studies of occupational physical activity and preterm birth range from 0.7 to 4, with most less than 2.(24) Two of five occupational activity studies suggest increased risk of small-for-gestational age birth.(55, 74-77) These studies vary widely in terms of their occupational activity measures and do not usually include detailed assessments of intensity, frequency, and duration of physical activity.

Limitations and Strengths

This study recruited women early in pregnancy and prospectively ascertained their pregnancy outcomes. The participants were volunteers planning a pregnancy and our results may not be generalizable to other populations. Birthweight was obtained from a vital records match, which lead to a substantial proportion of missing data (23%), however, missing birthweight data was not associated with physical activity, reducing the likelihood of bias. Physical activity was assessed through self-report early in pregnancy. Women were asked several detailed questions to describe their vigorous physical activities which should have reduced exposure misclassification. The physical activity questionnaire we used in modified form had moderate to almost perfect evidence for test-retest reliability and moderate to substantial evidence for validity when compared to a structured diary among a sample of pregnant women.(29) However, like many other self-report questionnaires on physical activity, the correlations between the accelerometer and questionnaire were only fair for most assessments.(29) Moderate intensity activities, which are recommended during pregnancy (26, 27), were not measured in detail. Because the physical activity questions were asked early in pregnancy (around 14 weeks gestation) they may not reflect the appropriate exposure window in pregnancy for effects on timing of birth or birthweight. However, the responses at this point in pregnancy would not have been affected by the manifestation of some conditions that commonly lead to medically indicated preterm birth (pre-eclampsia, hypertension). Thus, our exposure measurement is less susceptible to reverse causality.

The detailed exposure measurements allowed us to examine the modes of vigorous physical activity as well as frequency and duration of vigorous recreational activities as separate exposures, which has not been reported previously in the literature. The physical activity recommendations from the American College of Obstetricians and Gynecologists (26) and the U.S. Department of Health and Human Services (27) do not currently specify safe amounts of vigorous activity.

Conclusion

In summary, first-trimester vigorous physical activity does not appear to be detrimental to the timing of birth or birthweight. Our data support a reduced risk of preterm birth with first-trimester vigorous recreational activity, particularly with increased frequency of vigorous recreational activity sessions. Further investigation of the modes of physical activity will clarify if recreational activity differs from other activity types. Additionally, future studies should investigate intensity, duration, and frequency of physical activity sessions, controlling for total volume of physical activity.

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Appendix

Appendix 1

Crude and adjusted[a] odds ratios (OR) with 95% confidence intervals (CI) of first- trimester physical activity based on perceived exertion with preterm birth, *Right From the Start,* North Carolina, 2004-2007 (N=1,552).

	Total N[b] (% Preterm)	Crude OR (CI)	Adjusted OR (CI)
Total activity			
None/Non-vigorous activity[c]	1,022 (19)	1*	1
1 – 30 min/week of vigorous activity	92 (8)	1.0 (0.4, 2.2)	1.0 (0.4, 2.3)
31 – 60	84 (2)	0.3 (0.1, 1.2)	0.2 (0.05, 1.0)
61 – 435	303 (5)	0.6 (0.3, 1.1)	0.6 (0.3, 1.2)
>435	51 (14)	2.0 (0.9, 4.5)	1.2 (0.5, 3.1)
Recreational activity			
None	503 (8)	1	1
Non-vigorous recreational activity[c]	753 (7)	1.0 (0.6, 1.5)	1.2 (0.7, 2.0)
1 – 75 min/week of vigorous activity	100 (4)	0.5 (0.2, 1.4)	0.5 (0.2, 1.6)
76 – 140	97 (5)	0.7 (0.3, 1.7)	0.8 (0.3, 2.2)
>140	99 (4)	0.2 (0.1, 1.0)	0.3 (0.1, 1.4)
Frequency of vigorous recreational activity sessions			
0 or 1 session/week	1,285 (7)	1*	1*
2 or 3	116 (7)	0.8 (0.2, 4.5)	0.9 (0.1, 5.1)
≥ 4	151 (0.7)	0.07 (0.005, 0.9)	0.06 (0.003, 0.9)
Duration of vigorous recreational activity sessions			
0 – 9 minutes	1,276 (7)	1	1
10 – 50	213 (3)	0.2 (0.03, 1.6)	0.3 (0.03, 2.4)
>50	63 (5)	0.6 (0.06, 5.3)	0.5 (0.04, 5.8)
Occupational activity			
None	1,363 (7)	1	1
Non-vigorous occupational activity[‡]	128 (4)	0.5 (0.2, 1.3)	0.5 (0.2, 1.4)
1 – 30 min/week of vigorous activity	24 (4)	0.5 (0.07, 3.9)	0.3 (0.03, 2.7)
31 – 180	17 (12)	1.7 (0.4, 7.6)	1.4 (0.3, 7.5)

	Total N[b] (% Preterm)	Crude OR (CI)	Adjusted OR (CI)
>180	20 (10)	0.7 (0.1, 5.5)	0.6 (0.1, 4.8)
Outdoor/indoor household activity			
None	176 (11)	1	1
Non-vigorous household activity[c]	1,200 (6)	0.6 (0.4, 1.1)	0.5 (0.3, 0.9)
1 – 30 min/week of vigorous activity	59 (7)	0.6 (0.2, 1.9)	0.5 (0.1, 1.6)
31 – 90	64 (6)	0.6 (0.2, 1.9)	0.4 (0.1, 1.3)
>90	53 (11)	1.1 (0.4, 3.0)	1.1 (0.3, 3.3)
Child/adult care activity			
None	735 (7)	1	1
Non-vigorous child/adult care activity[c]	653 (7)	0.9 (0.6, 1.4)	0.7 (0.4, 1.3)
1 – 30 min/week of vigorous activity	53 (9)	1.3 (0.5, 3.4)	1.0 (0.3, 3.2)
31 – 120	63 (6)	0.9 (0.3, 2.6)	0.9 (0.3, 3.3)
>120	48 (6)	1.2 (0.4, 3.3)	1.0 (0.3, 3.7)
Started exercising in preparation for getting pregnant			
Not reported	1,499 (7)	1	1
Reported	53 (0)	0.8 (0.2, 2.6)	0.6 (0.1, 2.8)
Change in vigorous activity compared to before pregnancy			
Stayed the same	511 (8)	1	1
Decrease	989 (6)	0.8 (0.5, 1.2)	0.7 (0.5, 1.2)
Increase	52 (10)	1.6 (0.7, 4.0)	1.4 (0.5, 3.9)

[a]Table items are adjusted for maternal age, race/ethnicity, education, income, marital status, alcohol, body mass index, cigarette smoking, illicit drug use, history of miscarriage, history of preterm birth, parity, vaginal bleeding, nausea/vomiting, diabetes, starting to exercise in preparation for getting pregnant and change in vigorous activity compared to before pregnancy and all the modes of physical activity. Frequency of recreational activity and duration of activity are adjusted for vigorous recreational activity.

[b]Total number of participants not missing for any variables in the model.

[c]"Non-vigorous activity" indicates she reported performing activity but she did not characterize it as vigorous.

[*]Group p-value < 0.05

Appendix

Appendix 2

Adjusted[a] linear regression coefficients for the associations between first-trimester physical activity measures based on perceived exertion and birthweight for gestational age, *Right From the Start,* North Carolina, 2004-2007 (N=1,118).

	N (%)[b]	Crude Beta (CI)	Adjusted Beta[c] (CI)
Total activity			
None/Non-vigorous activity[d]	725 (65)	0	0
1 – 30 min/week of vigorous activity	67 (6)	15 (-91, 121)	15 (-89, 119)
31 – 135	167 (15)	-20 (-92, 52)	-39 (-108, 31)
>135	159 (14)	93 (20, 166)	57 (-15, 128)

	N (%)[b]	Crude Beta (CI)	Adjusted Beta[c] (CI)
Recreational activity			
None	367 (33)	0[*]	0
Non-vigorous recreational activity[d]	527 (47)	-73 (-130, -16)	-60 (-117, -3)
1 – 75 min/week of vigorous activity	78 (7)	-131 (-234, -29)	-96 (-192, -0.2)
76 – 140	71 (6)	-57 (-167, 52)	-46 (-148, 56)
>140	75 (7)	28 (-80, 135)	-28 (-127, 71)
Frequency of vigorous recreational activity sessions			
0 or 1 session/week	916 (82)	0	0
2 or 3	84 (8)	195 (-7, 297)	82 (-104, 269)
≥ 4	118 (11)	101 (-110, 311)	40 (-154, 234)
Duration of vigorous recreational activity sessions			
0 – 9	908 (81)	0	0
10 – 50	164 (15)	59 (-172, 290)	14 (-205, 233)
>50	46 (4)	31 (-235, 297)	-65 (-316, 186)
Outdoor/indoor household activity			
None	117 (10)	0	0
Non-vigorous household activity[d]	867 (78)	29 (-54, 112)	-61 (-139, 16)
1 – 30 min/week of vigorous activity	45 (4)	107 (-34, 247)	-19 (-155, 118)
31 – 90	51 (5)	54 (-85, 193)	-71 (-203, 60)
>90	38 (3)	101 (-52, 255)	70 (-75, 215)
Occupational activity			
None	989 (88)	0	0
Non-vigorous occupational activity[d]	88 (8)	-7 (-101, 87)	27 (-59, 113)
1 – 30 min/week of vigorous activity	17 (2)	-125 (-316, 66)	-65 (-254, 124)
31 – 180	9 (0.8)	-88 (-378, 202)	-144 (-405, 118)
>180	15 (1)	-128 (-360, 105)	-51 (-254, 153)
Child/adult care activity			
None	517 (46)	0[**]	0
Non-vigorous child/adult care activity[d]	486 (43)	115 (61, 168)	8 (-65, 82)
1 – 30 min/week of vigorous activity	35 (3)	222 (80, 365)	97 (-52, 246)
31 – 120	43 (4)	130 (-2, 262)	-20 (-157, 118)
>120	37 (3)	191 (55, 328)	25 (-123, 174)
Started exercising in preparation for getting pregnant			
Not reported	1,080 (97)	0	0
Reported	38 (3)	48 (-90, 186)	-38 (-165, 89)
Change in vigorous activity compared to before pregnancy			
Stayed the same	356 (32)	0	0
Decrease	733 (66)	29 (-25, 83)	9 (-41, 60)
Increase	29 (3)	-93 (-255, 69)	-7 (-157, 143)

[a]Also adjusted for maternal age, height, race/ethnicity, education, income, marital status, alcohol use, body mass index, cigarette smoking, illicit drug use, infant sex, history of miscarriage, history of preterm birth, parity, vaginal bleeding, nausea/vomiting, and diabetes

[b]Total number of participants not missing for any variables in the model.

[c]In grams

[d]"Non-vigorous activity" indicates she reported performing activity but she did not characterize it as vigorous.

[*]Group p-value < 0.05

[**]Group p-value < 0.01

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Table 1

Descriptive statistics for the three birth outcomes (gestational age, preterm birth, and birthweight) and covariates of interest, for the *Right From the Start*, North Carolina, 2004-2007[a].

	N (%)
Total N	1,647
Gestational days at delivery, mean (SD)	277 (13)
Birthweight, mean (SD)[b]	3,511 (458)
Preterm birth	
Yes	108 (7)
No	1,539 (93)
Total activity	
None	34 (2)
Non-vigorous activity[c]	1034 (64)
1 – 30 minutes/week of vigorous activity	98 (6)
31 – 60	90 (6)
61 – 435	317 (20)
>435	53 (3)
Mean (SD)	76 (270)
Median (IQR)	0 (0, 60)
Recreational activity	
None	545 (33)
Non-vigorous recreational activity[c]	782 (48)
1 – 75 minutes/week of vigorous activity	107 (7)
76 – 140	99 (6)
>140	103 (6)
Mean (SD)	28 (100)
Median (90%[d])	0 (90)
Frequency of vigorous recreational activity sessions (number/week)	
0 or 1	1,357 (83)
2 or 3	166 (10)
≥ 4	114 (7)
Average duration of vigorous recreational activity sessions (minutes)	
0 – 9	1,349 (82)
10 – 50	220 (13)
>50	67 (4)
Outdoor/indoor household activity	
None	185 (11)
Non-vigorous household activity[c]	1,258 (77)
1 – 30 minutes/week of vigorous activity	68 (4)
31 – 90	69 (4)
>90	59 (4)

	N (%)
Mean (SD)	14 (101)
Median (90%[d])	0 (20)
Occupational activity	
None	1,443 (88)
Non-vigorous occupational activity[c]	133 (8)
1 – 30 minutes/week of vigorous activity	27 (2)
31 – 180	18 (1)
>180	20 (1)
Mean (SD)	10 (107)
Median (99%[d])	0 (300)
Child/adult care activity	
None	774 (47)
Non-vigorous child/adult care activity[c]	691 (42)
1 – 30 minutes/week of vigorous activity	58 (4)
31 – 120	64 (4)
>120	52 (3)
Mean (SD)	24 (186)
Median (90%[d])	0 (5)
Reported she started exercising in preparation for getting pregnant	
Yes	56 (3)
No	1,587 (97)
Change in vigorous activity compared to before pregnancy	
Increase	53 (3)
Decrease	1,042 (63)
Stayed the same	547 (33)
Age	
≤ 24	202 (12)
25 – 29	592 (36)
30 – 34	584 (35)
35 – 39	248 (15)
≥40	21 (1)
Race	
White/Non-Hispanic	1,275 (78)
Black/Non-Hispanic	193 (12)
Hispanic	86 (5)
Native American/Asian/Other	89 (5)
Education	
≤ 12 years	157 (10)
Some college	244 (15)
≥ 4 years of college	1,246 (76)

	N (%)
Annual family income	
≤ $40,000	370 (23)
40,001 – 80,000	620 (39)
>80,000	610 (38)
Marital status	
Married/Living as married	1,552 (94)
Other	95 (6)
Alcohol	
Never	245 (15)
Current	80 (5)
Recent quit (≤ 4 months since interview)	815 (50)
Distant quit (>4 months)	503 (31)
Body mass index	
<18.5	28 (2)
18.5 – 24.9	977 (60)
25 – 29.9	353 (22)
≥ 30	261 (16)
Smoking in the first trimester	
None	1,249 (76)
Former	256 (16)
1 – 9 cigarettes/day	84 (5)
≥ 10 cigarettes/day	53 (3)
Drug use[e]	
Yes	55 (3)
No	1,588 (97)
History of miscarriage	
Yes	356 (22)
No	1,288 (78)
History of preterm birth	
Yes	135 (8)
No	1,509 (92)
Parity	
0	781 (48)
1	585 (36)
≥ 2	278 (17)
Vaginal bleeding in the first trimester	
Yes	503 (31)
No	1,139 (69)
Nausea in the first trimester	
No	167 (10)
Yes, without vomiting	734 (45)
Yes, with vomiting	741 (45)

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	N (%)
Diabetes	
Yes	44 (3)
No	1,598 (97)

[a]All variables are missing <5% except birthweight for which vital records linkage could not retrieve 23%.

[b]Calculated only among term births, N = 1,539, N=1,184 not missing birthweight.

[c]"Non-vigorous activity" indicates she reported performing activity but she did not characterize it as vigorous.

[d]IQR is 0, 0, so the 90th percentile is shown; for occupational activity the 90th percentile is also 0, so the 99th percentile is shown.

[e]Items queried: cocaine, crack, heroin, ecstasy, angel dust, PCP, downers, LSD and marijuana.

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Table 2

Crude and adjusted[a] odds ratios (OR) with 95% confidence intervals (CI) of first- trimester physical activity based on perceived exertion with preterm birth, *Right From the Start,* North Carolina, 2004-2007 (N=1,552).

	Total N[b] (% Preterm)	Crude OR (CI)	Adjusted OR (CI)
Total activity			
None/Non-vigorous activity[c]	1,022 (19)	1[*]	1
1 – 30 min/week of vigorous activity	92 (8)	1.0 (0.4, 2.2)	1.0 (0.4, 2.3)
31 – 60	84 (2)	0.3 (0.1, 1.2)	0.2 (0.05, 1.0)
61 – 435	303 (5)	0.6 (0.3, 1.1)	0.6 (0.3, 1.2)
>435	51 (14)	2.0 (0.9, 4.5)	1.2 (0.5, 3.1)
Recreational activity			
None	503 (8)	1[*]	1
Non-vigorous recreational activity[c]	753 (7)	1.0 (0.6, 1.5)	1.2 (0.7, 2.0)
≥ 1 min/week of vigorous activity	296 (13)	0.5 (0.2, 0.9)	0.6 (0.3, 1.2)
Frequency of vigorous recreational activity sessions			
0 or 1 session/week	1,285 (7)	1[*]	1[**]
2 or 3	116 (7)	0.8 (0.2, 4.5)	1.0 (0.2, 5.4)
≥ 4	151 (0.7)	0.07 (0.005, 0.9)	0.08 (0.006, 1.0)
Duration of vigorous recreational activity sessions			
0 – 9 minutes	1,276 (7)	1	1
10 – 50	213 (3)	0.2 (0.03, 1.6)	0.4 (0.07, 2.6)
>50	63 (5)	0.6 (0.06, 5.3)	0.5 (0.07, 4.1)
Occupational activity			
None	1,363 (7)	1	1
Non-vigorous occupational activity[‡]	128 (4)	0.5 (0.2, 1.3)	0.6 (0.2, 1.5)
≥ 1 min/week of vigorous activity	61 (22)	0.9 (0.3, 2.5)	0.6 (0.2, 2.0)
Outdoor/indoor household activity			
None	176 (11)	1	1
Non-vigorous household activity[c]	1,200 (6)	0.6 (0.4, 1.1)	0.5 (0.3, 0.9)
≥ 1 min/week of vigorous activity	176 (8)	0.8 (0.4, 1.6)	0.5 (0.2, 1.3)
Child/adult care activity			
None	735 (7)	1	1
Non-vigorous child/adult care activity[c]	653 (7)	0.9 (0.6, 1.4)	0.7 (0.4, 1.3)
≥ 1 min/week of vigorous activity	164 (7)	1.1 (0.6, 2.1)	0.9 (0.4, 2.2)
Started exercising in preparation for getting pregnant			
Not reported	1,499 (7)	1	1
Reported	53 (0)	0.8 (0.2, 2.6)	0.6 (0.1, 2.8)
Change in vigorous activity compared to before pregnancy			
Stayed the same	511 (8)	1	1
Decrease	989 (6)	0.8 (0.5, 1.2)	0.7 (0.5, 1.2)

	Total N[b] (% Preterm)	Crude OR (CI)	Adjusted OR (CI)
Increase	52 (10)	1.6 (0.7, 4.0)	1.3 (0.5, 3.6)

[a]Table items are adjusted for maternal age, race/ethnicity, education, income, marital status, alcohol, body mass index, cigarette smoking, illicit drug use, history of miscarriage, history of preterm birth, parity, vaginal bleeding, nausea/vomiting, diabetes, starting to exercise in preparation for getting pregnant and change in vigorous activity compared to before pregnancy and all the modes of physical activity. Frequency of recreational activity and duration of activity are adjusted for vigorous recreational activity.

[b]Total number of participants not missing for any variables in the model.

[c]"Non-vigorous activity" indicates she reported performing activity but she did not characterize it as vigorous.

*Group p-value < 0.05

**Group p-value < 0.01

Table 3

Adjusted[a] linear regression coefficients for the associations between first-trimester physical activity measures based on perceived exertion and birthweight for gestational age, *Right From the Start,* North Carolina, 2004-2007 (N= 1,118).

	N (%)[b]	Crude Beta (CI)	Adjusted Beta[c] (CI)
Total activity			
None/Non-vigorous activity[d]	725 (65)	0	0
≥ 1 min/week of vigorous activity	393 (35)	32 (-21, 84)	3 (-45, 52)
Recreational activity			
None	367 (33)	0*	0
Non-vigorous recreational activity[d]	527 (47)	-73 (-130, -16)	-62 (-118, -5)
≥ 1 min/week of vigorous activity	224 (20)	-57 (-128, 14)	-57 (-124, 9)
Frequency of vigorous recreational activity sessions			
0 or 1 session/week	916 (82)	0	0
2 or 3	84 (8)	195 (-7, 397)	82 (-104, 269)
≥ 4	118 (11)	101 (-110, 311)	40 (-154, 234)
Duration of vigorous recreational activity sessions			
0 – 9	908 (81)	0	0
10 – 50	164 (15)	59 (-172, 290)	14 (-205, 233)
>50	46 (4)	31 (-235, 297)	-65 (-316, 186)
Outdoor/indoor household activity			
None	117 (10)	0	0
Non-vigorous household activity[d]	867 (78)	29 (-54, 112)	-62 (-139, 15)
≥ 1 – 30 min/week of vigorous activity	134 (12)	86 (-19, 190)	-15 (-114, 85)
Occupational activity			
None	989 (88)	0	0
Non-vigorous occupational activity[d]	88 (8)	-7 (-101, 87)	24 (-62, 111)
≥ 1 min/week of vigorous activity	41 (4)	-118 (-251, 15)	-75 (-199, 50)
Child/adult care activity			
None	517 (46)	0**	0
Non-vigorous child/adult care activity[d]	486 (43)	115 (61, 168)	10 (-63, 84)
≥ 1 – 30 min/week of vigorous activity	115 (11)	179 (94, 264)	35 (-67, 137)
Started exercising in preparation for getting pregnant			
Not reported	1,080 (97)	0	0
Reported	38 (3)	48 (-90, 186)	-31 (-158, 96)
Change in vigorous activity compared to before pregnancy			
Stayed the same	356 (32)	0	0
Decrease	733 (66)	29 (-25, 83)	14 (-36, 64)
Increase	29 (3)	-93 (-255, 69)	-12 (-162, 139)

[a]Also adjusted for maternal age, height, race/ethnicity, education, income, marital status, alcohol use, body mass index, cigarette smoking, illicit drug use, infant sex, history of miscarriage, history of preterm birth, and parity.

[b]Total number of participants not missing for any variables in the model.

[c]In grams

[d]"Non-vigorous activity" indicates she reported performing activity but she did not characterize it as vigorous.

[*]Group p-value < 0.05

[**]Group p-value < 0.0001

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