Physical activity during pregnancy and infant’s birth weight: results from the 3D Birth Cohort

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ABSTRACT

Aim To evaluate the association between maternal physical activity and infant’s birth weight or risk of inappropriate weight for gestational age (GA), and whether this association differs by infant’s sex, maternal body mass index (BMI) or pregnancy complications in a prospective cohort study.

Methods 1913 pregnant women from the 3D Birth Cohort (Québec, Canada) completed the Pregnancy Physical Activity Questionnaire at each trimester. Energy expenditure (metabolic equivalent of task (MET) *hours/week) for total activity, sports and exercise and vigorous intensity activities was calculated. The associations with birth weight and risk of inappropriate weight for GA were evaluated by regression modelling. Interactions were tested with infant’s sex, maternal prepregnancy BMI, gestational diabetes, hypertensive disorders and premature birth.

Results Each 1 MET/hours/week increase in sports and exercise in the first trimester was associated with a 2.5 g reduction in infant’s birth weight (95% CI −4.8 to −0.3) but was not associated with the risk of small weight for GA. In contrast, although not significant, a 17% reduction in the risk of large for GA weight was observed in women with increased sports and exercise. Furthermore, in women with subsequent pre-eclampsia (but not normotensive or hypertensive women), each 1 MET/hours/week increment spent in any vigorous exercise in the first trimester reduced the infant’s birth weight by 19.8 g (95% CI −35.2 to −4.3).

Conclusions Pregnant women with higher sports and exercise levels in the first trimester delivered infants with a lower birth weight. The risk of reducing infant’s birth weight with vigorous exercise in women who develop pre-eclampsia later in pregnancy requires evaluation.

INTRODUCTION

Physical activity in pregnancy has been shown to influence perinatal outcomes.1–4 However, as physical activity parameters such as type, intensity and timing during pregnancy might exert different maternal and fetoplacental adaptations,5,6 the effects of various physical activity stimuli on birth weight need a thorough investigation.

Moderate intensity exercise in early pregnancy has been shown to improve placental function in low-risk pregnancy,5,7 but in women who will develop a pregnancy complication, its impacts on fetal growth are unclear. Indeed, the effects of exercise on fetal growth remain unknown in pregnancies with endothelial dysfunction and abnormal perfusion or preterm birth. Other characteristics such as infant’s sex and maternal body mass index (BMI)8 may also modulate this association.

Furthermore, although moderate intensity physical activity seems relatively safe in uncomplicated pregnancies,9 there are
concerns about vigorous exercise, as decreases in uteroplacental blood flow and transient fetal bradycardia have been observed following strenuous exercise.\textsuperscript{10-14} Yet, nearly 20% of pregnant women report performing vigorous exercise in early pregnancy.\textsuperscript{15}

Using data from a large birth cohort, the objectives of this study were to evaluate the association between maternal physical activity, namely sports and exercise practice, vigorous exercise and total activity, and infant’s birth weight or risk of inappropriate weight for gestational age (GA). We hypothesized that this association would differ according to infant’s sex, maternal obesity status and the development of prematurity, gestational diabetes or hypertensive disorders of pregnancy.

**METHODS**

**Population and setting**

The 3D Birth Cohort recruited 2366 mother–father–child triads (singleton pregnancy) from 10 tertiary care centres in the province of Quebec from May 2010 to August 2012 (last delivery in 2013) with the primary aim of evaluating the impact of maternal anxiety on child’s neurodevelopment at age 2.\textsuperscript{16} For the present study, analyses were performed in 1913 (81%) pregnant women (81%) recruited <14 weeks at recruitment. Reasons for exclusion (n=453) were withdrawal from the study (n=99), miscarriage or termination of pregnancy (n=130), stillbirth (n=5), missing birth weight (n=41) or sex (n=15) and insufficient physical activity data (<20% of data, n=163). Research ethics board of all involved institutions approved the study. All participants provided written informed consent for themselves and their infant. The study was reported according to the STROBE statement.\textsuperscript{17}

**Design**

The 3D Birth Cohort collected extensive perinatal data, starting in the first trimester of pregnancy. Briefly, participating women were met between 8–13\textsuperscript{6/7} weeks, between 20–24\textsuperscript{6/7} weeks and between 32–34\textsuperscript{6/7} weeks of gestation by trained research assistants to collect sociodemographics, obstetrical and medical history during a structured interview. Perinatal history (ultrasound data, glucose tolerance tests, urine analyses) and pregnancy, delivery and neonatal outcomes were prospectively documented from medical charts. Women’s weight, height and blood pressure were measured at each visit, whereas prepregnancy weight was recalled at the first visit. Participating fathers had height and weight measured at the first visit.

For the present study, the primary outcome was the infant’s birth weight, collected from medical charts. Secondary outcomes included small and large birth weight for GA (SGA and LGA, respectively), defined as a birth weight adjusted for GA and sex <10th and >90th percentile, respectively, based on Canadian reference values.\textsuperscript{18}

Following each visit, women completed a web-based version of the Pregnancy Physical Activity Questionnaire (PPAQ), a questionnaire validated for pregnancy.\textsuperscript{19, 20} to document their physical activity practice in the preceding month. Women reported the time (per day or week) they spent for each activity. Each activity was then assigned an intensity value in metabolic equivalent of task (MET, where 1 MET=energy expended at rest), based either on field measurements in pregnant women or on values found in the compendium of physical activity.\textsuperscript{19, 21} This provided an energy expenditure for each activity expressed in MET*hours/week. Following this, total energy expenditure (total physical activity) was derived from all activities listed in the PPAQ, regardless of their context (ie, occupational, sports and exercise, transportation, household and care giving) or intensity (ie, sedentary, light, moderate and vigorous). Energy expenditure spent at sports and exercise was derived from activities of at least light intensity (≥1.5 METs) performed during leisure time. Finally, energy expenditure spent at vigorous intensity activities was also calculated by including leisure time activities with an intensity of ≥6 METs (eg, jogging). These physical activity exposures were calculated for prepregnancy and for each trimester separately.

Sociodemographic, medical and lifestyle characteristics included maternal ethnicity, education, parity, household income, medication use, drugs and alcohol use, smoking, history of pregestational diabetes or hypertension and sleep habits (Pittsburgh Sleep Quality Index).\textsuperscript{22-24} Gestational diabetes diagnosis was based on biochemical analyses when available (27%, 2013 Canadian Diabetes Association criteria)\textsuperscript{25} or on diagnosis noted in medical charts. Gestational hypertension and pre-eclampsia were defined as hypertension first diagnosed during pregnancy (systolic blood pressure ≥140 mm Hg and/or diastolic blood pressure ≥90 mm Hg, measured on two different occasions) and hypertension combined with proteinuria.\textsuperscript{26} GA at delivery was based on the first trimester ultrasound (31%) or the date of the last menstrual period.\textsuperscript{27} Preterm birth was defined as delivery <37 weeks. Maternal prepregnancy BMI was calculated using self-reported prepregnancy weight and height measured at the first visit.\textsuperscript{28} Gestational weight gain was calculated by subtracting prepregnancy weight to the last recorded weight before delivery. Infant’s birth length and sex were collected from medical charts.

**Statistical analyses**

All analyses were performed using SAS V.9.4. Data are presented as mean±SD or n (%). Variations over time in maternal energy expenditure were analysed using paired t-tests with adjustment for multiple
comparisons. Comparisons were restricted to consecutive measures (ie, first trimester vs prepregnancy, second vs first trimesters and third vs second trimesters).

Multiple regression modelling was used to estimate the effect of physical activity exposures on infant’s birth weight. To assess the risk variation of LGA or SGA as a function of energy expenditure, relative risk (RR) estimates were calculated separately for each outcome using log-binomial regression. We also verified if there were statistical interactions with prepregnancy BMI category (<18.5, 18.5–24.9, 25–29.9, >30 kg/m²), infant’s sex and pregnancy complications (gestational diabetes, gestational hypertension, pre-eclampsia and preterm birth). Gestational hypertension and pre-eclampsia were combined in the same models, further adjusted for hypertension prior to pregnancy. When the interaction was significant, results were presented for each stratum separately; otherwise, global results were presented.

Regression analyses were performed with and without adjustment variables. Variables were either selected from the literature (ie, maternal prepregnancy BMI, age, parity, smoking, drug use, education, ethnicity, prepregnancy physical activity and physical activity in other trimesters, infant’s sex, GA at delivery and gestational weight gain) or if they caused ≥10% variation in the exposure coefficient in the crude model for at least one of the outcomes of interest (ie, study centre, paternal weight, history of diabetes prior to pregnancy and third trimester sleep score). GA, maternal prepregnancy BMI, weight gain, paternal weight, third trimester sleep score and physical activity were treated as continuous variables. Age was categorised as follows: <25, 25–35 and >35 years; education was dichotomised based on high school completion (yes/no); parity was categorised as 0, 1 or ≥2; ethnic groups were defined as Caucasian, multi-ethnic or other; drug use and smoking were categorised as current users, former users or non-users; history of diabetes and of hypertension prior to pregnancy were dichotomised (yes/no). In order to limit overadjustment, gestational weight gain and physical activity in subsequent trimesters were tested as potential mediators using a SAS Macro. To reduce potential bias associated with missing data, a multiple imputation procedure based on the missing at random (MAR) assumption was applied, since all items used to calculate energy expenditure scores were not always answered. Indeed, composite scores of energy expenditure had non-observation rates of 18%–19%, 28%–44% and 33%–46% for the first, second and third trimesters, respectively. Twenty-five (25) imputed datasets were generated, and estimates from the 25 analysis replicates were combined to obtain a valid statistical inference. Baseline characteristics and pregnancy outcomes were presented using the non-imputed dataset.

To determine whether deviation from the MAR assumption could have biased inferences, sensitivity analyses were performed. In addition to performing the analyses with the raw dataset, the following procedure was applied: (1) various percentiles qi (eg, j=10%, 25%, 50%, 75% and 90%) of energy expenditure in the raw dataset were calculated; (2) missing energy expenditure components were replaced by the qi values and (3) the imputed data were used for confounders.

**RESULTS**

Main baseline characteristics and pregnancy outcomes are presented in tables 1 and 2. Characteristics of the entire 3D Birth Cohort can be found elsewhere. Compared with excluded women, included women were more likely to be Caucasian (72.8 vs 55.4%), non-smoking (87.2 vs 82.9%), primiparous (55.5 vs 48.3%), have a lower prepregnancy BMI (23.9±5.0 vs 24.5±5.4 kg/m²) and deliver at a later GA (39.4±1.4 vs 37.9±4.4 weeks, all p<0.05). However, prepregnancy energy expenditure related to either total physical activity, sports and exercise or vigorous activities was similar.

Overall, maternal energy expenditure decreased from prepregnancy to late pregnancy (table 3). Vigorous exercise was reported by 35.5%, 31.4% and 18.6% of women during the first, second and third trimesters.

None of the potential mediators evaluated through mediation analysis had significant indirect effects in the association between maternal physical activity and birth weight. We thus included gestational weight gain and physical activity in subsequent trimesters as confounders in additional models.

In adjusted analyses, energy expenditure spent at sports and exercise during the first trimester was negatively associated with birth weight (table 4). According to adjusted model A, infants of women doing 11.7 METs*hours/week of sports and exercise (mean value in this cohort, equivalent to ~3 hour/week of brisk walking, which is slightly above current recommendations) compared with 0 MET*hours/week would experience a 29.72 g decrease in birth weight (95% CI –55.88 to –3.50). This association was however attenuated after adjustment for gestational weight gain and physical activity in subsequent trimesters (~2.17 g per MET*hours/week, 95% CI –4.60 to 0.251).

The association between energy expenditure spent at vigorous exercise during the first trimester and birth weight differed by pre-eclampsia status (p for interaction=0.025 and 0.023 in adjusted models A and B, table 5), whereas it did not differ by gestational hypertension status (p for interaction=0.783 and 0.625 in adjusted models A and B, table 5). Among women who developed pre-eclampsia, each 1 MET*hours/week increase in vigorous exercise during the first trimester was associated with a ~20 g decrease in birth weight.
This is equivalent to a 61.26 g reduction (95% CI -109.23 to -13.26) for an energy expenditure of 3.1 METs*hours/week (mean value in this cohort, equivalent to ~30 min/week of light jogging\(^2\)). This association persisted even after adjustment for vigorous exercise practice in subsequent trimesters (-19.7 g per MET*hours/week, 95% CI -35.23 to -4.20).

The association between physical activity exposures and birth weight did not differ by infant’s sex, maternal prepregnancy BMI, prematurity or diabetes status. There were no associations between second or third trimester physical activity exposures and infant’s birth weight.

Finally, no association was observed with the occurrence of SGA or LGA, with the exception of a near-significant reduction in the risk of LGA (adjusted model B, RR 0.83, 95% CI 0.67 to 1.02) found with increasing energy expenditure spent at sports and exercise during the first trimester (table 6). No interactions were detected in the evaluation of the risk for SGA or LGA.

**Sensitivity analyses**

Sensitivity analyses using the raw dataset (without missing data, n=809–821) resulted in consistent findings for the associations between first trimester sports and exercise and birth weight (2.66 g per MET*hours/week, p=0.075), and between first trimester vigorous exercise and birth weight in women with pre-eclampsia (25.72 g per MET *hours/week, p=0.007). When replacing missing physical activity components by predetermined percentiles, the association between sports and exercise during the first trimester (table 6). No interactions were detected in the evaluation of the risk for SGA or LGA.

**Table 1 Women’s baseline characteristics**

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>N</th>
<th>Mean±SD or n (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Study centre</td>
<td>1913</td>
<td></td>
</tr>
<tr>
<td>Montreal (8 centres)</td>
<td>1438</td>
<td>(75.2)</td>
</tr>
<tr>
<td>Quebec City</td>
<td>349</td>
<td>(18.4)</td>
</tr>
<tr>
<td>Sherbrooke</td>
<td>126</td>
<td>(6.6)</td>
</tr>
<tr>
<td>Age at first visit, year</td>
<td>1908</td>
<td>31.4±4.5</td>
</tr>
<tr>
<td>Prepregnancy BMI, kg/m(^2)</td>
<td>1808</td>
<td>23.9±5.0</td>
</tr>
<tr>
<td>Underweight (&lt;18.5)</td>
<td>110</td>
<td>(6.1)</td>
</tr>
<tr>
<td>Normal weight (18.5–24.9)</td>
<td>1161</td>
<td>(64.2)</td>
</tr>
<tr>
<td>Overweight (25–29.9)</td>
<td>325</td>
<td>(18.0)</td>
</tr>
<tr>
<td>Obese (≥30)</td>
<td>212</td>
<td>(11.7)</td>
</tr>
<tr>
<td>Gestational age at first visit, weeks</td>
<td>1908</td>
<td>11.6±1.8</td>
</tr>
<tr>
<td>Maternal ethnic origin</td>
<td>1909</td>
<td></td>
</tr>
<tr>
<td>Caucasian (white)</td>
<td>1389</td>
<td>(72.8)</td>
</tr>
<tr>
<td>African-American, Asian, Hispanic, First Nation</td>
<td>447</td>
<td>(23.4)</td>
</tr>
<tr>
<td>Multiethnic</td>
<td>73</td>
<td>(3.8)</td>
</tr>
<tr>
<td>Education: completed high school</td>
<td>1899</td>
<td>1067 (98.3)</td>
</tr>
<tr>
<td>Marital status: married or living with a partner</td>
<td>1911</td>
<td>1816 (95.0)</td>
</tr>
<tr>
<td>Working before pregnancy (full time or part time)</td>
<td>1911</td>
<td>1569 (82.1)</td>
</tr>
<tr>
<td>Household income ≥$60 000 per year</td>
<td>1830</td>
<td>1294 (70.7)</td>
</tr>
<tr>
<td>Parity (Para)</td>
<td>1912</td>
<td></td>
</tr>
<tr>
<td>0</td>
<td>1062</td>
<td>(55.5)</td>
</tr>
<tr>
<td>1</td>
<td>624</td>
<td>(32.6)</td>
</tr>
<tr>
<td>≥2</td>
<td>226</td>
<td>(11.9)</td>
</tr>
<tr>
<td>Smoking status</td>
<td>1860</td>
<td></td>
</tr>
<tr>
<td>Non-smoker (never smoked)</td>
<td>1247</td>
<td>(67.0)</td>
</tr>
<tr>
<td>Ex-smoker</td>
<td>375</td>
<td>(20.2)</td>
</tr>
<tr>
<td>Smoked during first trimester</td>
<td>238</td>
<td>(12.8)</td>
</tr>
<tr>
<td>History of drug use</td>
<td>1909</td>
<td></td>
</tr>
<tr>
<td>Used or tried before pregnancy</td>
<td>1005</td>
<td>(52.7)</td>
</tr>
<tr>
<td>Used or tried during first trimester</td>
<td>46</td>
<td>(2.4)</td>
</tr>
<tr>
<td>Never tried</td>
<td>858</td>
<td>(44.9)</td>
</tr>
<tr>
<td>Medical history</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pregestational diabetes</td>
<td>1907</td>
<td>10 (0.5)</td>
</tr>
<tr>
<td>Pregestational hypertension</td>
<td>1902</td>
<td>20 (1.1)</td>
</tr>
<tr>
<td>Paternal weight at visit 1, kg</td>
<td>1450</td>
<td>83.8±15.0</td>
</tr>
</tbody>
</table>

Data are presented without imputation for missing values.

**Table 2 Pregnancy outcomes**

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>N</th>
<th>Mean±SD or n (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gestational age at delivery, weeks</td>
<td>1913</td>
<td>39.4±1.4</td>
</tr>
<tr>
<td>Preterm delivery (&lt;37 weeks)</td>
<td>1913</td>
<td>106 (5.5)</td>
</tr>
<tr>
<td>Gestational weight gain, kg</td>
<td>1765</td>
<td>14.3±5.4</td>
</tr>
<tr>
<td>Gestational diabetes</td>
<td>1910</td>
<td>197 (10.3)</td>
</tr>
<tr>
<td>Hypertensive disorders of pregnancy</td>
<td>1913</td>
<td>193 (10.1)</td>
</tr>
<tr>
<td>Gestational hypertension</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pre-eclampsia</td>
<td>1913</td>
<td>77 (4.0)</td>
</tr>
<tr>
<td>Birth weight, g</td>
<td>1913</td>
<td>3376.1±488.0</td>
</tr>
<tr>
<td>Male sex</td>
<td>1913</td>
<td>965 (50.4)</td>
</tr>
<tr>
<td>Birth length, cm</td>
<td>1729</td>
<td>51.1±2.4</td>
</tr>
<tr>
<td>Large for gestational age</td>
<td>1913</td>
<td>141 (7.4)</td>
</tr>
<tr>
<td>Small for gestational age</td>
<td>1913</td>
<td>161 (8.4)</td>
</tr>
</tbody>
</table>

Data are presented without imputation for missing values.
Thus, beyond an effect on birth weight gain during the first half of pregnancy (see online supplementary tables 1 and 2), associated with increased neonatal weight and adiposity. We also recently reported that vigorous physical activity assessed by accelerometry in the first trimester and further developed pre-eclampsia in later pregnancy delivered infants with a smaller birth weight, an association not found in normotensive women or women with gestational hypertension. Our findings highlight that maternal exercise in early pregnancy might be an important determinant of fetal growth, although physical activity in the later stages of pregnancy might also play a role.

**Discussion**

**Main findings**

In this large pregnancy cohort, women with a higher sports and exercise energy expenditure during the first trimester delivered infants with a reduced birth weight, an effect not found in normotensive women or women with gestational hypertension. Interestingly, women who performed vigorous exercise in the first trimester and further developed pre-eclampsia in later pregnancy delivered infants with a smaller birth weight, an association not found in normotensive women or women with gestational hypertension. Our findings highlight that maternal exercise in early pregnancy might be an important determinant of fetal growth, although physical activity in the later stages of pregnancy might also play a role.

**Interpretation**

In the present study, inverse associations between maternal energy expenditure and birth weight were all detected in the first trimester, independently from prepregnancy physical activity. Other evidence also suggests that the first trimester might be a sensitive period for fetal growth programming, with excessive weight gain during the first half of pregnancy associated with increased neonatal weight and adiposity. We also recently reported that vigorous physical activity assessed by accelerometry in the first half of pregnancy was an independent predictor of neonatal adiposity, regardless of subsequent physical activity practice. Thus, beyond an effect on birth weight, maternal physical activity in early pregnancy may also influence infant’s body composition, which may have a long-term beneficial impact on childhood obesity risk. Despite reducing birth weight, first trimester sports and exercise was not associated with an increased risk of SGA, which is reassuring and consistent with previous reports. Moreover, our study and others suggest a reduction in the risk of large infants with maternal exercise.

The observed association between exercise and birth weight appeared partially dependent on gestational weight gain. Indeed, physical activity interventions can reduce gestational weight gain, whereas excessive gestational weight gain has been associated with the risk of delivering a larger neonate. Epigenetic mechanisms could also be involved, as total energy expenditure in early pregnancy has been associated with a reduced cord blood DNA methylation of the PLAGL1 gene, whose methylation level is positively associated with fetal growth. Methylation of this imprinted gene might mediate the association between maternal physical activity and birth weight, as it attenuates this association.

An interesting finding in our cohort is the association between first trimester vigorous exercise energy expenditure in early pregnancy and birth weight, as it attenuates this association.

**Table 3** Physical activity participation from the Pregnancy Physical Activity Questionnaire

<table>
<thead>
<tr>
<th>Mean ± SD* in MET-hours/week</th>
<th>Prepregnancy</th>
<th>First trimester</th>
<th>Second trimester</th>
<th>Third trimester</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total energy expenditure</td>
<td>266.1±0.7</td>
<td>215.8±0.5†</td>
<td>192.6±1.3†</td>
<td>186.9±1.8†</td>
</tr>
<tr>
<td>By intensity</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sedentary</td>
<td>75.8±0.3</td>
<td>73.9±0.3</td>
<td>47.4±0.4</td>
<td>46.9±0.6</td>
</tr>
<tr>
<td>Light</td>
<td>95.5±0.3</td>
<td>77.9±0.3</td>
<td>88.8±1.0</td>
<td>90.3±0.9</td>
</tr>
<tr>
<td>Moderate</td>
<td>87.6±0.5</td>
<td>60.9±0.5</td>
<td>54.2±0.5</td>
<td>48.3±0.7</td>
</tr>
<tr>
<td>Vigorous</td>
<td>7.2±0.08</td>
<td>3.1±0.05†</td>
<td>2.3±0.05†</td>
<td>1.4±0.03†</td>
</tr>
<tr>
<td>By type</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Household/care giving</td>
<td>89.1±0.4</td>
<td>72.7±0.4</td>
<td>91.8±0.9</td>
<td>91.5±0.9</td>
</tr>
<tr>
<td>Occupational activity</td>
<td>103.0±0.5</td>
<td>85.8±0.6</td>
<td>25.4±0.8</td>
<td>19.8±0.7</td>
</tr>
<tr>
<td>Sports and exercise</td>
<td>18.4±0.1</td>
<td>11.7±0.1†</td>
<td>12.5±0.1†</td>
<td>11.8±0.1†</td>
</tr>
<tr>
<td>Transportation</td>
<td>29.0±0.2</td>
<td>23.5±0.1</td>
<td>30.9±0.5</td>
<td>30.0±0.5</td>
</tr>
</tbody>
</table>

*Mean of the 25 imputed datasets.
†Different from preceding period at p<0.0001 (with Bonferroni correction).
‡Different from preceding period at p<0.05 (with Bonferroni correction).
§Excluding women not working/studying/doing voluntary work (n=1563–1749). MET, metabolic equivalent of task.
expenditure with a non-negligible decreased birth weight in infants born to pre-eclamptic women. As pre-eclampsia can be associated with impaired placentation and uteroplacental circulation, it is possible that the insufficient placenta of these women cannot adapt sufficiently to the stress produced by vigorous exercise, leading to a reduction, although relatively small, in fetal growth. In support of this hypothesis, a previous study evaluating the acute effect of a cycling session on uteroplacental blood flow suggested a greater increase in the resistance index in pregnant women with pregnancy complications including pre-eclampsia compared with controls.

### Table 4
Overall associations between maternal physical activity (in MET-hours/week) and infant’s birth weight (g)

<table>
<thead>
<tr>
<th>Per MET-hours/week</th>
<th>Crude model</th>
<th>Adjusted model A*</th>
<th>Adjusted model B†</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Estimate</td>
<td>95% CI p Value</td>
<td>Estimate 95% CI p Value</td>
</tr>
<tr>
<td>Total energy expenditure</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>First trimester</td>
<td>0.23</td>
<td>-0.02 to 0.49 0.076</td>
<td>-0.23 -0.54 to 0.09 0.154</td>
</tr>
<tr>
<td>Second trimester</td>
<td>0.46</td>
<td>0.10 to 0.83 0.014</td>
<td>-0.01 -0.43 to 0.41 0.947</td>
</tr>
<tr>
<td>Third trimester</td>
<td>0.49</td>
<td>0.10 to 0.88 0.015</td>
<td>-0.01 -0.52 to 0.51 0.972</td>
</tr>
<tr>
<td>Sports and exercise</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>First trimester</td>
<td>-1.19</td>
<td>-3.18 to 0.80 0.243</td>
<td>-2.54 -4.78 to 0.30 0.027</td>
</tr>
<tr>
<td>Second trimester</td>
<td>-0.83</td>
<td>-2.93 to 1.27 0.437</td>
<td>-0.56 -2.90 to 1.78 0.639</td>
</tr>
<tr>
<td>Third trimester</td>
<td>-0.91</td>
<td>-3.42 to 1.59 0.475</td>
<td>0.41 2.41 to 3.23 0.776</td>
</tr>
<tr>
<td>Vigorous exercise</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>First trimester</td>
<td>-0.69</td>
<td>-4.16 to 2.78 0.695</td>
<td>-2.64 -6.17 to 0.89 0.142</td>
</tr>
<tr>
<td>Second trimester</td>
<td>0.08</td>
<td>-4.25 to 4.41 0.972</td>
<td>0.07 2.46 to 4.40 0.973</td>
</tr>
<tr>
<td>Third trimester</td>
<td>0.29</td>
<td>-6.36 to 6.95 0.931</td>
<td>1.87 8.18 to 4.44 0.562</td>
</tr>
</tbody>
</table>

*Adjusted for gestational age at delivery, infant’s sex, study centre, maternal prepregnancy BMI, age, education, ethnicity, parity, drug use, smoking, paternal weight, history of diabetes, third trimester sleep score, physical activity prior to pregnancy and in a previous trimester, where applicable.
†Adjusted for variables of model A plus gestational weight gain.
MET, metabolic equivalent of task.

### Table 5
Associations between vigorous exercise during first trimester and infant’s birth weight according hypertensive disorder status

<table>
<thead>
<tr>
<th>Per 1 MET-hours/week increase</th>
<th>Adjusted model A*‡</th>
<th>Adjusted model B‡</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pre-eclampsia (n=77)</td>
<td>-20.57 -36.50 to -4.65 0.011</td>
<td>-19.76 -35.24 to -4.28 0.012</td>
</tr>
<tr>
<td>Gestational hypertension (n=116)</td>
<td>-0.28 -13.64 to -13.08 0.967</td>
<td>1.63 -11.50 to 14.76 0.808</td>
</tr>
<tr>
<td>No hypertensive disorder (n=1720)</td>
<td>-2.19 -5.82 to 1.44 0.238</td>
<td>-1.69 -5.32 to 1.86 0.350</td>
</tr>
</tbody>
</table>

*Adjusted for gestational age at delivery, infant’s sex, study centre, maternal prepregnancy BMI, age, education, ethnicity, parity, drug use, smoking, paternal weight, history of diabetes prior to pregnancy, third trimester sleep score, physical activity prior to pregnancy and interaction between hypertensive disorder and physical activity, and history of hypertension prior to pregnancy.
‡p=0.025 for the interaction between first trimester vigorous physical activity and pre-eclampsia status.
†Adjusted for gestational age at delivery, infant sex, study centre, maternal prepregnancy BMI, age, education, ethnicity, parity, drug use, smoking, paternal weight, history of diabetes prior to pregnancy, third trimester sleep score, physical activity prior to pregnancy, interaction between hypertensive disorder and physical activity, history of hypertension prior to pregnancy and gestational weight gain.
‡p=0.023 for the interaction between first trimester vigorous physical activity and pre-eclampsia status.
MET, metabolic equivalent of task.
Accordingly, since

To establish the

while providing additional infor-

recommendations can be made.

poorly described, more studies are needed before any

nancy (30% in this cohort) and since its effects remain

vigor

also have been more prone to complete the PPAQ.

might help preventing pre-eclampsia, although

Women with a higher physical activity practice might

reviews also indicate that physical activity in early preg-

lished, as we might not have had sufficient power to

the fetus of pre-eclamptic women remains to be estab-

lations. Indeed, women included in the study were

might not be generalisable to all pregnant popula-

whether this decrease in birth weight is detrimental for

outcomes based on standardised criteria also allowed

methodological considerations

The strengths of the present study include the prospec-

evaluation of physical activity during each

represent cause–effect relationships. However, our

rose index increased in the

UPVI group, whereas it decreased in the control

group, and three women from the UPVI group de-

developed transient absent end diastolic flow. These studies

suggest that suboptimal perfusion might occur with

exercise in women who go on to develop pre-

eclampsia, contributing to a decreased fetal growth.

Our finding indicates that subtle exercise-induced

perfusion modifications could occur even before clin-

cial signs of the disease are observed. However,

whether this decrease in birth weight is detrimental for

the fetus of pre-eclamptic women remains to be estab-

lished, as we might not have had sufficient power to

evaluate the risk of SGA in this subsample. Previous

reviews also indicate that physical activity in early preg-

nancy might help preventing pre-eclampsia, although

evidence is still mitigated.‡

Accordingly, since

vigorous exercise seems quite prevalent in early preg-

nancy (30% in this cohort) and since its effects remain

poorly described, more studies are needed before any

recommendations can be made.

**Methodological considerations**

The strengths of the present study include the prospec-

evaluation of physical activity during each trimester of pregnancy using a validated questionnaire.

The detailed characterisation of participants and

outcomes based on standardised criteria also allowed

the study of physical activity during pregnancy while

considering characteristics for which the effects of

physical activity have been poorly described.

Our study has some limitations. First, our results

might not be generalisable to all pregnant popula-

tions. Indeed, women included in the study were

mostly Caucasians and of high socioeconomic status.

Women with a higher physical activity practice might

also have been more prone to complete the PPAQ.

Second, an overestimation of physical activity or

misclassification of intensity is possible with self-

report. However, data derived from the PPAQ corre-

late with acceptable accuracy with objective data

obtained by accelerometry during pregnancy, and

despite a possible overestimation. To establish the

precise effects of various physical activity intensities

and levels on birth weight, future cohorts should

nevertheless use objective measures of physical

activity such as accelerometry. As with any observa-

tional studies, the observed associations may not

represent cause–effect relationships. However, our

results are consistent with previous meta-analyses of

randomised trials while providing additional infor-

mation regarding the impact of exercise intensity

and timing on the association with birth weight.

Finally, our dataset had a relatively high proportion

of missing values, with missing physical activity data

increasing over time. However, the use of a multiple

imputation procedure might be preferable in terms of

results validity than complete case analysis only.

Additionally, sensitivity analyses comforted our find-

ings. Accordingly, we believe our results remain

noteworthy.

**CONCLUSION**

A decreased birth weight without detrimental effects

on birth weight extremes with sports and exercise

practice in the first trimester reinforces exercise

guidelines and underlines the importance of exercise

in the early months of pregnancy. Although vigorous

exercise might still be adequate for some women, the

need for an ‘upper safety limit’ should be clarified

given its potential effects on pregnancy outcomes and

its apparently high prevalence in early pregnancy.

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Correction notice  This paper has been amended since it was published Online First. Owing to a scripting error, some of the publisher names in the references were replaced with ‘BMJ Publishing Group’. This only affected the full text version, not the PDF. We have since corrected these errors and the correct publishers have been inserted into the references.

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REFERENCES


