

The association of daily physical activity and birth outcome: a population-based cohort study

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Abstract The potential relationship between daily physical activity and pregnancy outcome remains unclear because of the wide variation in study designs and physical activity assessment measures. We sought to prospectively quantify the potential effects of the various domains of physical activity on selected birth outcomes in a large unselected population. The sample consisted of 11,759 singleton pregnancies from the Avon longitudinal study of parents and children, United Kingdom. Information on daily physical activity was collected by postal questionnaire for self-report measures. Main outcome measures were birth weight, gestational age at delivery, preterm birth and survival. After controlling for confounders, a sedentary lifestyle and paid work during the second trimester of pregnancy were found to be associated with a lower birth weight, while ‘bending and stooping’ and ‘working night shifts’ were associated with a higher birth weight. There was no association between physical exertion and duration of gestation or survival. Repetitive boring tasks during the first trimester was weakly associated with an increased risk of preterm birth (<37 weeks) (adjusted odds ratio [OR] =

1.25, 95% CI 1.04–1.50). ‘Bending and stooping’ during the third trimester was associated with a reduced risk of preterm birth (adjusted OR = 0.73, 95% CI 0.63–0.84). Demanding physical activities do not have a harmful effect on the selected birth outcomes while a sedentary lifestyle is associated with a lower birth weight. In the absence of either medical or obstetric complications, pregnant women may safely continue their normal daily physical activities should they wish to do so.

Keywords Birth weight · Gestational duration · Motor activity · Premature birth · Perinatal mortality

Abbreviations

CI	Confidence interval
OR	Odds ratio
ALSPAC	Avon Longitudinal Study of Parents and Children

Introduction

Birth weight has a major impact on the general health and survival of infants [1]. Two important processes govern birth weight, i.e., the duration of gestation and the intrauterine growth rate. Low birth weight is thus caused by either early delivery or intrauterine growth restriction (IUGR), or a combination of both [2–4].

There has been limited study on the effect of daily physical activity on birth outcome, and the results are inconsistent. Some researchers report a positive relation between the various domains of physical activity and birth outcome, while others find either a negative relationship or

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none at all [5–19]. Most prior studies [6, 9, 15] focused on the association of vigorous physical activity and birth outcome in selected groups of pregnant women, such as aerobic dancers and elite athletes. Authors of three recent reviews [20–22] concluded that the majority of epidemiological studies in this field observed a neutral or protective effect of physical activity on selected maternal-child health outcomes. However, given the wide variation in study designs and physical activity assessment measures, it was impossible to provide an overall quantitative estimate of risk.

Physical activity may be defined as ‘any bodily movement produced by skeletal muscle that results in energy expenditure’ [23]. The magnitude of the physiological response to physical activity is determined by age, physical conditions, body weight, body position, concurrent physiological adaptations to pregnancy and psychological factors. Since physical activity has many interrelated dimensions, its quantification is very complex. Several techniques are available for assessing physical activity. Indirect assessment of physical activity by questionnaire is the most practical and widely accepted approach in large-scale epidemiological studies [20–22].

The purpose of our study was to quantify the magnitude of the associations between daily physical activity and birth outcome measures such as birth weight, duration of gestation and perinatal death.

Methods

Data

The research data were derived from a large population-based cohort consisting of pregnant women who took part in the Avon Longitudinal Study of Parents and Children (ALSPAC) [24]. ALSPAC is a geographically based birth cohort designed to analyze environmental and other factors that might affect the health and development of children. Pregnant women who lived in one of three health districts in Bristol, UK were approached. The core sample consisted of pregnant women who were due to deliver between April 1st 1991 and December 31st 1992. A total of 14,663 pregnant women (i.e., approximately 85% response) were enrolled in the study, completed antenatal questionnaires, and agreed to the collection of detailed birth record information. For the current analyses, women with multiple pregnancies ($n = 390$), non-white women ($n = 2,513$) and those who were delivered prior to 16 weeks’ gestation ($n = 1$) were excluded. After these exclusions, the remaining research sample consisted of 11,759 singleton pregnancies, yielding an equivalent number of infants of whom 11,737 were born alive.

Table 1 Questions pertaining to daily physical activities during pregnancy

Are/were you mostly sitting?
Are/were you bending a lot?
Are/were you standing much of the time?
Are/were you doing repetitive, boring tasks?
Are/were you using a lot of physical energy?*
Are you bending and stooping nowadays?
Nowadays, at least once a week do you engage in any regular activity like brisk walking, gardening, housework, jogging, cycling, etc. long enough to work up a sweat? **
Sporting activities***

* Referred to as ‘physical exertion’

** Referred to as ‘strenuous physical activity’

*** Including jogging, aerobics, antenatal exercise, yoga, squash, badminton, swimming, brisk walking, weight training, cycling and other exercising

Measurement of exposure

Physical activity was assessed by asking questions pertaining to regular physical activities, including housework and occupational activity (Table 1) using a validated postal questionnaire for self-report measures of habitual activity [25]. Information concerning daily activities was asked once during the first trimester of pregnancy and once in the second trimester. Employment status was ascertained by the question ‘are you currently in paid work?’ and was reassessed in the second and third trimester, respectively. Furthermore there were questions enquiring about shift work including night shifts, standing and repetitive boring tasks. The response options were divided in dichotomous categories, i.e., ‘yes’ and ‘no’.

Furthermore, women were asked to report their engagement in leisure time physical activities, including sports such as jogging, cycling, and squash, among others. These variables were categorized into four response options, i.e., ‘never’, ‘less than 1 h per week’, ‘between 2 and 6 h per week’ and ‘more than 7 h per week’.

Additional information on the questionnaires can be obtained from the authors.

Measurement of background variables and potential confounders

Variables considered affecting the birth outcome measures of interest were identified from a literature search [4, 26–32]. These potentially confounding variables were then sought in the ALSPAC data set. Variables with more than 20% missing or inappropriate values were excluded from the analyses since these could unduly distort the effect of other variables in the model. For this reason the variables ‘partner’s weight’, ‘partner’s height’ and ‘maternal social

economic status based on maternal occupation' were excluded.

Information on background variables was obtained from the pregnant women using self-reported questionnaires. A history of low birth weight was assessed by the question: "were any of your babies under 5 lb 8oz (2,500 g) at birth?". History of preterm birth by the question; "were any of your babies born more than 3 weeks early?" History of hypertension was determined by the response to "have you ever had hypertension (high blood pressure)?" Current smoking habits were addressed by the following trimester-specific questions: "did you smoke regularly during the first 3 months of pregnancy?" (first trimester); "did you smoke regularly during the last 2 weeks?" (second trimester) and "how many cigarettes per day are you smoking at the moment" (third trimester). The ALSPAC questionnaires were designed to determine actual smoking habits at each trimester of pregnancy thereby minimizing recall bias and equivocal answers when the mother had decided to quit smoking at some point during each trimester. For each trimester, the responses regarding smoking were regrouped into a dichotomous variable: 'yes-no'. Subjective maternal health ("how would you describe your health?") was assessed by the following response options: 1 always fit & well; 2 usually fit & well; 3 sometimes unwell; 4 often unwell 5 always unwell. The woman's pre-pregnancy body mass index (BMI) was recoded from a continuous variable into a categorical variable, divided in 6 groups: <20, 20–24.99, 25–29.99, 30–34.99, 35–39.99, ≥ 40 . The level of maternal stress was measured in the second and third trimester by the derived variable 'Crown Crisp score', adding anxiety, depression and somatic scales into one variable.

Outcome measures

Three birth outcome measures were analyzed, i.e., crude 'birth weight' in grams (continuous variable), 'gestational duration' in weeks as a continuous variable or as 'preterm birth', i.e., before 37 completed weeks of gestation (y/n) as a categorical variable and 'survival' (y/n) as a categorical variable. The variable 'survival' was recoded into two categories, i.e., (1) 'fetal death from 16 weeks' onward or neonatal death occurring the first 7 days after birth' and (2) 'alive after 7 days'.

Statistical analyses

First, to identify an association with the outcomes of interest, univariate analyses of background variables and potential confounders were carried out using chi-square, *t*-test, ANOVA and correlation coefficients, depending on the continuous or dichotomous nature of the data (SPSS 14.0.1). Next, statistically significant variables ($P < 0.05$) emerging

from the univariate analyses were entered in the multivariate analyses together with each measurement of exposure. The variable 'birth weight' was adjusted for 'gestational duration'. However, 'gravidity' and 'live births' were excluded due to their similarity to 'parity'. Also, 'maternal height' and 'maternal weight' were excluded due to their inherent similarity to 'maternal BMI'. The multivariate analyses were conducted in three different stages reflecting the trimester specific exposure sequence i.e., (1) variables included were known in the first trimester of pregnancy and emerged as statistically significant from the univariate analyses, (2) statistically significant variables were known in the first and second trimesters were included, and (3) statistically significant variables were included if known in all three trimesters of pregnancy.

Backward linear regression analyses were used for the outcome measures 'birth weight' and 'gestational duration', while binominal logistic regression was used for 'survival' and 'preterm birth'. Regression analyses for all outcome measures were done separately for each physical activity variable. The final results of the three multivariate analyses are reported in the form of regression coefficients (' β ') together with the 95% confidence intervals (CI) or odds ratios (OR). In the regression analyses, we used the critical inclusion value for significance at the $P = 0.05$ level (two tailed probability) and the critical exclusion value at the $P = 0.15$ level.

Results

Approximately 4.0% ($n = 464$) of women delivered an infant weighing less than 2,500 grams, while 4.2% ($n = 494$) delivered prior to 37 weeks' gestation. In total 11,720 out of 11,759 (99.7%) infants survived the antenatal and perinatal period.

Tables 2, 3, and 4 demonstrate the univariate associations between the potentially confounding variables with birth weight (Table 2), gestational duration (Table 3) and preterm birth (Table 4). Tables 5 and 6 demonstrate the variables of trimester specific exposure to various physical activities showing the adjusted associations with the birth outcome measures following multivariate analyses. A sedentary lifestyle was found to be independently associated with a lower birth weight. The same is true for having paid work in the second trimester. Having night shifts in the second trimester and 'bending and stooping' in the third trimester were significantly associated with a higher birth weight (Table 5). Doing repetitive boring tasks in the first trimester was associated with an increased risk of preterm birth, while 'working night shifts' in the third trimester was associated with a reduction in the risk of preterm birth (Table 6). None of the physical activity variables were found to have an independent, statistically significant association with

Table 2 General and trimester-specific univariate associations of potential confounders and birth weight (grams; continuous variable)

	Effect size (β^a)	95% CI	P value ^b
<i>General</i>			
Male sex of child	110.6	91.5, 129.7	<0.001
History of LBW	-464.5	-511.9, -417.1	<0.001
History of PTB	-317.4	-361.3, -273.4	<0.001
History of spontaneous abortion	31.4	7.6, 55.3	0.01
History of hypertension	6.7	-12.0, 25.4	NS
Hospitalisation during pregnancy	-103.3	-157.8, -48.8	<0.001
Parity	89.4	74.7, 104.0	NS
Home ownership	128.4	49.0, 207.8	<0.001
Marital status (married)	100.9	56.2, 145.6	<0.001
Maternal educational level	99.8	65.2, 134.5	<0.001
Maternal social economic status	-3.7	-9.9, 2.6	NS
Paternal social economic status	115.9	48.3, 183.4	<0.001
Maternal BMI (pre-pregnancy)	227.5	74.4, 380.6	<0.001
Paternal weight	1.4	0.2, 2.7	NS
Paternal height	3.5	1.4, 5.6	<0.001
Maternal age at LMP	-37.0	-61.6, -12.5	NS
Maternal age at delivery	-45.7	-70.3, 21.2	NS
Smoking before pregnancy	-99.6	-123.9, -75.4	0.001
Drug abuse	-189.5	-331.8, -47.2	<0.001
<i>1st trimester</i>			
Smoking	-164.1	-186.7, -141.5	<0.001
Alcohol use	-265.0	-320.7, -209.3	0.01
<i>2nd trimester</i>			
Smoking	-193.8	-168.2, -218.4	<0.001
Alcohol use	20.7	2.4, 39.1	0.008
Negative mood	-1.5	-3.6, 0.5	NS
Poor maternal health	1.6	-7.9, 11.2	NS
In paid work	-43.7	-64.8, -22.7	<0.001
Shift work	1.7	-12.8, 16.2	NS
Night shift	52.1	12.6, 91.5	0.01
<i>3rd trimester</i>			
Smoking	-74.1	-134.4, -10.9	<0.001
Alcohol use	-217.7	-313.0, -125.7	<0.001
Negative mood	1.7	-0.3, 3.7	NS
Poor maternal health	10.2	-3.5, 23.9	NS
In paid work	-20.3	-43.2, 2.5	NS
Shift work	45.5	-10.3, 101.3	NS
Night shifts	71.6	7.5, 135.6	<0.001

CI confidence interval

^a Beta (regression coefficient)^b Statistically significant
 $P < 0.05$

gestational duration. Physical activity was not associated with fetal and neonatal survival (results not given).

Discussion

After controlling for a large number of potentially confounding variables and other effect modifiers, we find that physically demanding activities, including sporting activities, are not associated with adverse birth outcome in terms of

lower birth weight, gestational duration or poor fetal and neonatal survival. In contrast, a sedentary lifestyle is associated with a small but significant negative effect on birth weight (Table 5). The same is true for having paid work in the second trimester. 'Doing repetitive boring tasks' in the first trimester was the only variable that showed an apparent association with an increased likelihood of preterm birth, although the magnitude of this risk was small. The precise underlying mechanism of the latter finding has not been clarified. Previous research has also observed a negative

Table 3 General and trimester-specific univariate associations of potential confounders and gestational duration (weeks)

	Effect size (β^a)	95% CI	P value ^b
<i>General</i>			
Male sex of child	0.16	0.10, 0.23	<0.001
History of LBW	-1.08	-1.23, -0.92	<0.001
History of PTB	-1.17	-1.31, -1.03	<0.001
History of spontaneous abortion	0.02	-0.06, 0.10	NS
History of hypertension	-0.23	-0.32, -0.13	<0.001
Hospitalisation during pregnancy	-0.32	-0.51, -0.14	<0.001
Parity	0.01	-0.04, 0.06	NS
Home ownership	-0.02	-0.05, 0.02	NS
Marital status (married)	-0.02	-0.05, 0.01	NS
Maternal educational level	-0.06	-0.12, -0.01	<0.001
Maternal social economic status	-0.01	-0.05, 0.00	NS
Paternal social economic status	-0.03	-0.03, 0.02	NS
Maternal BMI (pre-pregnancy)	2.94	2.88, 2.98	<0.001
Paternal weight	0.00	0.00, 0.01	NS
Paternal height	-0.01	-0.01, 0.00	NS
Maternal age at LMP	-0.25	-0.34, -0.15	NS
Maternal age at delivery	0.24	0.15, 0.33	0.031
Smoking before pregnancy	0.12	-0.03, 0.27	NS
Drug abuse	0.01	-0.17, 0.19	NS
<i>1st trimester</i>			
Smoking	-0.02	-0.23, 0.20	NS
Alcohol use	-0.02	-0.09, 0.04	NS
<i>2nd trimester</i>			
Smoking	0.07	0.31, 0.18	0.004
Alcohol use	-0.01	-0.06, 0.06	NS
Negative mood	-0.01	-0.01, 0.00	NS
Poor maternal health	-0.003	-0.02, 0.01	NS
In paid work	0.06	-0.02, 0.14	NS
Shift work	-0.12	-0.29, 0.05	NS
Night shifts	0.21	-0.02, 0.44	NS
<i>3rd trimester</i>			
Smoking	-0.10	-0.33, 0.13	NS
Alcohol use	-0.92	-1.85, -0.01	0.031
Negative mood	0.01	-0.01, 0.01	NS
Poor maternal health	-0.83	-1.22, -0.44	<0.001
In paid work	-0.08	-0.15, -0.01	0.023
Shift work	0.06	-0.22, 0.34	NS
Night shifts	-0.06	-0.45, 0.34	NS

CI confidence interval

^a Beta (regression coefficient)^b Statistically significant
 $P < 0.05$

effect of ‘doing repetitive, boring tasks’ and ‘employment status’ on birth outcome. Mamèlle et al. [33] characterised these circumstances by the term ‘occupational fatigue’. It consisted of five sources, namely posture, work on an industrial machine, physical exertion, mental stress and environment. They demonstrated a statistically significant association between occupational fatigue and preterm birth. Newman et al. [34] showed that each source of occupational fatigue was independently associated with a significantly

increased risk of preterm premature rupture of membranes among nulliparous women but not among multiparous women.

One unexpected finding was that (working night shifts) was associated with a slightly increased birth weight. This finding could be explained by the so-called ‘healthy worker effect’. Women who are employed tend to be in better health at the offset than those who are out of work. This observation could also be explained by the women’s

Table 4 General and trimester-specific univariate associations of potential confounders and preterm birth <37 weeks (categorical)

	Effect size (OR ^a)	95% CI	P value ^b
<i>General</i>			
Male sex of child	0.76	0.63, 0.91	0.003
History of LBW	2.36	1.53, 3.62	<0.001
History of PTB	2.98	2.04, 4.33	<0.001
History of spontaneous abortion	1.04	0.77, 1.40	NS
History of hypertension	1.22	1.04, 1.43	0.015
Hospitalisation during pregnancy	1.59	1.28, 1.97	<0.001
Parity	0.79	0.69, 0.90	0.001
Home ownership	0.97	0.88, 1.07	NS
Marital status (married)	0.92	0.83, 1.02	NS
Maternal educational level	1.00	0.89, 1.13	NS
Maternal social economic status	1.04	0.96, 1.14	NS
Paternal social economic status	0.90	0.82, 0.99	NS
Maternal BMI (pre-pregnancy)	1.12	0.95, 1.34	NS
Paternal weight	1.01	1.00, 1.02	NS
Paternal height	1.00	0.98, 1.02	NS
Maternal age at LMP	0.78	0.59, 1.04	NS
Maternal age at delivery	1.27	0.96, 1.69	NS
Smoking before pregnancy	0.97	0.60, 1.57	NS
Drug abuse	1.26	0.77, 2.05	NS
<i>1st trimester</i>			
Smoking	1.02	0.52, 2.00	NS
Alcohol use	0.89	0.74, 1.08	NS
<i>2nd trimester</i>			
Smoking	0.85	0.40, 1.80	NS
Alcohol use	1.10	0.92, 1.31	NS
Negative mood	0.99	0.97, 1.01	NS
Poor maternal health	1.13	1.05, 1.23	0.002
In paid work	1.06	0.81, 1.38	NS
Shift work	1.14	0.65, 2.01	NS
Night shifts	1.80	0.77, 4.20	NS
<i>3rd trimester</i>			
Smoking	0.90	0.45, 1.83	NS
Alcohol use	1.34	1.23, 1.45	<0.001
Negative mood	1.02	0.99, 1.05	NS
Poor maternal health	1.21	1.08, 1.34	0.001
In paid work	1.15	0.86, 1.53	NS
Shift work	0.73	0.30, 1.78	NS
Night shifts	0.48	0.15, 1.60	NS

^a Odd's ratio^b Statistically significant $P < 0.05$

characteristics linked to selective implementation of preventive measures (job withdrawal or reassignment) [35]. Others [36, 37], however, claim that physical demanding work, such as night and shift work, may increase the risk of adverse birth outcome. From a systematic review of the

literature on this topic Bonzini et al. [38] concluded that the balance of evidence tends to favour no effect, or an effect that is no more than a moderate.

The strength of our study is its size and prospective nature, thereby minimizing recall bias. In fact, the effect of daily physical activity on the selected birth outcomes could be quantified thereby controlling for a large number of potential confounders and effect modifiers. Moreover, pregnant women were asked about their daily physical activities. A relatively small number of studies have provided longitudinal data on the effect of daily physical activity patterns on birth outcome. Using data from the 1988 National Maternal and Infant Health Survey in the United States, Leiferman et al. [5] concluded that regular leisure physical activity during pregnancy had no deleterious effect on pregnancy outcome. In contrast, Hegaard et al. [39] recently concluded from a population-based longitudinal study among healthy pregnant women in Denmark that moderate-to-heavy leisure time physical activity was associated with a significantly reduced risk of preterm birth. Others [12, 35, 40–42] reported that prolonged periods of standing and physically demanding work are associated with a modestly increased risk of preterm delivery. We could not confirm their findings.

This investigation has several limitations. It was based on questionnaires completed by the pregnant woman and her partner. Self-reported data can be criticized because for their subjective nature. Assessment of daily activities during pregnancy is complex because of the various domains of physical activity. The questionnaires used in our survey tried to overcome this problem by adding questions pertaining to household activities, leisure time activities, and employment status, among others. Wildschut et al. [25] argued that this strategy facilitates the understanding of the complex relationship between the way of life and pregnancy outcome. Interpretation of the findings, however, could be hampered by the fact that not all questions were properly validated (e.g., leisure time activities).

Most variables were broadly categorised, lacking a measure for the dimension of the dose of activity (i.e., frequency and duration and intensity). Questions were asked with few answer options, for example 'never—sometimes—often—always' or had dichotomous options, e.g., with the questions concerning night and shift work. Unfortunately, no data were available on the frequency of night and shift work. Apart from the broad categorisation, some questions were only asked in certain trimesters. For example, information on daily physical activity was only asked in the first and second trimesters of pregnancy. As the length of the questionnaire was restricted, it was decided by the ALPAC research team at the onset of the study not to include questions pertaining to daily physical

Table 5 Trimester-specific associations with birth weight (in grams, continuous variable) ($n = 8,879$). Statistically significant variables ($P < 0.05$) emerging from the univariate analyses (see Table 2) were entered in the final model

	Effect size (β^a): unadjusted	Effect size (β^a): adjusted	95% CI	<i>P</i> value
1st trimester				
Sitting	-38.4	-21.4	-39.3, -3.5	0.019
Standing	-10.4	-15.6	-33.6, 2.3	0.088
2nd trimester				
Sitting 2nd and 3rd trim	-37.1	-21.6	-39.6, -3.7	0.018
In paid work	-43.7	-17.9	-32.0, -3.9	0.009
Night shifts	52.1	27.6	11.8, 43.5	<0.001
3rd trimester				
Bend and stoop	130.8	37.8	20.3, 55.3	<0.001
Night shifts	71.6	91.4	-15.0, 197.8	0.092

^a Beta (regression coefficient) and CI 95% confidence interval

Table 6 Trimester-specific associations with the risk of preterm birth (categorical variable) ($n = 11,123$). Statistically significant variables ($P < 0.05$) emerging from the univariate analyses (see Table 4) were entered in the final model

	Effect size (OR ^a): unadjusted	Effect size (OR ^a): adjusted	95% CI	<i>P</i> value
1st trimester				
Repetitive boring tasks	1.22	1.25	1.04, 1.50	0.016
3rd trimester				
Bend and stoop	0.60	0.73	0.63, 0.84	<0.001
Night shifts	0.48	0.67	0.47, 0.95	0.025

^a OR odds ratio, CI 95% confidence interval

activity in the third trimester of pregnancy. In addition, this team was anxious to assess whether the activity level of the prospective mother affect her risk of preterm delivery. Consequently, it was deemed necessary to ask these questions prior to the third trimester. The same is true for the questions concerning exercise, such as jogging and swimming, were only asked in the second trimester, not in the first or third trimester. Because of this, it is impossible to be more precise in the conclusions concerning the effects of these activities during specific trimesters. The same is true for occupational activities. The absence of an association between physical activity and fetal and neonatal survival could be explained by a lack of power. Also, because of the multiple testing of the various domains of physical activity, it is possible that the associations that we have found are chance findings. Furthermore, some of the effect sizes showed a major attenuation after adjustment. This could imply that the remaining effect may be a residual confounding effect. Despite the large number of potential effect modifiers tested, the issue of residual confounding by for instance genetic, environmental or lifestyle factors remains unresolved.

Finally, the variable 'maternal social economic status' was not included in the regression analyses because of the high percentage of missing values (>20%). Maternal socio-

economic status is based on the occupation of the pregnant woman. The relatively high number of missing values ($n = 2,170$) can be explained mainly by the categories of teenage women and housewives who do not have a formal occupation. Multiple imputation was considered, but due to the non-random nature of the missing values for this variable a sensitivity analyses was disregarded. It is, however, unlikely that the absence of this variable influenced the findings of our study since other measures of maternal socio-economic status were included in the model, such as paternal socio-economic status, maternal education and house ownership.

Despite these methodological limitations, the findings of our large scale study may be used for generating a policy guideline for physical activity of pregnant women attending antenatal care. In the absence of either medical or obstetric complications, pregnant women may be advised to safely continue their normal daily physical activities should they wish to do so. They can be reassured that physically demanding activities, such as exercise and sports, are not associated with the adverse birth outcomes considered in this study. At the same time, however, our findings do not permit firm conclusions about occupational activities in light of the uncertainties associated with paid work and the birth outcomes of interest.

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Conflict of interest statements None declared.

Ethical approval The law and ethics committee for the Avon longitudinal study of parents and children approved this study.

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