Prospective Study of Physical Activity of Preterm Born Children from Age 5 to 14 Years

Juliane Spiegler, MD[1,2], Marina Mendonca, PhD[1], and Dieter Wolke, PhD, Dr rer nat h.c[1]

Objective To investigate whether level of prematurity (very, moderate, late preterm, vs full term) is associated with physical activity from childhood to adolescence and to identify factors in childhood that predict moderate-vigorous physical activity in early adolescence.

Study design Parents reported on physical activity at the age 5, 7, and 11 years (n = 12 222-14 639) and adolescents self-reported on moderate-vigorous physical activity at 14 years (n = 10 974). At age 14 years, a subgroup was also assessed by wrist accelerometer (n = 4046).

Results Prematurity was associated with a small or no difference in physical activity at each time point. At age 14 years, moderate-vigorous physical activity in self-report and accelerometer was higher in male adolescents, those of white ethnicity, or higher parental education, having been taken to live sport events at age 5 or 7 years or having taken part in organized physical activity at 5 or 7 years.

Conclusions In this representative national cohort study in the United Kingdom, preterm birth was not found to be associated with physical activity between 5 and 14 years. Organized physical activity and watching sport events early in life may increase moderate to vigorous physical activity in adolescents. *(J Pediatr 2019;208:66-73)*.

See related articles, p 50 and 74

Participation in physical activity is deemed to be important for everyone, and the World Health Organization recommends 60 minutes of moderate-vigorous physical activity every day for children age 5-17 years.[1] However, physical activity declines from childhood onward[2] and adolescents are at high risk of insufficient physical activity.[3]

Preterm born infants, especially those born very premature (<32 weeks of gestation) are at an increased risk for neurocognitive problems,[4] motor problems,[5] reduced lung function,[6] or social or behavior problems[7] that might negatively influence participation in physical activity. Thus, tailored advice to participate in physical activity[8] may be needed for individuals born preterm.

There are mixed findings on the association between prematurity and participation in physical activity. Some studies reported that preterm birth is associated with lower rates of physical activity at age 5-6 years[9] or age 6-17 years,[10] but others found no differences in physical activity at age 11 and 15 years between those born preterm or full term.[11] However, it is unclear whether all preterm children are at particular risk to participate less in physical activity or whether it is mainly those who are born very preterm[12,13] or those who suffer from chronic lung disease[14,15] or motor impairment.[16] Thus studies that distinguish between different levels of prematurity such as very, moderately, and late preterm may provide further insight whether all preterm children or those born earliest are at highest risk of lower levels of physical activity. As a range of socioeconomic factors such as parental education,[17] parenting,[18,19] and individual differences such as sex, obesity,[20] intelligence,[21] or asthma[22] have been found to influence physical activity, these should be taken into account when analyzing physical activity according to gestation.

This study aimed to investigate whether participation in physical activity at different ages in childhood (5, 7, 11, 14 years) is less frequent in very, moderately, or late preterm children compared with full term born children in the Millennium Cohort Study using parental report, self-report, and accelerometer data. Second, this study investigated whether social, parenting, or individual factors assessed before 8 years of age predict physical activity in early adolescence (ie, at age 14 years).

Methods

The Millennium Cohort Study is a representative longitudinal study of 18 818 infants born in the United Kingdom (UK).[23] A random sample was drawn

UK United Kingdom

From the [1]Department of Psychology and Division of Mental Health and Well-Being, University of Warwick, Coventry, United Kingdom; and [2]Department of Pediatrics, University of Lübeck, Lübeck, Germany

The Economic and Social Research Council, United Kingdom, has provided the main funding for the Millennium Cohort Study. The Millennium Cohort Study is co-funded by a consortium of government departments, United Kingdom. J.S. was supported by a research fellowship from the DFG (Deutsche Forschungsgemeinschaft) (SP 1731/1-1). The authors declare no conflicts of interest.

https://doi.org/10.1016/j.jpeds.2018.12.013

from Child Benefit registers of all infants born in England and Wales between September 2000 and August 2001, and in Scotland and Northern Ireland between November 2000 and January 2002, who were living in the UK at age 9 months. Over-sampling of ethnic minority and disadvantaged areas was used. Complex sample analysis of the dataset allows controlling for nonresponse/attrition.[24] Parents were interviewed for the first time when the children were age 9 months (survey 1) and again at 3 (survey 2), 5 (survey 3), 7 (survey 4), 11 (survey 5), and 14 (survey 6) years of age. Detailed information was collected on a range of socioeconomic and health factors.[23] Physical activity data are available for ages 5, 7, 11, and 14 years. Ethical approval and written informed consent was obtained for all surveys (London-Hampstead Research Ethics Committee, REC reference 14/LO/0868).

Participants

Of the 18 818 cohort members in the Millennium Cohort Study, we excluded 253 with missing gestational age.[25] To analyze participation in physical activity at the different age groups, all available data at these ages were used. Data of twins and triplets are included in the analysis.

Gestational Age

Gestational age in weeks was calculated using the mother's report of the expected due date, which corresponded well with data in routine hospital records.[26] Gestational age was grouped as very preterm (24^{+0}-31^{+6} weeks of gestation), moderately preterm (32^{+0}-33^{+6} weeks of gestation), late preterm (34^{+0}-36^{+6} weeks of gestation), and term (37^{+0} weeks of gestation and above).

Physical Activity Assessments

Days with organized child physical activity was reported by parents at the ages 5, 7, and 11 years. Days with un-organized physical activity were inquired from parents at the ages 7 and 11 years. At age 14 years, adolescents were asked how many days in the last week they engaged in at least 60 minutes of moderate-vigorous physical activity. The response categories for all variables about physical activity were "less than once a week," "1-2 days per week," "3-4 days per week," and "more than 5 days per week." Self-reported moderate-vigorous physical activity was dichotomized with a cut off at "3-4 days per week" to identify those that met at least the subsidiary recommendation in the UK[27] of one-half the recommended physical activity ("one-half moderate-vigorous physical activity").

Accelerometer data were collected by GENEActiv Original accelerometer devices on 1 day during the week and 1 weekend day calculating Euclidean norm minus 1. Moderate-vigorous physical activity by accelerometer was measured as 5-minute time windows that started with a 5-second epoch value equal to or higher than 100 mg Euclidean norm minus 1 and for which 80% of subsequent 5-second epoch values were equal to or higher than the 100-mg threshold.[28] This cut-off was chosen because physical activity in adolescence includes short periods of high physical activity (eg, team sports), which would be underestimated by the use of longer bout duration.[28] Data for weekdays and weekend days were analyzed separately and then combined so that weekdays were weighted by 5, weekend days by 2, and the result was divided by 7 as previously described.[29] Moderate-vigorous physical activity measured by accelerometer was grouped as 0-29 minutes (less than one-half the recommended time), 30-59 minutes (one-half, but less than recommended time), 60-119 minutes (recommended time), and 120 minutes and above (more than twice the recommended time).

Factors

A detailed description of all socioeconomic, parenting, and child factors that were entered as potential predictors of physical activity at age 14 years are listed in the **Appendix** (available at www.jpeds.com).

Statistical Analyses

Statistical analysis was performed using IBM SPSS Statistics v 24 (IBM Corp, Armonk, New York). Bivariate and categorical variables were compared using χ^2 test. Parental and self-reported days of organized and un-organized physical activity as well as grouping of moderate-vigorous physical activity measured by accelerometer for the gestational age groups is shown using complex sample analysis[24] to control for attrition. Correlation between self-reported physical activity and moderate-vigorous physical activity measured by accelerometer at age 14 years was analyzed using Spearman rank-order correlation.

Stepwise logistic and linear regressions were performed to analyze the association between early childhood predictors and self-reported "½ moderate-vigorous physical activity" or minutes of "moderate-vigorous physical activity measured by accelerometer" at age 14 years. Dependent variables were "½ moderate-vigorous physical activity" for the logistic regression and "moderate-vigorous physical activity measured by accelerometer" for the linear regression. Model 1 reports unadjusted ORs and 95% CIs for all predictors. Model 2 reports on adjusted OR (CI) for socioeconomic factors (ethnicity, parental vocational qualification, number of siblings in household, lone parenthood status,[17] income below 60% poverty index, living in safe area,[30] parental education[18]), parenting factors (having attended a sporting event with the child,[18] Pianta Scale Closeness and Conflict[19]), and individual factors (sex, cognitive development,[21] asthma,[14] motor problems,[16] overweight or obesity at age 5 years,[20] engaging in at least weekly organized physical activity at 5 and 7 years[31]) that were significant in model 1. In model 3, all significant factors from the socioeconomic, parenting, and individual model 2 were included. The same approach was used in the linear regression showing coefficient beta (β) and 95% CI and labeled model 4-6. A sensitivity analysis was performed using model 7 and 8 including all factors analyzed in model 1 and model 4, respectively.

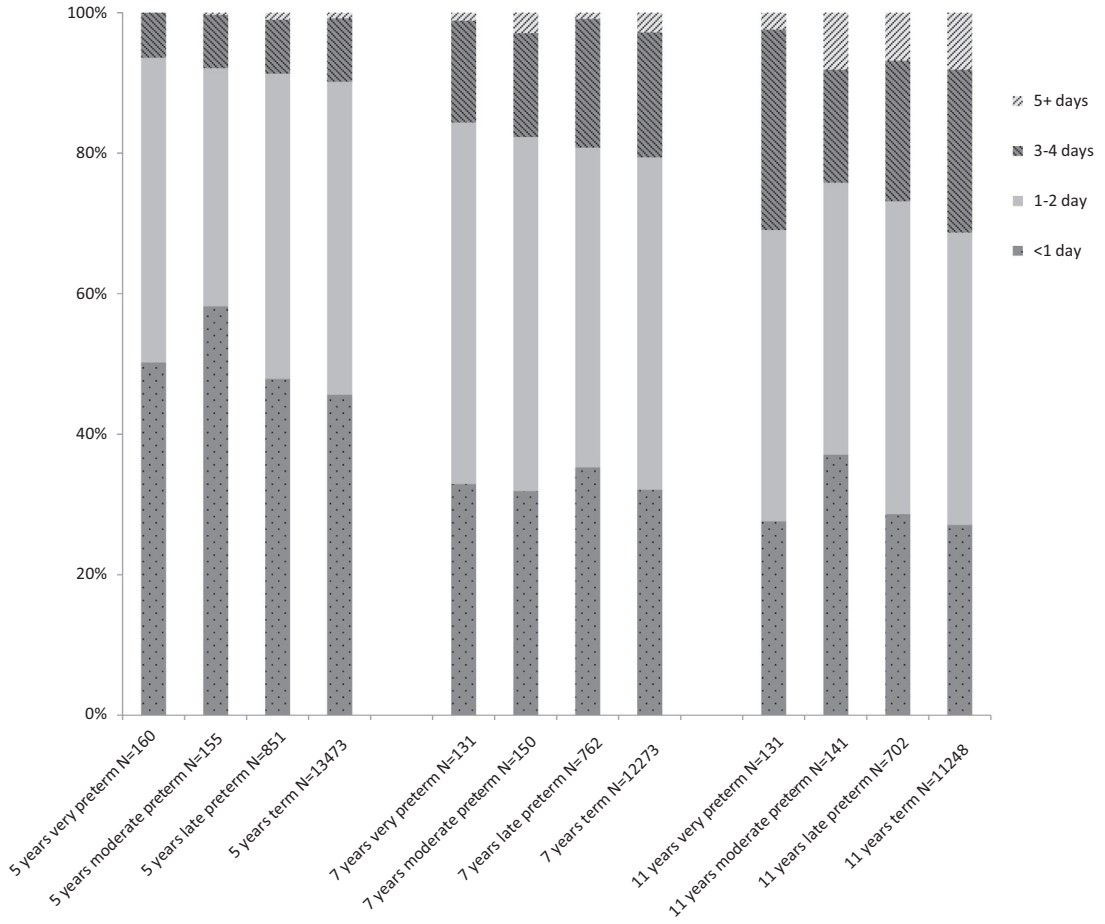

Figure 2. Participation in organized physical activity (club or class) by gestational age groups at age 5, 7, and 11 years as reported by parents (days per week). Group differences are not significant.

Results

A detailed description of the response rates is available.[32,33] Response rates declined over time (96% at age 9 months, 81% at age 3, 79% at age 5, 71% at age 7, 66% at age 11, and 59% at age 14 years). A flow chart of study participation and exclusion is shown in **Figure 1** (available at www.jpeds.com). More families at high social risk were lost to follow-up. For all descriptive analysis, this was controlled for by using complex sample analysis[24] and predicted percentages are given. A random subsample of 10 337 cohort members was asked to wear the accelerometer devices, resulting in 4046 valid datasets. Reasons for missing/invalid data were mainly "device not returned" (24%), "device not placed" (11%), and "device not worn on specified days" (11%) (**Figure 1**).[33] Comparison of sociodemographic and economic variables of cohort members with and without self-reported moderate-vigorous physical activity or accelerometer data at age 14 years is shown in **Table I** (available at www.jpeds.com); children with severe motor impairment were more likely to be lost to follow-up. The distribution of gestational age groups included in the Millennium Cohort Study corresponds well to data for preterm birth rates in the UK.[34]

Parental reports of organized physical activity were available at age 5 years in 14 639 (79%), at age 7 years in 13 316 (71%), and at age 11 years in 12 222 (66%) children. Parental reports on un-organized physical activity were available at age 7 years in 13 313 (71%) and at age 11 years in 12 219 (66%) children. At age 14 years, self-reported moderate-vigorous physical activity was available in 10 974 (59%) and moderate-vigorous physical activity measured by accelerometer in 4046 (22%) adolescents.

Organized Physical Activity Age 5-11 Years

No difference in organized physical activity was seen at age 5 years ($P = .23$), 7 years ($P = .29$), or 11 years ($P = .17$) across all gestational age groups (**Figure 2**).

Sex differences in organized physical activity were significant for all age groups (**Figure 3**; available at www.jpeds.com). At age 5 years, boys were less likely to participate in any organized sport ($P < .001$), and at age 11 years girls were less

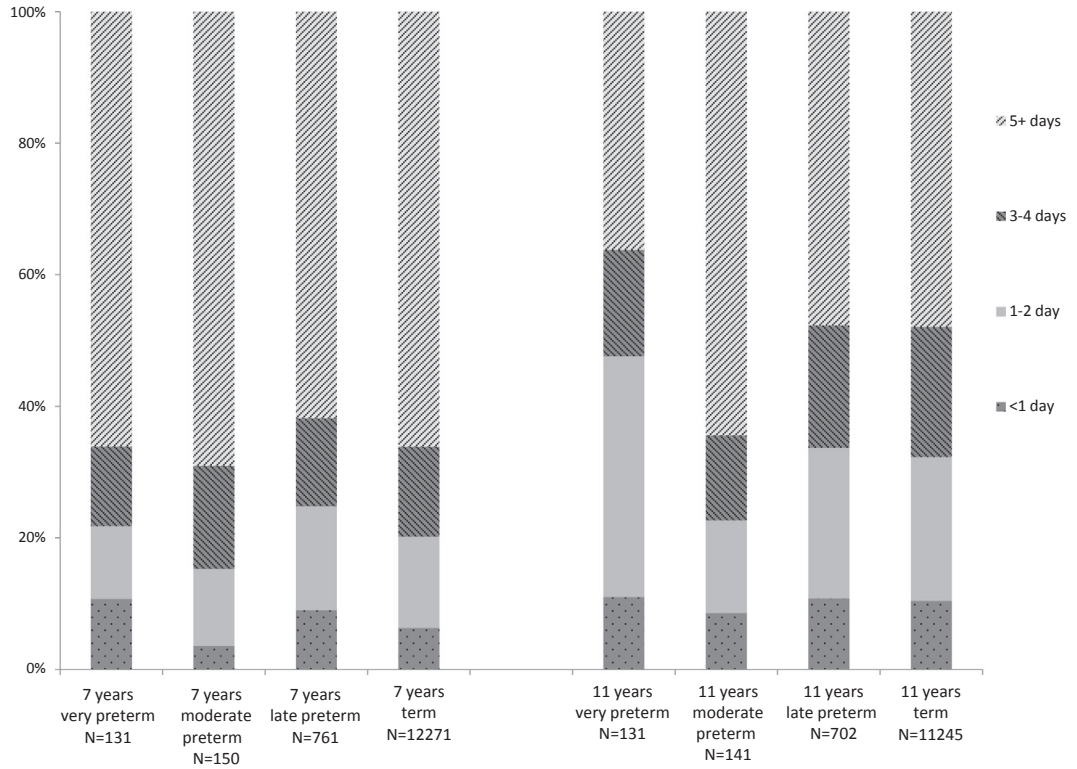

Figure 4. Participation in unorganized physical activity (with siblings, friends) by gestational groups at age 7 and 11 years as reported by parents (days per week). Group differences are significant at age 11 years ($P < .05$).

likely ($P < .001$). At age 7 years, boys reported more days with organized physical activity than girls ($P < .05$). The sex differences were seen across all gestational age groups.

Un-organized Physical Activity Age 7 and 11 Years

Differences in un-organized physical activity were not seen with across gestational age groups at age 7 years ($P = .17$), but they were noted at age 11 years ($P < .05$) (**Figure 4**). Parents of moderately preterm born children reported the highest rates of un-organized physical activity at age 11 years.

Sex differences in un-organized physical activity were significant for all age groups (**Figure 5**; available at www.jpeds.com). At age 7 ($P < .05$) and age 11 ($P < .001$) years, boys had more days of un-organized physical activity than girls. The sex differences were seen across all gestational age groups.

Physical Activity at Age 14 Years

Self-reported Physical Activity. The recommended daily moderate-vigorous physical activity of 60 minutes was reported by 19% of term born, 17% late preterm born, 12% moderately preterm born, and 11% very preterm born adolescents. Differences in moderate-vigorous physical activity were significant for the gestational age groups at age 14 years ($P < .01$) (**Figure 6**).

Differences in gestational age groups were significant in both sexes (both $P < .05$); moderately preterm born female adolescents reported the least physical activity (**Figure 7**; available at www.jpeds.com).

Accelerometer Data. Overall, 23% of term born, 25% late preterm born, 34% moderately preterm born, and 19% very preterm born adolescents were engaged in the recommended daily 60 minutes of moderate to vigorous activity. Differences in moderate-vigorous physical activity measured by accelerometer were not significant by gestational age groups at age 14 years ($P = .29$) (**Figure 8**; available at www.jpeds.com). Moderate-vigorous physical activity measured by accelerometer was highly variable in all gestational age groups (mean, [SD]; 40 [49] minutes for term, 45 [75] minutes for late preterm, 51 [42] minutes for moderate preterm, and 37 [33] minutes for very preterm). Sex differences were seen in all gestational age groups (**Figure 9**; available at www.jpeds.com).

Self-reported moderate-vigorous physical activity at age 14 years correlated with moderate-vigorous physical activity measured by accelerometer data for all gestational age groups (Spearman rank-order correlation for term: 0.25, $P < .001$; late preterm: 0.31, $P < .001$; moderate preterm: 0.22, $P = .14$; very preterm adolescents: 0.42, $P < .01$).

Predictors of Activity at Age 14 Years

Overall results of both the logistic regression (self-reported moderate-vigorous physical activity) and linear regression

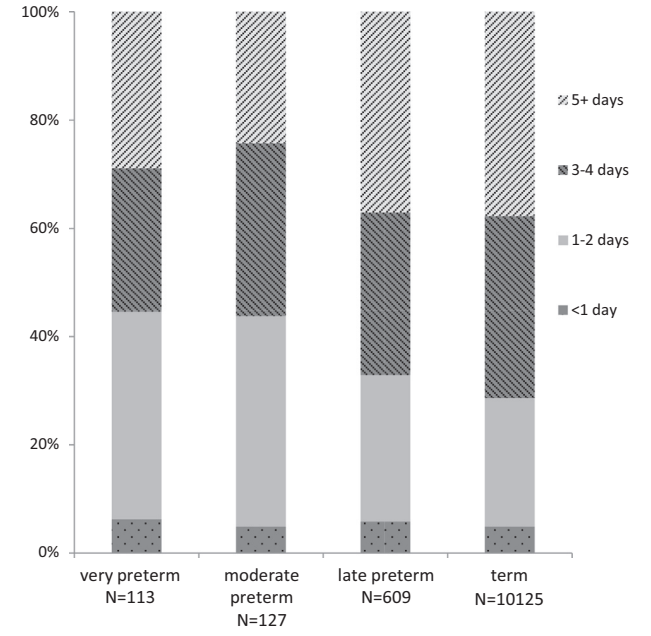

Figure 6. Adolescents (14 years) reporting days with moderate to vigorous activity for more than 60 minutes during the prior week by gestational age groups. Differences between gestational age groups are significant ($P < .01$).

(accelerometer) were similar. At age 14 years self-reported "½ moderate-vigorous physical activity" was more likely met and "moderate-vigorous physical activity measured by accelerometer" was higher in male adolescents, having been taken to watch a live sport event at age 7 years or having been engaged in organized physical activity at age 5 or 7 years (**Table II**). "½ moderate-vigorous physical activity" was more likely reported in those with highly educated parents whereas white ethnicity predicted higher "moderate-vigorous physical activity measured by accelerometer." Gestational age was not associated with "moderate-vigorous physical activity measured by accelerometer," but moderately preterm adolescents were less likely to self-report "½ moderate-vigorous physical activity." Adolescents with severe motor problems were less likely to report "½ moderate-vigorous physical activity," a similar negative influence was seen in "moderate-vigorous physical activity measured by accelerometer," but only few children with severe motor impairment had valid "moderate-vigorous physical activity measured by accelerometer" (6/4046) compared with the self-reported "½ moderate-vigorous physical activity" (26/10 311). More cohort members of white ethnicity and those having engaged in organized physical activity at age 5 and 7 years had complete datasets and were included in model 3 and 6 (**Table III**; available at www.jpeds.com).

To test for sensitivity, the analysis was repeated including all factors of model 1 in model 7 (logistic regression "½ moderate-vigorous physical activity") and all of model 4 in model 8 (linear regression "moderate-vigorous physical activity measured by accelerometer") (**Table IV**; available at www.jpeds.com). Results of model 7 were similar to model 3. Results of model 8 were similar to model 6 but ethnicity did not influence moderate-vigorous physical activity measured by accelerometer after controlling for other socioeconomic variables, whereas speech impairment was associated with increased activity and overweight with decreased activity.

Discussion

In a large cohort from the UK, less than one-fourth of adolescents reported the recommended daily amount of moderate-vigorous physical activity.[1] This was found whether self-reports or accelerometer data were used. This is consistent with findings from Germany,[35] other European countries, and northern America.[36] The physical activity assessed with accelerometer in the Millennium Cohort Study, however, is significantly lower than found in Brazil,[28] but similar to other European countries.[29] Potentially modifiable factors found to increase physical activity are engagement in organized physical activity at a young age or having been taken to a life sport event during childhood. A positive effect of taking young children to watch a sport event on subsequent physical activity has been described previously.[18] The finding of early engagement in organized physical activity to predict physical activity during adolescence is consistent with other studies.[31] Nevertheless, these predictors only explained an increase of 4-6 minutes of moderate-vigorous physical activity per day. The direction of these associations need to be interpreted cautiously as active children may have self-selected to have interest to watch live sport events or engage in organized physical activity at an early age. Primary controlled prevention studies monitoring the effect of promoting live sport events and participation in organized physical activity during childhood on physical activity later in life are required. As shown before repeatedly,[2,3] it was found that female adolescents are less physically active than male adolescents.

In light of the uncertainty within the literature to whether prematurity is related to physical activity in adolescence, this large representative national cohort from the UK provides evidence that according to parental reports between 5 and 11 years, very, moderate, and late preterm born children in the Millennium Cohort Study engaged as much in organized or un-organized physical activity as term born peers. These results are supported by other birth cohorts[11,37,38] or studies linked to neonatal data that exclude chronic motor or lung impairment.[39,40] Differences in physical activity participation were reported in preterm infants with impaired lung[14] or motor function,[16] and these subgroups of preterm children could profit from individually tailored advice regarding participation in physical activity. Studies analyzing extremely preterm born children at age 10 years reported conflicting results with both similar[38] amounts of physical activity measured by accelerometer and lower amounts of

Table II. Factors assessed before 8 years of age that are associated with self-reported "½ moderate-vigorous physical activity" or accelerometer assessed minutes of "moderate-vigorous physical activity assessed by accelerometer" at age 14 years

	Self-reported ½ moderate-vigorous physical activity			Accelerometer measured moderate-vigorous physical activity		
	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
Factors	**OR (95%CI)**	**OR (95%CI)**	**OR (95%CI)**	**β (95%CI)**	**β (95%CI)**	**β (95%CI)**
Socioeconomic (age 9 mo)						
Ethnicity white	**1.21 (1.09 to 1.35)**	1.10 (0.98 to 1.24)		**9 (5 to 14)**	**8 (4 to 13)**	**6 (2 to 9)**
High parental vocational qualification	**1.33 (1.21 to 1.46)**	1.08 (0.97 to 1.21)		2 (−1 to 5)		
High parental education	**1.42 (1.30 to 1.54)**	**1.27 (1.15 to 1.41)**	**1.19 (1.07 to 1.31)**	1 (−2 to 5)		
Income below 60% poverty index	**0.73 (0.66 to 0.79)**	**0.83 (0.74 to 0.92)**	0.97 (0.87 to 1.08)	**−5 (−8 to (−1))**	−3 (−7 to 0.4)	
Siblings in household	**0.96 (0.93 to 1.00)**	1.00 (0.96 to 1.05)		−1 (−3 to 0.3)		
Lone parenthood status	**1.24 (1.10 to 1.39)**	0.97 (0.85 to 1.11)		3 (−2 to 8)		
Living in safe area	**0.87 (0.80 to 0.95)**	0.93 (0.85 to 1.01)		−2 (−5 to 1)		
Parenting						
Pianta Scale Conflict (age 3 y)	**0.99 (0.98 to 1.00)**	0.99 (0.98 to 1.00)		0.1 (−0.2 to 0.4)		
Pianta Scale Closeness (age 3 y)	**1.03 (1.01 to 1.05)**	1.02 (1.00 to 1.05)		0 (−1 to 1)		
Having attended a sporting event with the child at age 4-5 y	**1.73 (1.52 to 1.97)**	**1.31 (1.13 to 1.53)**	**1.25 (1.08 to 1.44)**	**7 (3 to 10)**	2 (−2 to 6)	
Having attended a sporting event with the child at age 6-7 y	**1.98 (1.77 to 2.20)**	**1.80 (1.59 to 2.04)**	**1.40 (1.24 to 1.57)**	**11 (8 to 15)**	**10 (7 to 13)**	**4 (1 to 7)**
Individual						
Sex male	**1.94 (1.78 to 2.11)**	**1.96 (1.77 to 2.18)**	**1.79 (1.63 to 1.97)**	**17 (14 to 21)**	**19 (16 to 21)**	**18 (15 to 20)**
Very preterm	**0.62 (0.42 to 0.90)**	1.09 (0.64 to 1.88)	0.74 (0.48 to 1.15)	−3 (−18 to 12)		
Moderate preterm	**0.57 (0.40 to 0.81)**	**0.59 (0.39 to 0.90)**	**0.59 (0.40 to 0.86)**	11 (−4 to 25)		
Late preterm	0.92 (0.77 to 1.10)	0.88 (0.71 to 1.09)	0.91 (0.74 to 1.11)	5 (−1 to 12)		
Multiple	0.93 (0.72 to 1.21)			0 (−10 to 9)		
Normal cognitive development (age 3 y)	**1.21 (1.06 to 1.39)**	0.96 (0.81 to 1.14)		3 (−3 to 9)		
Normal speech development (age 3 y)	**1.33 (1.18 to 1.50)**	1.12 (0.96 to 1.31)		2 (−3 to 7)		
Asthma (age 5 y)	**1.16 (1.03 to 1.31)**	1.15 (0.99 to 1.32)		−2 (−6 to 1)		
Severe motor problems (age 5 y)	**0.18 (0.08 to 0.40)**	**0.25 (0.09 to 0.69)**	**0.19 (0.08 to 0.44)**	−21 (−53 to 11)		
Overweight (age 5 y)	**0.86 (0.76 to 0.96)**	0.93 (0.81 to 1.06)		**−4 (−8 to (−0.5))**	−3 (−7 to 0.5)	
Obese (age 5 y)	**0.83 (0.69 to 1.01)**	0.95 (0.75 to 1.19)		−2 (−8 to 4)	0 (−6 to 6)	
Weekly organized sport (age 5 y)	**1.46 (1.34 to 1.59)**	**1.31 (1.17 to 1.46)**	**1.21 (1.09 to 1.34)**	**5 (2 to 8)**	**5 (2 to 7)**	**4 (1 to 7)**
Weekly organized sport (age 7 y)	**1.67 (1.53 to 1.83)**	**1.52 (1.35 to 1.71)**	**1.37 (1.23 to 1.53)**	**9 (6 to 13)**	**6 (3 to 9)**	**5 (2 to 8)**

½ moderate-vigorous physical activity: self-reported moderate to vigorous physical activity of ≥60 minutes on at least 3-4 days per week. Moderate-vigorous physical activity measured by accelerometer: minutes of 5-minute windows with 80% activity (ENMO >100 mg) measured by wrist accelerometer. For gestational age groups term born is reference group; for obesity/overweight normal weight is reference.

Dependent variable is "½ moderate-vigorous physical activity" for the logistic regression (model 1-3) and "moderate-vigorous physical activity-measured by accelerometer" for the linear regression model 4-6. Model 1 shows unadjusted OR and 95% CI. In model 2, OR (CI) are adjusted for socioeconomic predictors (n = 10 570, Cox and Snell $r^2 = 0.009$), for parenting predictors (n = 7748, Cox and Snell $r^2 = 0.018$), for individual predictors (n = 8085, Cox and Snell $r^2 = 0.038$). Model 3 uses all significant predictors of models 1 (n = 9562; Cox and Snell $r^2 = 0.044$). Model 4 shows unadjusted coefficient β (β) and 95% CI. In model 5 β (CI) are adjusted for socioeconomic predictors (n = 4037, adjusted $r^2 = 0.004$), for parenting predictors (n = 3724, adjusted $r^2 = 0.014$), for individual predictors (n = 3720, adjusted $r^2 = 0.064$). Model 6 uses all significant predictors of models 5 (n = 3716; adjusted $r^2 = 0.067$). *P* values < .05 are shown in bold.

physical activity[41] measured via questionnaire, but it remains unclear whether any reduction is due to the extremely preterm birth or rather the higher rate of lung impairment or motor dysfunction. Some cross-sectional studies[9,42] or survey studies[10] reported lower participation rates in physical activity in preterm children; however, these studies have in common, that preterm birth status relied solely on parental report years later.

A reduction of physical activity has been described in preterm cohort studies during adolescence and early adulthood using questionnaires.[8,41] Both accelerometer studies during childhood (age 10 years)[38] or adolescence (age 15 years)[11] showed no differences in physical activity between gestational age groups. Analyzing self-reported physical activity of the Millennium Cohort Study, moderately preterm born children reported less physical activity at age 14 years than term born adolescents. However, this was not confirmed by accelerometer data within the same cohort measured shortly thereafter. Thus, moderately preterm born adolescents seem to perceive themselves as less active than other gestational groups. The reason for this biased self-perception is unclear. A similar discrepancy was seen in the "Helsinki Study of Very Low Birth Weight Preterm Adults" as well as the "ESTER (Preterm Birth, Pregnancy and Offspring Health in Adult Life)" study with differences in questionnaire data on physical activity,[43,44] but no difference in accelerometer data in the early twenties[45,46] compared with term born controls. Therefore, a combination of accelerometer and questionnaire data about physical activity including organized and un-organized activity is required for valid conclusions. These indicate that there is little difference in physical activity between those born preterm or full term.

Strengths of this study are the sample size of preterm children exceeding most neonatal cohort studies.[47] This

allowed for analysis across gestational ages and controlling for a large number of potential confounders. Furthermore, we were able to assess subjective and objective assessments of physical activity, which only correlate moderately.

There are also limitations. Even in this large cohort, extremely preterm born children were rare and statistical power restricted. Analysis splitting the very preterm group into those below 28 weeks of gestation (n = 29-39) and 28-31 weeks of gestation (n = 83-121) indicated no differences in physical activity. Assessment of physical activity changed from parental to self-report in adolescence according to more independence of adolescence. The 14-year assessment did not anymore differentiate between organized and un-organized activity. The accelerometer module measured was limited to 2 days only although 6-7 days are recommended to assess habitual physical activity.[48,49] However, the correlations with self-reports are similar to those reported for 6-day monitoring attesting to similar reliability.[50] Cohort members participating in the accelerometer module were more active during childhood, and accelerometer data might have overestimated physical activity compared with the initial Millennium Cohort Study sample.

In the Millennium Cohort Study, very, moderate, and late preterm born children age 5 to 14 years were as physically active as their term-born peers. However, moderately preterm-born adolescents perceived themselves as less active at age 14 years and this may warrant further study. Engaging in organized physical activity at an early age and being taken to watch live sport event might improve physical activity in adolescence. ■

We thank The Center for Longitudinal Studies, UCL Institute of Education for the use of these data and the UK Data Archive and UK Data Service for making them available. However, they bear no responsibility for the analysis or interpretation of these data. We thank all participants of the Millennium Cohort Study.

Submitted for publication Aug 31, 2018; last revision received Nov 12, 2018; accepted Dec 5, 2018.

Reprint requests: Juliane Spiegler, MD, Klinik für Kinder-und Jugendmedizin, Universität zu Lübeck, Ratzeburger Allee 160, 23538 Lübeck, Germany. E-mail: uni@dr-spiegler.de

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Appendix

Factors

All socioeconomic variables were taken from the first survey at age 9 months and included sex,[1] ethnicity (classified as white or other),[1] highest national vocational qualification of child's parents or carer[1] (competence based qualification dichotomized to high (≥4 = nursing or professional qualification at degree level) or low), highest education of the child's parents or carer classified as high (equivalent to high school diploma) or low,[1] income below 60% poverty index,[1] living in a safe area,[2] number of siblings living in the household,[1] and lone parenthood status[1] (classified as parent not living with a partner).

Having attended a sporting event with the child between the ages 4-5 years (inquired at age 5 years) or 6-7 years (inquired at age 7 years) was analyzed.[3] The Pianta Scale for Conflict (score range 7 [lowest conflict] to 35 [highest conflict]) and Closeness[4] (score range 7 [lowest warmth] to 35 [highest warmth]) was inquired at age 3 years and used as measure for parenting stress and positive parent-child relationship.[5]

At age 3 years, cognitive development (Bracken Composite Score[6]) and speech development (British Ability Scales Vocabulary Test[7]) were classified as either normal or more than 1 SD below average.[8] As relevant medical problems that potentially influence participation, we analyzed the diagnosis of asthma[9] at age 5 years and being diagnosed with a longstanding health condition which international classification of diseases (ICD) code implicated motor problems[5] at age 5 years (ICD G80-G83 [cerebral palsy and other paralytic syndromes], R26-R29 [abnormalities of gait and mobility, other lack of coordination, other symptoms and signs involving the nervous and musculoskeletal systems], Q05 [Spina bifida], G14 [post-polio syndrome]). Overweight or obesity[10] at age 5 years was classified using the UK cut-offs for body mass index for the corresponding age and sex.[11]

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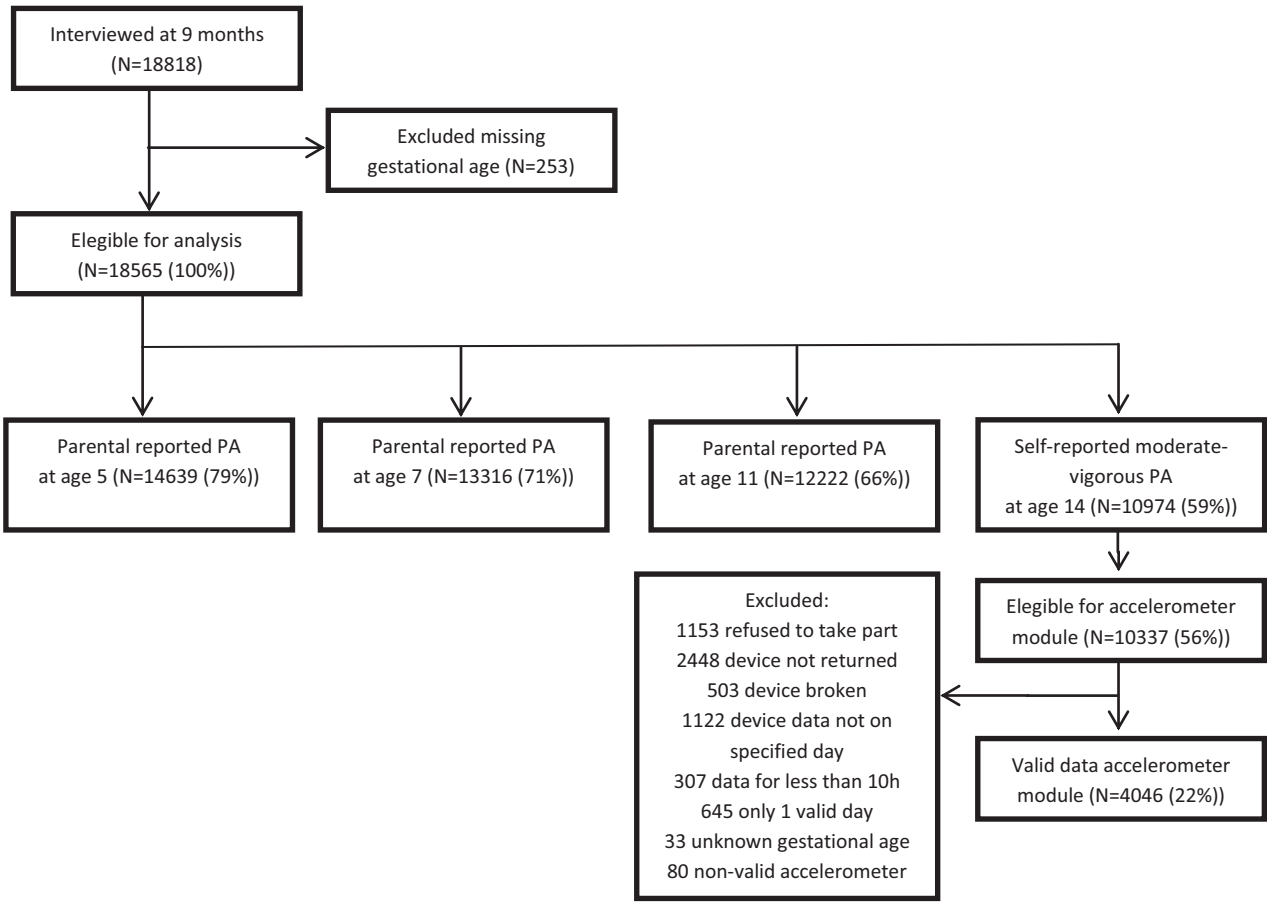

Figure 1. Flow chart of study participation and exclusions. Percentages are of the original sample at 9 months with valid gestational age n = 18 565.

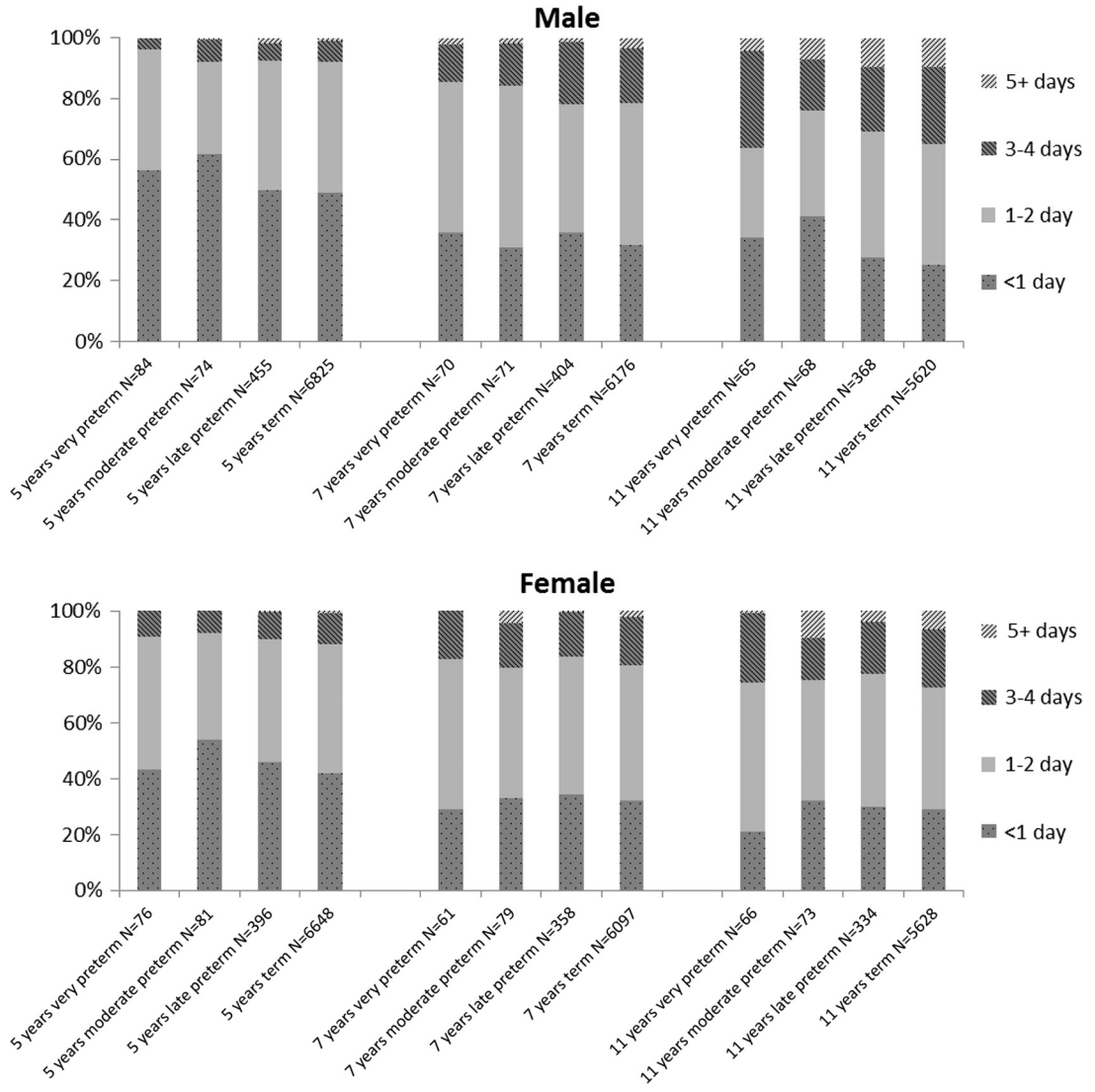

Figure 3. Participation in organized physical activity (club or class) by gestational age groups for male and female children at age 5, 7, and 11 years as reported by parents (days per week). Group differences are not significant.

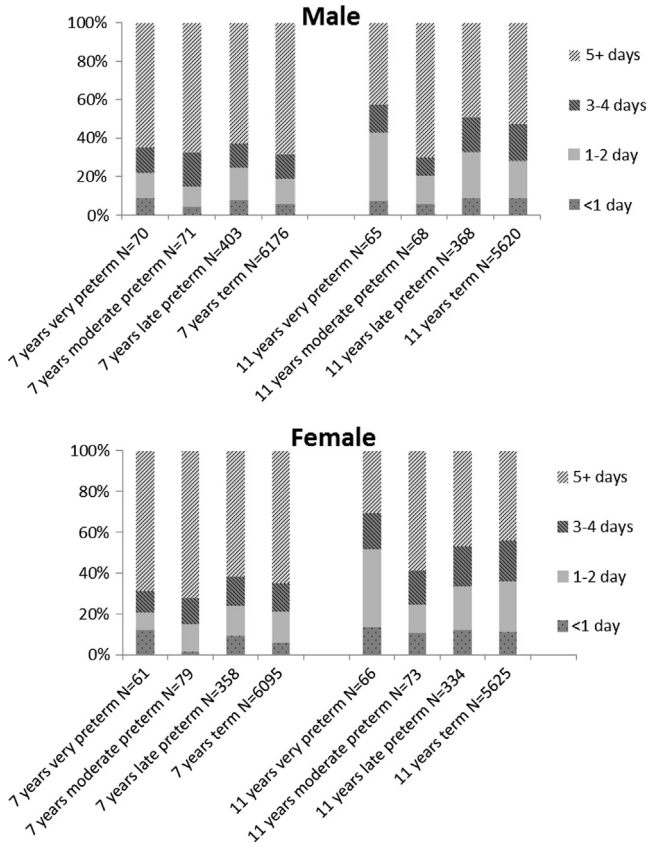

Figure 5. Participation in unorganized physical activity (with siblings, friends) by gestational groups for male and female children at age 7 and 11 years as reported by parents (days per week). Group differences are significant at age 11 years ($P < .05$).

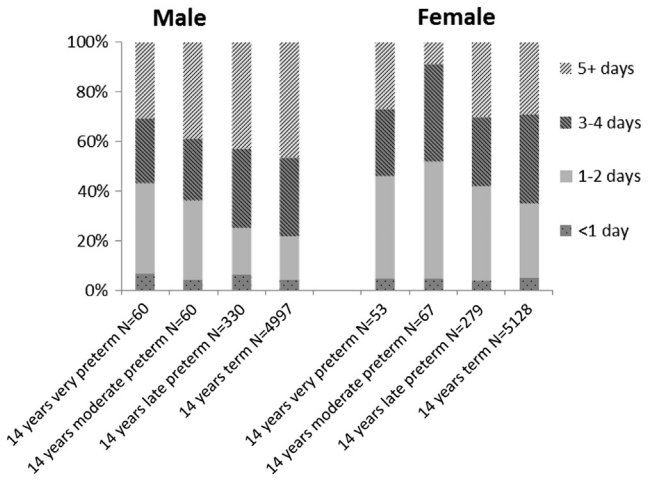

Figure 7. Adolescents (14 years) reporting days with moderate to vigorous activity for more than 60 minutes during the prior week by gestational groups for male and female adolescents. Differences between gestational age groups are significant ($P < .05$ for male, $P < .01$ for female).

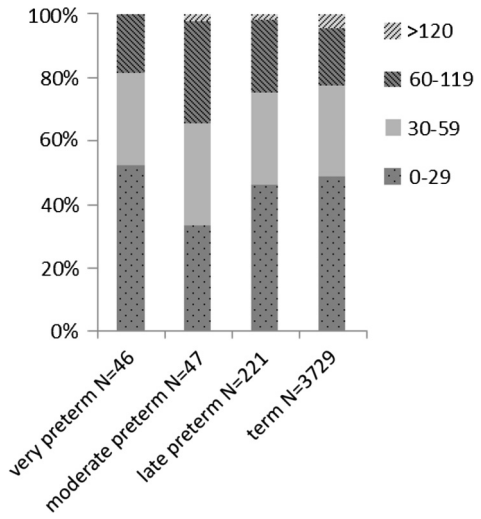

Figure 8. Minutes of moderate-vigorous physical activity measured by accelerometer (80% bouts in 5-minute time windows) by gestational age groups at age 14 years. Differences between gestational age groups are not significant. Complex sample analysis excluded 3 term born adolescents due to missing weight.

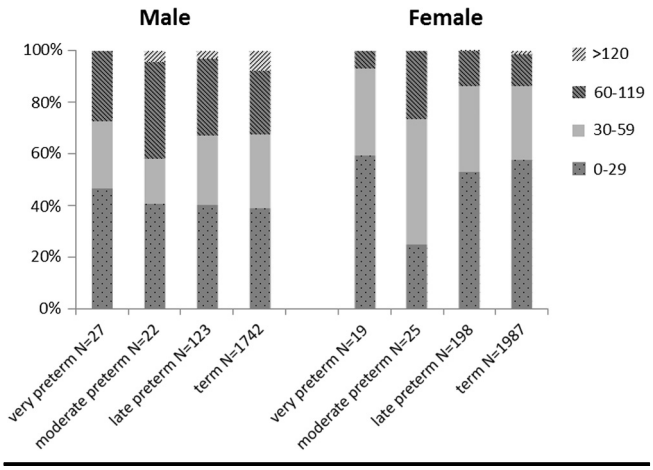

Figure 9. Minutes of moderate-vigorous physical activity measured by accelerometer (80% bouts in 5-minute time windows) by gestational age groups for male and female adolescents at age 14 years. Differences between gestational age groups are not significant.

Table I. Comparison of participants without and with self-reported moderate-vigorous physical activity and nonvalid and valid moderate-vigorous physical activity measured by accelerometer data at age 14 years in the Millennium Cohort Study

	No self-reported moderate-vigorous physical activity	Self-reported moderate-vigorous physical activity						Nonvalid moderate-vigorous physical activity accelerometer data	Valid moderate-vigorous physical activity accelerometer data					
	n = 7591	n = 10 974	*P* value	Very preterm n = 113	Moderately preterm n = 127	Late preterm n = 609	Term n = 10 125	n = 14 519	n = 4046	*P* value	Very preterm n = 46	Moderately preterm n = 47	Late preterm n = 221	Term n = 3732
Gestational age (wk)	39 (2)	39 (2)	1.0	29 (2)	33 (1)	36 (1)	**40 (1)**	39 (2)	39 (2)	1.0	29 (2)	33 (1)	36 (1)	**40 (1)**
Birth weight (kg)	3.3 (0.66)	3.3 (0.67)	<.05	1.3 (0.49)	2.0 (0.52)	2.6 (0.69)	**3.4 (0.59)**	3.3 (0.67)	3.4 (0.65)	<.05	1.3 (0.59)	2.0 (0.52)	2.6 (0.53)	**3.4 (0.57)**
Sex male	4060 (54%)	5447 (50%)	<.001	60 (53%)	60 (47%)	330 (54%)	**4997 (49%)**	7591 (52%)	1916 (47%)	<.001	27 (59%)	22 (47%)	123 (56%)	**1744 (47%)**
Ethnicity white	6276 (83%)	9098 (83%)	.62	85 (75%)	110 (87%)	503 (83%)	8400 (83%)	11 869 (82%)	3505 (87%)	<.001	35 (76%)	**44 (94%)**	**196 (89%)**	**3230 (87%)**
High parental vocational qualification	1380 (18%)	3174 (29%)	<.001	**32 (28%)**	35 (28%)	**162 (27%)**	**2945 (29%)**	3235 (22%)	1319 (33%)	<.001	**16 (35%)**	13 (28%)	**73 (33%)**	**1217 (33%)**
Income below 60% poverty index	3342 (44%)	3455 (32%)	<.001	40 (35%)	**42 (33%)**	**209 (34%)**	**3164 (31%)**	5718 (40%)	1079 (27%)	<.001	19 (41%)	**12 (26%)**	**60 (27%)**	**988 (27%)**
High parental education	2536 (34%)	5323 (50%)	<.001	**55 (49%)**	**62 (49%)**	**269 (45%)**	**4937 (50%)**	5664 (40%)	2195 (55%)	<.001	21 (47%)	26 (55%)	**123 (56%)**	**2025 (55%)**
Families with multiple births	239 (3%)	277 (3%)	<.05	23 (20%)	30 (24%)	**84 (14%)**	140 (1%)	403 (3%)	113 (3%)	.95	**14 (30%)**	14 (30%)	40 (18%)	45 (1%)
Very preterm	103 (1%)	113 (1%)	<.05	113 (100%)	0	0	0	170 (1%)	46 (1%)	.62	46 (100%)	0	0	0
Moderate preterm	73 (1%)	127 (1%)		0	127 (100%)	0	0	153 (1%)	47 (1%)		0	47 (100%)	0	0
Late preterm	477 (6%)	609 (6%)		0	0	609 (100%)	0	865 (6%)	221 (6%)		0	0	221 (100%)	0
Full term	3938 (91%)	10 125 (92%)		0	0	0	10 125 (100%)	13 331 (92%)	3732 (92%)		0	0	0	3732 (100%)
Severe motor impairment	22 (0.5%)	26 (0.3%)	<.05	**2 (2.0%)**	3 (2.5%)	2 (0.4%)	19 (0.2%)	42 (0.4%)	6 (0.2%)	<.05	0	2 (4.4%)	0	4 (0.1%)
Watched life sport event age 7	824 (26%)	2653 (26%)	.52	21 (22%)	23 (19%)	144 (26%)	2465 (26%)	2246 (26%)	1031 (27%)	.11	10 (26%)	7 (16%)	61 (30%)	953 (27%)
Weekly sport														
Age 5	1950 (45%)	5635 (55%)	<.001	47 (44%)	**58 (48%)**	296 (52%)	**5234 (55%)**	5305 (49%)	2280 (59%)	<.001	23 (51%)	**25 (54%)**	**126 (59%)**	**2106 (59%)**
Age 7	1985 (62%)	7051 (70%)	<.001	62 (64%)	77 (64%)	365 (66%)	**6547 (70%)**	6247 (66%)	2789 (73%)	<.001	21 (55%)	**34 (77%)**	**148 (73%)**	**2586 (73%)**

ENMO, Euclidean norm minus 1.

Moderate-vigorous physical activity measured by accelerometer: minutes of 5-minute windows with 80% bout activity (ENMO > 100 mg) measured by wrist accelerometer. Significant differences ($P < .05$) of nonparticipants and participants of the different gestational age groups are shown in bold.

Table III. Comparison of cohort members included in the logistic regression model 3 and the linear regression model 6 at age 14 years to those with missing data

Factors	Included in model 3 n = 9562	Missing data model 3 n = 1412	*P* value	Included in model 6 n = 3716	Missing data model 6 n = 330	*P* value
Ethnicity white	8194 (86%)	904 (64%)	<.001	3275 (88%)	230 (71%)	<.001
High parental education	4956 (52%)	367 (31%)	<.001	2084 (57%)	111 (35%)	<.001
Having attended a sporting event with the child at age 4-5	1538 (16%)	92 (12%)	<.01	597 (16%)	24 (15%)	.58
Having attended a sporting event with the child at age 6-7	2550 (27%)	103 (19%)	<.001	1013 (27%)	18 (19%)	.07
Sex male	4721 (49%)	726 (51%)	.15	1752 (47%)	164 (50%)	.37
Very preterm	91 (1%)	22 (2%)	<.05	38 (1%)	8 (2%)	.11
Moderate preterm	116 (1%)	11 (1%)		44 (1%)	3 (1%)	
Late preterm	517 (5%)	92 (7%)		200 (5%)	21 (6%)	
Full term	8838 (92%)	1287 (91%)		3434 (92%)	298 (90%)	
Severe motor problems (age 5 y)	25 (0.3%)	1 (0.1%)	.5	6 (0.2%)	0 (0%)	.61
Weekly organized sport (age 5 y)	5339 (56%)	296 (38%)	<.001	2206 (59%)	74 (45%)	<.001
Weekly organized sport (age 7 y)	6776 (71%)	275 (50%)	<.001	2736 (74%)	53 (57%)	<.001

Table IV. Sensitivity analysis of influencing factors for self-reported "½ moderate-vigorous physical activity" or measured minutes of "moderate-vigorous physical activity" age 14 years

Factors	Model 7 OR (95%CI)	Model 8 β (95%CI)
Socioeconomic (age 9 mo)		
Ethnicity white	0.96 (0.78 to 1.17)	4 (−3 to 10)
High parental vocational qualification	1.05 (0.92 to 1.20)	1 (−3 to 4)
High parental education	**1.18 (1.03 to 1.34)**	−2 (−6 to 1)
Income below 60% poverty index	1.02 (0.87 to 1.19)	2 (−3 to 6)
Siblings in household	1.03 (0.97 to 1.10)	0 (−2 to 1)
Lone parenthood status	1.08 (0.89 to 1.31)	6 (−1 to 12)
Living in safe area	0.91 (0.81 to 1.03)	−1 (−4 to 2)
Parenting		
Pianta Scale Conflict (age 3 y)	1.00 (0.99 to 1.01)	0 (−0.3 to 0.3)
Pianta Scale Closeness (age 3 y)	1.00 (0.97 to 1.03)	0 (−1 to 1)
Having attended a sporting event with the child at age 4-5 y	**1.24 (1.05 to 1.46)**	1 (−3 to 5)
Having attended a sporting event with the child at age 6-7 y	**1.40 (1.22 to 1.61)**	**5 (1 to 9)**
Individual		
Sex male	**1.77 (1.58 to 1.99)**	**17 (13 to 20)**
Very preterm	0.92 (0.51 to 1.67)	−5 (−23 to 12)
Moderately preterm	**0.58 (0.36 to 0.93)**	2 (−13 to 18)
Late preterm	0.87 (0.68 to 1.11)	6 (−1 to 13)
Multiple	1.16 (0.78 to 1.72)	1 (−10 to 12)
Normal cognitive development (age 3 y)	0.93 (0.75 to 1.14)	2 (−4 to 8)
Normal speech development (age 3 y)	1.21 (0.99 to 1.46)	**−7 (−12 to (−1))**
Asthma (age 5 y)	1.09 (0.93 to 1.28)	−2 (−6 to 3)
Severe motor problems (age 5 y)	**0.24 (0.08 to 0.67)**	−21 (−57 to 15)
Overweight (age 5 y)	0.91 (0.78 to 1.05)	**−5 (−9 to (−0.5))**
Obese (age 5 y)	0.99 (0.77 to 1.29)	1 (−6 to 9)
Weekly organized sport (age 5 y)	**1.19 (1.05 to 1.34)**	**4 (0 to 7)**
Weekly organized sport (age 7 y)	**1.47 (1.29 to 1.68)**	**6 (2 to 10)**

½ moderate-vigorous physical activity: self-reported moderate to vigorous physical activity of ≥ 60 minutes on at least 3-4 days per week. Moderate-vigorous physical activity-measured by accelerometer: minutes of 5-minute windows with 80% bout activity (ENMO > 100 mg) measured by wrist accelerometer. For gestational age groups term born is reference group; for obesity/overweight normal weight is reference. Model 7 includes all variables analyzed in the logistic regression model 1 (n = 6813, Cox and Snell $r^2 = 0.047$) with "½ moderate-vigorous physical activity" as dependent variable. Model 8 (n = 2732, $r^2 = 0.059$) includes all variables analyzed of the linear regression model 4 with "moderate-vigorous physical activity-measured by accelerometer" as dependent variable.