Physical activity during pregnancy and language development in the offspring

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Abstract

Background—In rodents, physical activity during pregnancy has been associated with improved learning and memory in the offspring. We used data from the Avon Longitudinal Study of Parents and Children (born 1991-1992) to investigate maternal physical activity during pregnancy and offspring language development.

Methods—At 18 weeks of gestation, women reported the hours per week they participated in eleven leisure-time physical activities and the hours per week spent in general physical activity (leisure, household, occupational, etc.). Caregivers completed a modified MacArthur Infant Communication scale at 15 months. Verbal IQ was measured at age 8 years. Regression analysis was used to examine the associations of physical activity with MacArthur score (>75th percentile) and verbal IQ. The number of participants available for analyses ranged from 4517 to 7162.

Results—Children of women in the two highest quintiles of leisure activity (compared with no leisure activity) were more likely to have high 15-month MacArthur scores (Adjusted odds ratio (95% Confidence Interval): 1.2 [0.9, 1.4] and 1.4 [1.1, 1.7], respectively). Leisure activity was not associated with IQ; while general physical activity was linked with lower verbal IQ (1 and 3 points lower for the two highest quintiles).

Conclusions—The most robust finding was a transient increase in offspring vocabulary score at young ages with maternal leisure activity. Differences in the associations with leisure-time physical activity compared with general physical activity need further exploration.

Physical activity in pregnant mice and rats has been associated with neurogenesis in the hippocampus of the offspring's brain.[1-5] This neurogenesis was associated with functional

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improvements in offspring memory[1-3] and learning.[1, 4] The hippocampus is integral in how humans remember words, potentially through its role in associative thinking.[6, 7] As new words are learned, changes occur in the metabolic activity of the hippocampus.[8] Thus, language acquisition, as is done in children, may be mediated by the hippocampus.

In humans, one small study reported that five year-old children of women who exercised during pregnancy scored higher on a general intelligence test and an oral language skills test compared with women who discontinued exercising during pregnancy.[9] The difference in language skills is intriguing given the potential role of the hippocampus in vocabulary acquisition.

We hypothesized that maternal physical activity during pregnancy would be associated with more advanced language development in young children. This was the first analysis addressing this question in humans, and thus we had no a priori assumptions about the strength of the association. We used data from the Avon Longitudinal Study of Parents and Children (ALSPAC) to investigate the association between maternal physical activity during pregnancy and offspring language development at 15 months, 38 months and 8 years of age. We further hypothesized that it would be harder to show an association between prenatal activity and language among older children as other factors such as social environment, education and home environment become more influential as a child ages. Thus, we focused our analysis on the 15 month measure.

METHODS

ALSPAC is a longitudinal study of pregnant women and their offspring[10]. Pregnant women living in the former county of Avon, were invited to participate early in pregnancy. Data have been collected on both mothers and children via medical record linkage, self-administered questionnaires and direct clinic assessments. Participants provided informed consent and ethical approval for the study was obtained from the ALSPAC Ethics and Law Committee and the Local Research Ethics Committees. We included only offspring of singleton pregnancies that resulted in a live birth and survived to one year (Figure 1). Only the first born child of women who had more than one child in ALSPAC was included.

Physical activity measures

We examined two physical activity measures. The first was a leisure-time physical activity (LTPA) index[11]. The LTPA index was calculated from a series of questions asked at 18 weeks gestation. Women were asked how many hours per week they engaged in jogging, aerobics, antenatal exercises, keep fit exercises, yoga, squash, tennis/badminton, swimming, brisk walking, weight training, and cycling. They were also invited to describe any "other" activities. Each activity was assigned a metabolic equivalent (MET) value[12, 13] as described previously,[11] however, we also assigned a MET value to the "other" activities. Each response category was assigned one number (never = 0, less than one hour per week = 0.5, 2 – 6 hours per week = 4, and at least 7 hours per week = 7) which was multiplied by the assigned MET values. These values were then summed to create the LTPA index. Women were considered missing an LTPA index only if they were missing data for every activity, i.e. we assumed that if a woman had responded for some activities but not others, the latter were not done at all. Women who reported zero LTPA were the referent, values greater than zero were categorized into quintiles.

Second, we examined a measure of "general physical activity". At 18 weeks and 32 weeks of gestation, women were asked a question that encompassed all modes of physical activity.

> 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? If yes, how many hours a week?

As described above, women who reported zero hours were the referent category and the remainder was divided into quintiles. While general physical activity was measured at two time points, the analysis focuses on the measure from 18 weeks of gestation. We present sensitivity analyses for the 32 week measure.

The two measures of physical activity capture different aspects of activity. LTPA index is specific to leisure activity and includes sports and exercise, while the general physical activity measure may include occupational and household activities. It is unclear what women report as general physical activity since they were only asked how many hours per week they do the activity and they were not asked to enumerate the activities. The LTPA index is based on a specific set of questions while general physical activity is the response to a very broad question. Finally, general physical activity includes the phrase "long enough to work up a sweat" which may elicit more intense activities, while the questions that comprise the LTPA index do not always specify an intensity.

We also dichotomized each measure (LTPA index and general physical activity) based on the American College of Obstetrics and Gynecology's recommendation for physical activity during pregnancy which is for 2.5 hours of moderate exercise per week[14]. We assumed moderate activity was 6 METs such that women with an LTPA index of 15 or greater (6×2.5) were classified as meeting the recommendation. For the general physical activity variable, meeting the recommendation was defined as at least 2.5 hours per week.

Outcome variables

We examined three outcome variables related to language development: MacArthur score at 15 and 38 months of age and the verbal IQ score from the Wechsler Intelligence Scale.

Vocabulary acquisition was measured using a modified MacArthur Infant Communication questionnaire. Caregivers reported whether a child "understands," "understands and says," or "neither" for each of 134 words at 15 months, 123 words at 38 months. The total number of words the child "understands" was dichotomized at the 75th percentile of the distribution at each age. A dichotomy was chosen since the distribution is not normal. In a sensitivity analysis, we used the words the child "understands and says" to define the dichotomous variable. The number of words the child "understands" was chosen as the primary outcome because we believe it to be a better reflection of the underlying biological mechanism: maternal physical activity increases neurodevelopment in the hippocampus leading to improvements in learning and memory. We hypothesize that the "understands" variable is a better reflection of learning and memory than the "understand and says" variable because a child does not need to "say" a word in order to have learned it.

All children who were still alive and engaged with the study were invited to an in-person assessment at age 8 years. At this visit the Wechsler Intelligence Scale for Children, version III, was administered by trained staff.

Covariates

Covariates considered in this analysis included variables measured: a) during pregnancy: maternal age, education, ethnicity, parity, highest family occupational social class, hours worked, smoking, alcohol use (measures/week), anxiety score and depression score (Crown-Crisp experiential index), weighted life events, fish consumption, and any infection; b) variables measured at 15 months: forms of childcare, The Home Observation for

Measurement of Environment (HOME) score, maternal and paternal parenting scores derived from questions about how the parent interacts with the child, and duration of breastfeeding; and c) at 38 months: the number of hours the child watched TV. The child's exact age in months was also included. Infant gender was included in the linear regression. Preterm birth was defined as birth at less than 37 completed weeks of gestation and low birth weight as less than 2500g.

Analyses

We used multivariable logistic regression to examine the association of physical activity with a high MacArthur score. We used multivariable linear regression to assess the association of physical activity with verbal IQ score. We also investigated the use of log-binomial models to estimate risk ratios for these data,

To determine if our association was specific to the verbal IQ score, we also examined the associations of physical activity with performance IQ and the verbal comprehension subtest. Language development may differ between boys and girls, thus we also investigated interactions with child's sex.

For the 15 month and 8 year outcomes, we compared four different sets of models. First we examined crude models. Second, models were adjusted for the characteristics most strongly associated with cognitive development (maternal age, education, HOME score, and occupation). Third, variables hypothesized to be direct ancestors of both physical activity and language development were selected from a Directed Acyclic Graph [15] (maternal education, crowding index, HOME score, maternal age, race, head of household occupation, parity, anxiety, any first trimester infection, weighted life events, depression, and hours worked during pregnancy). Fourth, we present a fully-adjusted model that includes all of the previous covariates plus variables that were hypothesized to be associated with physical activity through an unmeasured, "healthy mom" characteristic (maternal parenting score, paternal parenting score, duration of breastfeeding, alcohol intake during pregnancy, smoking during pregnancy, fish consumption, sources of childcare, age at questionnaire completion). For example, a "healthy mom" characteristic may cause both her breastfeeding behaviour and her physical activity behaviour. Preterm birth and low birth weight were examined as potential mediators. We present overall p-values which test whether at least one of the estimates is different from zero. We examined a high MacArthur score at 38 months of age using the fully-adjusted logistic regression model (model 4).

All models were restricted to women who had information on all of the covariates (a complete case analysis). A sensitivity analysis using multiple imputation was performed to determine the robustness of the results to missing data.[16] We attempted to use log-binomial models to examine the associations between physical activity and high MacArthur score, however, the fully adjusted model did not converge, even after employing the COPY method[17]. Thus we used a logistic regression and present the results of the log-binomial models that did converge in supplemental table 5.

All analyses were performed with SAS software, version 9. SAS Institute Inc., Cary, NC, USA.

RESULTS

At recruitment, women were mostly between the ages of 25 and 35, parous, of white race, had received formal education to at least 16 years of age (an ordinary or "O" level), lived in a household whose head was in a managerial or professional occupation (Table 1). Most of the women drank no alcohol (70%), and were non-smokers (75%). Thirty-three percent of

the women reported zero hours of general physical activity per week and 15% were classified as zero on the LTPA index. The two measures of physical activity were correlated; the Spearman correlation coefficient was 0.35 (p<0.0001).

The median MacArthur score at 15 months was 8 (interquartile range (IQR): 3, 20). At 38 months the median was 120 (IQR: 112, 123). The mean and median verbal IQ scores were both 107 (standard deviation: 17).

The 15 and 38 month MacArthur scores were correlated, r = 0.31, p<0.0001. The correlations between MacArthur scores and verbal IQ score were weaker, at 15 months the correlation was 0.05 (p<0.0001) and at 38 months it was 0.26 (p<0.0001).

MacArthur score above the 75th percentile, LTPA index

In unadjusted data, women in the second and top two quintiles of the LTPA index were more likely to have children with high MacArthur scores at 15 months. These estimates were weakened with adjustment, most dramatically in the fully adjusted model, but did not disappear. In the full model, compared with the children of women who scored a zero on the LTPA index, children of women in the two highest quintiles of LTPA index had 1.2 times (CI: 0.9, 1.4) and 1.4 times (CI: 1.1, 1.7) the odds of a high MacArthur score, respectively. A linear trend test of LTPA categories was of borderline significance (p=0.08, OR(CI) for a one category increase: 1.03 [1.0, 1.07]). At 38 months, the two highest quintiles of LTPA were not associated with MacArthur score (OR (CI): 0.9 [0.7, 1.1], 1.1 [0.9, 1.4], Supplemental Table 1).

In the fully adjusted model, women who met the recommendation for physical activity during pregnancy based on the LTPA index were more likely to have a child with a high MacArthur score (OR (CI): 1.2 (1.0, 1.3).

MacArthur score above the 75th percentile, general physical activity

In unadjusted analyses, women who performed at least 6 hours of general physical activity per week (the top two quintiles) were more likely to have children with high MacArthur scores at 15 months of age (Table 2). These estimates were halved with adjustment and most of the change in the estimates occurred in the fully adjusted model (compared with selected adjustment). In the fully adjusted model the highest quintile of activity (>10 hours) showed some association with high MacArthur score (OR (CI): 1.3 [1.0, 1.6]). There was no association when vocabulary score was measured at 38 months (Supplemental Table 1).

In the fully adjusted model, women who met the recommendation for physical activity during pregnancy based on general physical activity were more likely to have a child with a high MacArthur score (OR(CI): 1.1 (1.0, 1.3)).

Verbal IQ at age 8, LTPA index

In unadjusted data, the LTPA index was positively associated with verbal IQ score (Table 3). Adjustment for maternal age, education, head of household occupation, and HOME score removed most of the association. In the fully adjusted model, there was no association between meeting the physical activity recommendation (measured by LTPA index) and verbal IQ (beta (CI): 0.01 (-0.87, 0.89).

Verbal IQ at age 8, general physical activity

In unadjusted data, women who reported performing six hours per week or more (the top two quintiles) of general physical activity had children who scored three to six points lower than the children of women who reported zero hours of physical activity (Table 3). In

adjusted data, these associations were reduced by over half. In the full model, children of women in the two highest quintiles of general physical activity scored about 1 and 3 points lower, respectively, compared with the children of women who reported zero hours of physical activity per week. A linear trend test of the categories of general physical activity was not significant (p=0.17).

Women who met the recommendation for physical activity during pregnancy according to her general physical activity had children with lower verbal IQ (beta (CI): -1.1 (-2.0, -0.25).

Sensitivity analyses

Interactions between physical activity variables and child's gender were unimportant. Results were similar when using general physical activity measured at 32 weeks (rather than 18 weeks) of gestation (Supplemental Table 2). Adjusting for preterm birth or low birth weight did not influence any of the results.

We performed multiple imputation to determine the sensitivity of our results to missing data. The association between the highest quintile of LTPA index and 15 month MacArthur score persisted, although it was weaker (OR (CI): 1.2 [1.1, 1.4] compared with the non-imputed data 1.4 [1.1, 1.7]). General physical activity was not associated with MacArthur score at 15 months. The association between general physical activity >10 hours per week and a decreased verbal IQ also persisted (beta (CI): -2.5 [-3.8, -1.2] compared with the non-imputed data -2.8 [-4.5, -1.1]). LTPA index was not associated with verbal IQ.

We also explored the differences between 15 month vocabulary score and verbal IQ score by examining the associations at each time point among children with both measures. When limited to children who also had a verbal IQ score, the associations between the two highest quintiles of LTPA and 15 month MacArthur score were, 1.2 [0.9, 1.5] and 1.4 [1.1, 1.9] (overall p=0.02, N=4702) compared with the original results 1.2 [0.9, 1.4] and 1.4 [1.1, 1.7], respectively. When limited to children with a 15 month MacArthur score the association between general physical activity >10 hours per week and verbal IQ was -2.3 [-4.6, 0.10] (N=4525, overall p=0.006) compared with the original results -2.8 [-4.5, -1.1].

We performed six sensitivity analyses to further investigate the two strongest associations from this analysis 1) the association of higher LTPA index with high MacArthur score at 15 months and 2) the association of higher general physical activity with lower verbal IQ score. First, high MacArthur score was defined as a score above the 75th percentile. To determine the sensitivity to this cutpoint, the outcome was dichotomized at the 90th percentile. The fully-adjusted association between LTPA index and a MacArthur score above the 90th percentile was weaker and less precise, but in the same direction.

Second, the dichotomous MacArthur score variable was based on whether or not a child "understands" each word. We also looked at the fully-adjusted associations between LTPA index and high MacArthur score based on whether the child "understands and says" each word. The results were similar, and even slightly stronger.

Third, we examined maternal physical activity measured at 33 months post-partum and partner's physical activity (measured during the study pregnancy) as potential confounders. Adjusting for these factors strengthened the observed associations between the three highest quintiles of the LTPA index and high MacArthur score at 15 months, OR (CI) 1.20 (0.92, 1.57), 1.22 (0.94, 1.57), 1.44 (1.10, 1.88), p=0.008, compared with 1.08 (0.87, 1.35), 1.16 (0.94, 1.43), 1.40 (1.13, 1.74) reported in Table 2.

We performed three sensitivity analyses to investigate the association of general physical activity with verbal IQ. First, to determine if our association was specific to the verbal IQ score we examined the association between performance IQ and physical activity. The fully-adjusted association between general physical activity and performance IQ tended to be inverse, but the estimates were smaller and not statistically significant.

Second, we examined the fully-adjusted associations between physical activity and the verbal comprehension index subtest of the IQ test. The association with general physical activity was inverse in all categories and strongest for the highest level of activity (> 10 hours/ week of physical activity, beta: -1.7 (CI: -2.9, -0.60), overall p-value=0.01).

Third, we investigated the influence of covariates measured at age 8 including: family income, whether mom worked in paid employment, the number of older siblings in the study child's household, the frequency the study child participated in special classes (such as scouts, dance, karate, etc.), mom's LTPA index (measured at age 8), and whether the biological father lives with the study child. We also included the partner's general physical activity which was measured during the pregnancy. The beta estimates and confidence intervals for the association between the two highest quintiles of general physical activity and verbal IQ were -1.55 (-3.88, 0.78) and -1.79 (-4.46, 0.88), p=0.08, N=2112, compared with -1.40 (-2.94, 0.13) and -2.82 (-4.50, -1.14), N=4529 in Table 3.

COMMENTS

Children of women who engaged in higher levels of LTPA early in the second trimester were more likely to have a high vocabulary score at 15 months, but not at 38 months of age. Conversely, we found lower verbal IQ at age 8 years among the children whose mothers participated in the two highest levels of general physical activity while pregnant.

While the LTPA index has not been validated in this population, a Norwegian study of pregnant women found a similar series of questions was positively associated with energy expenditure.[18] Also, the modified version of the MacArthur used in the ALSPAC has not been validated. Due to the frequency of the dichotomous outcomes in this analysis, the odds ratio will be an overestimate of the analogous risk ratio.

As noted earlier, animal studies support an association between maternal physical activity and offspring development. Physical activity in pregnant mice and rats has been associated with neurogenesis in the hippocampus of the offspring's brain.[1-5] Specifically, physical activity was associated with an increase in hippocampal brain-derived neurotophic factor (BDNF) mRNA.[2-4] When serotonergic and noradrenergic systems were blocked, maternal physical activity was not positively associated with offspring learning and memory, suggesting a fundamental role for these systems.[1] Some of these studies also suggest that the alterations in the hippocampus are transient, persisting only a few weeks after birth. This may explain the disappearance of our association at 38 months of age. Alternatively, at 38 months of age other factors such as pre-school attendance and socialisation, may be more strongly related to vocabulary than the maternal physical activity experienced in utero.

Three studies by Clapp and colleagues reported some cognitive and behavioural benefits for the children of exercising women.[9, 19, 20] Our LTPA results are similar; however, the Clapp studies suggest differences in language skills and intelligence at age 5 years, but we saw no differences at 38 months of age. The subjects in the series of studies by Clapp et al. exercised regularly prior to pregnancy and were a highly select group for whom results might not be applicable to the general population. Also the comparison in the Clapp et al. studies was between women who discontinued regular exercise with women who continued

to exercise throughout pregnancy. This comparison is different from our comparison of various levels of physical activity with zero activity

The association of LTPA index with MacArthur score at 15 months persisted after adjustment for numerous confounders. However, residual confounding may explain these results. There may be factors that increase her physical activity and positively influence offspring language. We conducted a sensitivity analysis to describe the potential residual confounding. To produce the observed OR of 1.4, the most balanced scenario includes prevalences of the unmeasured confounder, U, of 0.8 and 0.5 for women in the highest quintile compared with referent women, respectively, and an OR of 3.5 for the association of a high MacArthur score with exposure to U (Supplemental Table 3).

In this study high levels of general physical activity were associated with lower verbal IQ at age 8, however, these associations changed dramatically after adjustment, suggesting high susceptibility to residual confounding. General activity may include occupational, household and leisure activities. Thus, general activity may be associated with chemical exposures, stress, or alternative work schedules (i.e. nursing) which may influence language development. In a sensitivity analysis, an unmeasured factor that was prevalent (70%) among women who reported >10 hours per week of general activity, and had a moderate effect on IQ (-6.5 points), would produce an association with verbal IQ score of -2.75 points (Supplemental Table 4).

If the association between general physical activity and verbal IQ is real, high levels of general physical activity may reflect over-exertion. Women reported activities they did "long enough to work up a sweat," which may reflect high intensity activity.[21] If so, women in the two highest quintiles of general activity were performing a high volume of intense activity.

It is unclear why the two physical activity measures suggest opposite associations. The LTPA index and general physical activity measures are capturing different modes of activity. LTPA index is specific to leisure activity and includes sports and exercise, while the general physical activity measure may include occupational and household activities. Different modes of physical activity may have different associations with pregnancy outcomes.[22-24] Also, the MacArthur questionnaire and the verbal IQ measure are not measuring the same underlying characteristics. The MacArthur is a reflection of the child's word use while the verbal IQ measures the ability to define and describe words, thus the two measures cannot be directly compared across time. Physical activity may be related specifically to associative memory and word recognition, without improving verbal IQ.

In summary, high levels of LTPA during pregnancy may be associated with increased vocabulary in early life; however there was no association at 38 months of age. At age 8 years general physical activity was negatively associated with verbal IQ. Given the support for an association between physical activity and cognition in the animal literature, further investigation of this topic in humans would be informative. Additionally, the differences between the two physical activity measures need further exploration.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

Acknowledgments

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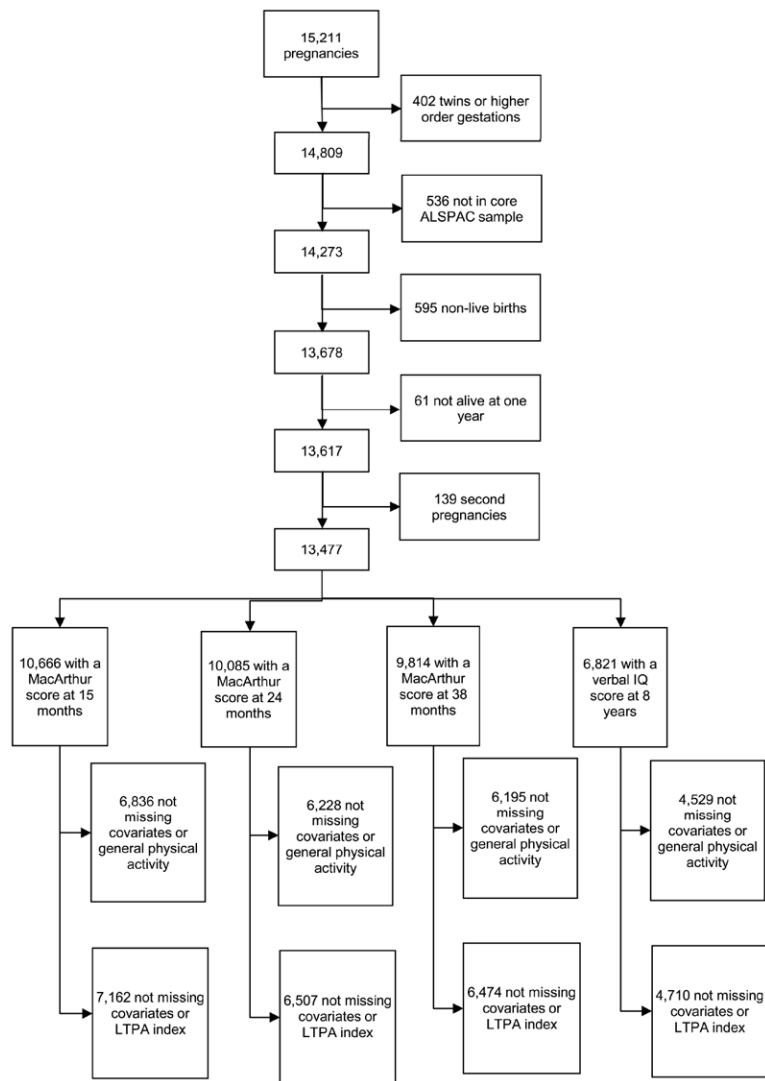
Figure 1.
Description of the derived analysis sample, Avon Longitudinal Study of Parents and Children, 1991-1992.

Table 1

Distribution of maternal, child, and family characteristics, Avon Longitudinal Study of Parents and Children, 1991-1992.

	Among all children alive at one year N (%)	Not missing 15 month MacArthur N (%)	Not missing 8 year IQ score N (%)
Total	13, 477	10, 666	6821
General physical activity[a]			
0 hours per week	3638 (33)	3035 (33)	2019 (34)
> 0 - 2	1890 (17)	1643 (18)	1166 (19)
> 2 - 4	1710 (16)	1482 (16)	1022 (17)
> 4 - 6	994 (9)	849 (9)	543 (9)
> 6 - 10	1377 (13)	1146 (13)	692 (12)
> 10	1330 (12)	1002 (11)	565 (9)
Missing	2538	1509	814
Leisure-time physical activity index[a]			
0	1814 (15)	1375 (14)	844 (13)
1 – 4.4	1836 (16)	1661 (17)	1071 (17)
>4.4 – < 15.2	1653 (14)	1299 (13)	930 (15)
15.2 – 18.2	2060 (18)	1737 (18)	1041 (17)
>18.2 – 27.65	2303 (20)	1968 (20)	1286 (20)
>27.65	2074 (18)	1669 (17)	1129 (18)
Missing	1737	957	520
Maternal age at delivery			
<20	985 (7)	542 (5)	217 (3)
21 - 25	3184 (24)	2249 (21)	1205 (18)
26 - 30	5276 (39)	4373 (41)	2891 (42)
31 - 35	3092 (23)	2699 (25)	1914 (28)
>35	940 (7)	803 (8)	594 (9)
Highest maternal education			
CSE	2410 (20)	1770 (17)	854 (13)
Vocational	1184 (10)	979 (10)	566 (9)
O level	4143 (35)	3632 (35)	2302 (35)
A level	2701 (23)	2439 (24)	1782 (27)
Degree	1543 (13)	1430 (14)	1038 (16)
Missing	1496	416	234
Household socioeconomic status			
Unskilled occupations, military	109 (1)	85 (0.9)	34 (0.5)
Partly-skilled occupations	551 (5)	430 (4)	222 (4)
Skilled, manual	1487 (13)	1188 (12)	634 (10)
Skilled, non-manual	2836 (26)	2433 (25)	1546 (25)
Managerial and technical	4630 (42)	4132 (43)	2874 (46)
Professional	1487 (13)	1376 (14)	993 (16)

	Among all children alive at one year N (%)	Not missing 15 month MacArthur N (%)	Not missing 8 year IQ score N (%)
Missing	2377	1022	518
Parity			
0	5617 (45)	4682 (46)	3087 (47)
1	4362 (35)	3588 (35)	2342 (35)
2	1783 (14)	1458 (14)	872 (13)
3	742 (6)	554 (5)	303 (5)
Missing	973	384	217
Duration of breastfeeding			
Never	2632 (24)	2266 (23)	1149 (18)
< 6 weeks	1730 (16)	1574 (16)	970 (15)
6 weeks – 3 months	1710 (16)	1528 (16)	1007 (16)
3 months – 6 months	1388 (13)	1266 (13)	903 (14)
> 6 months	3314 (31)	3139 (32)	2291 (36)
Missing	2703	893	501
HOME score[b]			
1 – 8	1570 (15)	1444 (14)	830 (13)
9 – 11	5808 (54)	5485 (54)	3431 (53)
12	3342 (31)	3170 (31)	2159 (34)
Missing	2757	567	401

[a]The minutes of activity > 0 and the LTPA index > 0 were categorized in quintiles

[b]Continuous variable that was divided at the 25th and 75th percentiles for presentation only, the continuous variable was used in modeling.

Table 2

Results of the logistic regression models of the association between physical activity at 18 weeks gestation and being above the 75th percentile of MacArthur vocabulary score at 15 months among women who were not missing information for any of the potential confounders (complete case analysis), Avon Longitudinal Study of Parents and Children, 1991-1992.

	N (%)	Crude		Adjusted for maternal age, education, household SES and HOME score		Selected Adjustment[a]		Fully Adjusted[b]	
		Odds ratio	CI	Odds ratio	CI	Odds ratio	CI	Odds ratio	CI
Leisure-time physical activity index[c]									
0	924 (13)	1***		1***		1***		1*	
>0 – <4.5	1245 (17)	0.97	0.78, 1.19	0.99	0.80, 1.23	1.00	0.80, 1.23	0.97	0.78, 1.21
4.5 – <15.2	1019 (14)	1.22	0.98, 1.50	1.21	0.97, 1.51	1.20	0.97, 1.50	1.17	0.93, 1.47
15.2 – <18.2	1241 (17)	1.17	0.95, 1.44	1.15	0.93, 1.42	1.13	0.92, 1.40	1.08	0.87, 1.35
18.2 – <27.65	1505 (21)	1.31	1.08, 1.59	1.30	1.06, 1.59	1.29	1.06, 1.58	1.16	0.94, 1.43
27.65	1228 (17)	1.67	1.37, 2.04	1.62	1.32, 1.99	1.62	1.32, 1.99	1.40	1.13, 1.74
General physical activity[c]									
0 hours per week	2227 (33)	1**		1*		1*		1	
>0 – 2	1300 (19)	1.08	0.92, 1.27	1.05	0.89, 1.23	1.05	0.89, 1.25	1.01	0.85, 1.20
>2 – 4	1130 (17)	1.19	1.01, 1.40	1.11	0.94, 1.32	1.12	0.94, 1.33	1.09	0.92, 1.31
>4 – 6	649 (9)	1.28	1.05, 1.56	1.24	1.01, 1.52	1.25	1.02, 1.54	1.19	0.96, 1.46
>6 – 10	825 (12)	1.23	1.02, 1.48	1.17	0.97, 1.41	1.16	0.96, 1.41	1.06	0.87, 1.29
>10	705 (10)	1.51	1.25, 1.83	1.49	1.22, 1.81	1.44	1.18, 1.76	1.26	1.02, 1.55

Abbreviation: CI, 95% confidence interval, HOME, Home Observation for Measurement of Environment, SES, socioeconomic status

*
Group P 0.01, two-sided

**
Group P 0.001, two-sided

***
Group P < 0.0001, two-sided

[a]
Adjustment for: maternal education, crowding index, HOME score, maternal age, race, head of household occupation, parity, anxiety, any infection in the first three months of pregnancy, weighted life events, depression, and hours worked during pregnancy.

[b]
In addition to the above, adjusted for: maternal parenting score, paternal parenting score, duration of breastfeeding, alcohol intake during pregnancy, smoking during pregnancy, fish consumption, sources of childcare, age at questionnaire completion.

[c]
Quintiles among those with values greater than zero.

Table 3

Results of the regression models of the association between physical activity at 18 weeks gestation and verbal IQ at age 8 among women who were not missing information for any of the potential confounders (complete case analysis), Avon Longitudinal Study of Parents and Children, 1991-1992.

	N (%)	Crude		Adjusted for maternal age, education, household SES and HOME score		Selected Adjustment[a]		Fully Adjusted[b]	
		Beta	CI	Beta	CI	Beta	CI	Beta	CI
Leisure-time physical activity index[c]									
0	586 (12)	0 **		0		0		0	
>0 – <4.5	795 (17)	3.23	1.47, 5.00	1.45	-0.19, 3.08	1.18	-0.45, 2.80	1.12	-0.48, 2.73
4.5 – <15.2	724 (15)	5.77	3.98, 7.57	1.95	0.26, 3.63	1.66	-0.02, 3.33	1.45	-0.22, 3.11
15.2 – <18.2	775 (16)	2.54	0.76, 4.31	0.63	-1.02, 2.27	0.57	-1.06, 2.20	0.45	-1.17, 2.06
18.2 – <27.65	994 (21)	4.68	2.99, 6.37	1.55	-0.02, 3.13	1.46	-0.11, 3.02	1.02	-0.54, 2.58
27.65	836 (18)	5.42	3.67, 7.16	1.63	-0.003, 3.27	1.45	-0.18, 3.08	0.89	-0.74, 2.53
General physical activity[c]									
0 hours per week	1494 (33)	1 **		1 **		1 *		1 *	
>0 – 2	928 (20)	2.78	1.44, 4.13	0.94	-0.31, 2.20	0.72	-0.54, 1.97	0.55	-0.69, 1.79
>2 – 4	778 (17)	0.48	-0.94, 1.91	0.18	-1.14, 1.51	0.03	-1.29, 1.35	0.003	-1.30, 1.31
>4 – 6	426 (9)	-1.01	-2.77, 0.76	-0.42	-2.06, 1.23	-0.26	-1.90, 1.37	-0.49	-2.11, 1.13
>6 – 10	500 (11)	-3.02	-4.69, -1.36	-1.52	-3.07, 0.02	-1.42	-2.97, 0.13	-1.40	-2.94, 0.13
>10	403 (9)	-6.03	-7.83, -4.22	-3.45	-5.15, -1.76	-2.91	-4.61, -1.21	-2.82	-4.50, -1.14

Abbreviation: CI, 95% confidence interval, IQ, Intelligence quotient, SES, socioeconomic status, HOME, Home Observation for Measurement of Environment

*
Group P< 0.01, two-sided

**
Group P< 0.0001, two-sided

[a] Adjustment for: maternal education, crowding index, HOME score, maternal age, race, head of household occupation, parity, anxiety, any infection in the first three months of pregnancy, weighted life events, depression, and hours worked during pregnancy.

[b] In addition to the above, adjusted for: maternal parenting score, paternal parenting score, duration of breastfeeding, alcohol intake during pregnancy, smoking during pregnancy, fish consumption, sources of childcare, age at interview and child's gender.

[c] Quintiles among those with values greater than zero.