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RESEARCH

Early life determinants of physical activity in 11 to 12 year olds: cohort study

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ABSTRACT

Objective To examine factors in early life (up to age 5 years) that are associated with objectively measured physical activity in 11-12 year olds.

Design Prospective cohort study.

Setting Avon longitudinal study of parents and children, United Kingdom.

Participants Children aged 11-12 years from the Avon longitudinal study of parents and children.

Main outcome measure Physical activity levels in counts per minute (cpm) and minutes of moderate to vigorous physical activity for seven days measured with a uniaxial actigraph accelerometer.

Results Valid actigraph data, defined as at least three days of physical activity for at least 10 hours a day, were collected from 5451 children. Several factors were associated with physical activity at ages 11-12 years. Regression coefficients are compared with the baseline of "none" for categorical variables: maternal brisk walking during pregnancy (regression coefficient 5.0, 95% confidence interval −8.5 to 18.5; cpm for <1 h/wk and ≥2 h/wk of physical activity 17.7, 5.3 to 30.1), maternal swimming during pregnancy (21.5, 10.9 to 32.1 and cpm for <1 h/wk and ≥2 h/wk of physical activity 24.2, 7.8 to 40.7), parents' physical activity when the child was aged 21 months (28.5, 15.2 to 41.8 and cpm of physical activity for either parent active and both parents active 33.5, 17.8 to 49.3), and parity assessed during pregnancy (2.9, −7.6 to 13.4 and cpm of physical activity for 1 and ≥2 parity 21.2, 7.1 to 35.3).

Conclusions Few factors in early life predicted later physical activity in 11-12 year olds. Parents' physical activity during pregnancy and early in the child's life showed a modest association with physical activity of the child at age 11-12 years, suggesting that active parents tend to raise active children. Helping parents to increase their physical activity therefore may promote children's activity.

INTRODUCTION

Regular physical activity is beneficial to the health of adults and is thought to be beneficial to the health of children.[1 2] Although there is less evidence of the benefit to children,[3] activity in childhood may be an important determinant of health in adulthood for several reasons. A systematic review of physical activity in adolescents and health suggests direct and indirect pathways by which physical activity in youth might affect later health.[4] Some risk factors for diseases as adults are associated with lower levels of physical activity in childhood.[5-7] Thus a hypothetical pathway for disease could be from fetal and early life factors to physical activity in childhood to childhood risk factors for disease in adulthood to disease in adulthood.[8] In support of this hypothetical pathway, associations have been reported between early life factors and childhood obesity. For example, birth weight and parental obesity both predict a child's obesity at age seven.[9] Some evidence also shows that premature babies have poorer motor coordination in childhood[10] and that such children may be less active than their peers.[11]

Physical activity is a complex multifactorial behaviour that is influenced by environmental and biological factors.[12] Although there is an extensive literature on the psychosocial and environmental factors that influence physical activity in children, much of it is cross sectional[13] and little is known about early life influences on children's physical activity.[8] One prospective study found that risk factors in early life for a sedentary lifestyle (<300 minutes of self reported physical activity per week) at age 10-12 years were being female, being the oldest sibling, having a high family income at birth, high maternal education at birth, and lower maternal reported physical activity of children at age 4 years.[8] To our knowledge no study has examined the influences in early life on children's objectively measured physical activity in a contemporary cohort with extensive data on early life. Objective methods of measuring physical activity have advantages over subjective methods, particularly in children, and should enable the nature of the associations between physical activity and health to be characterised more precisely.[14]

We examined the factors in early life (up to age 5 years) that are associated with objectively measured physical activity in a large contemporary cohort of children aged 11-12 years.

METHODS

The Avon longitudinal study of parents and children (ALSPAC) is a geographically based birth cohort that has been described in detail previously.[15] Briefly, all pregnant women in the former Avon health area who had an expected delivery date between 1 April 1991 and 31 December 1992 were invited to take part in the study. Overall, 14 541 women were enrolled, totalling 14 062 live births.

From pregnancy and continuing to this day, questionnaires have been sent to the mothers, their partners (the partner at the time the questionnaire was administered may not have been the biological father), and the children inquiring about their health and lifestyle, the parents' circumstances, and the health and development of the child. Since age 7 the children have been invited to research clinics for a series of physiological and psychometric measures. The children gave written assent from age 10 (cosigned by the main carer). For the study on physical activity verbal consent was given by the child and main carer.

Physical activity data

Children who attended the study clinic at age 11 were asked to wear an actigraph accelerometer (Actigraph AM7164 2.2; LLC, Fort Walton Beach, Fl) for seven days. The methods are described elsewhere.[16] Briefly, the actigraphs were initialised to start recording at 5 am on the day after the clinic visit. The children were given a timesheet to record the times that the actigraph was put on and taken off each day. They were also asked to record any times (in minutes) that they swam or cycled each day as the actigraph does not record cycling well and cannot be worn for swimming. The actigraphs were downloaded on to a computer and a customised macro was used to derive a series of variables describing levels and patterns of physical activity. Two outcome variables were used in this analysis: average counts per minute (cpm) over the valid measurement period—a measure of total activity that has been validated against activity energy expenditure estimated by doubly labelled water ($r=0.54$; $P<0.01$)[17]; and moderate to vigorous physical activity, as current recommendations for physical activity in children are framed in terms of time spent each day in such activity.[1] We used a cut-off point of cpm greater than 3600 to define moderate to vigorous physical activity.[18]

Table 1 | Potential risk factors up to age 5 years for obesity in adulthood

Potential determinant	Time of recording or method used to derive data	Categories or units
Birth outcomes:		
Birth weight	Birth	Continuous (100 g)
Ponderal index	Birth (birth weight/heel-crown length^3)	Continuous (kg/m^3)
Crown-heel length	Birth	Continuous (cm)
Head circumference	Birth	Continuous (cm)
Gestational age	Reported date of last menstrual period	Continuous (weeks)
Prenatal characteristics:		
Maternal body mass index before pregnancy	Questionnaire at 12 weeks	Continuous (kg/m^2)
Partner's body mass index before the pregnancy	Questionnaire at 12 weeks	Continuous (kg/m^2)
Maternal smoking during pregnancy	Questionnaire at 32 weeks	Yes or no
Partner smoking during the pregnancy	Questionnaire at 18 weeks	Yes or no
Maternal age at birth of child	Calculated from date of birth of mother	Years
Partner's age at birth of child	Calculated from date of birth of father	Years
Maternal brisk walking during pregnancy	Questionnaire at 18 weeks	Never, <1 h/wk, >2 h/wk
Maternal swimming during pregnancy	Questionnaire at 18 weeks	Never, <1 h/wk, >2 h/wk
Partner's physical activity	Questionnaire at 18 weeks	Hours per week
Parity*	Questionnaire at 18 weeks	0, 1, ≥2
Season of birth†	Birth records	
Early childhood (0-2 years):		
Activity	Questionnaire at 6 months	Combined score from 12 questions; possible range 12-72
Motor coordination	Questionnaire at 6 months	Combined score from 12 questions; possible range 12-72
Presence of partner	Questionnaire at 8 months	Yes or no
Maternal activity	Questionnaire at 21 months	Days per week engaged in activity
Partner's activity	Questionnaire at 21 months	Days per week engaged in activity
Time spent outside	Questionnaire at 24 months	<7, 7-13, or >13 (h/wk)
Breast feeding	Questionnaire at 6 months	Yes or no
Preschool (2-5 years):		
Time spent outside	Questionnaire at 38 months	<7, 7-13, or >13 (h/wk)
Time spent outside	Questionnaire at 54 months	<14, 14-20, or >20 (h/wk)
Television viewing	Questionnaire at 38 months	<10 or ≥10 h/wk
Television viewing	Questionnaire at 54 months	<10 or ≥10 h/wk
Duration of night time sleep	Questionnaire at 30 months	Hours per night

*Number of previous pregnancies resulting in live birth or still birth.
†Winter=December to February; spring=March to May; summer=June to August; autumn=September to November.[22]

Table 2 | Children in Avon longitudinal study of parents and children who attended research clinic and had valid data on physical activity compared with those who did not at age 11-12 years. Values are numbers (percentages) unless stated otherwise

Characteristic	No of children	No valid data (n=1451)	No of children	Valid data (n=5451)	P value
Child variables:					
Mean (SD) age (years)	1451	11.86 (0.25)	5386	11.81 (0.23)	<0.001
Mean (SD) body mass index (kg/m^2)	1417	19.5 (3.8)	5388	19.0 (3.3)	<0.001
Mean (SD) birth weight (g)	1414	3445 (537)	5121	3433 (523)	0.43
Boys	794	54.7	2593	47.6	<0.001
Girls	657	45.3	2858	5204	
Social class*:	1272		4806		
I and II	353	27.8	1428	29.7	0.19
III, non-manual	333	26.2	1308	27.2	
III, manual	375	29.5	1279	26.6	
IV and V	211	16.6	791	16.5	
Maternal education*:	1348		5029		
A level or university degree	196	13.5	825	16.4	0.04
O level	358	26.6	1343	26.7	
Vocational	464	34.4	1798	35.8	
None or CSE	330	24.5	1063	21.1	

*From I (high) to V (low).

We deleted from each file 10 or more minutes of consecutive zeros as we regarded these as periods when the monitor was not worn.[19] We also excluded any day of recording when the average cpm was less than 150 or more than 3 standard deviations above the mean[20] as we considered this level of physical activity to be behaviourally implausible. We considered activity data to be valid if the recording period was for at least 10 hours per day for at least three days.[16] The actigraphs were recalibrated when the batteries were changed—about every six months. Over the two year period of data collection, 267 actigraphs were used. Of the 518 calibrations, no adjustment was required in 394 (77%) cases.

Potential risk factors

We defined early life as the period from pregnancy to age 5 years as this includes some suggested critical periods of development: the intrauterine period, infancy, and the age of adiposity rebound. Age 5 is also a landmark for children as they start school and therefore their lives change noticeably. Potential risk factors were identified as characteristics in early life that were associated with physical activity in childhood,[8] obesity,[9] or other markers of the metabolic syndrome[5 6]; cardiorespiratory fitness or neuromotor function[10]; or activity behaviours that are known to display some tracking from early to later childhood.[8 21] Table 1 lists the potential risk factors, how they were derived, and the units used.

Potential confounders

We recorded socioeconomic variables at 32 weeks' gestation. The mother was asked to record her highest education level, which was categorised into none or CSE (exams at age 16), vocational, O level (exams at age 16, higher than CSE), A level (exams at age 18), or university degree. Social class groups were derived from the parents' occupation (classes I to V with III split into non-manual and manual) using the 1991 Office of Population Censuses and Surveys.[23] When the social class of the mother and partner differed, the lower of the two was used in the analysis to give the most variability within the variable.

Statistical analysis

We used three models to explore the role of confounders, with cpm as the outcome. Model 1 was adjusted

Table 3 | Associations between birth outcomes and counts per minute of physical activity in children aged 11-12 years from Avon longitudinal study of parents and children

	Model 1			Model 2		
Variable	No of children	Regression coefficient* (95% CI)	P value	No of children	Regression coefficient* (95% CI)	P value
Birth weight (100 g)	5058	−2.1 (−6.7 to 2.6)	0.383	4671	−0.4 (−6.3 to 5.5)	0.893
Ponderal index (kg/m^3)	4045	1.3 (−3.4 to 6.0)	0.600	3738	1.0 (−3.8 to 5.9)	0.670
Head circumference (cm)	4144	−5.2 (−10.8 to 0.3)	0.063	3834	−3.5 (−9.2 to 2.2)	0.233
Crown-heel length (cm)	4094	−3.6 (−9.4 to 2.1)	0.217	3786	−1.9 (−7.9 to 4.0)	0.521
Gestation (weeks)	5127	−1.3 (−6.1 to 3.5)	0.599	4739	−2.4 (−7.7 to 2.9)	0.376

Model 1 adjusted for age and sex. Model 2 adjusted for age, sex, and parental social class by occupation and mother's education.
*Standardised regression coefficient: change in counts per minute per standard deviation of variable: birth weight 5.2, ponderal index 3.1, head circumference 1.5, crown-heel length 2.4, and gestation 1.8.

for age and sex. Model 2 was adjusted for age, sex, maternal education, and social class. We have previously shown that physical activity is negatively associated with socioeconomic status and that boys are more active than girls in this population: median 644 cpm (interquartile range 528-772) for boys and 529 cpm (444-638) for girls; P<0.001.[24] We therefore included sex and socioeconomic status as potential confounders rather than as potential determinants. Model 3 was adjusted for the confounders in model 1 but restricted to those with all available data from model 2. Measures of size at birth were additionally adjusted for gestational age. Season of birth was additionally adjusted for season of measurement, as all children were seen at about age 11 years and 9 months, so season of birth is likely to be related to season of measurement. Models were run separately for each characteristic—that is, they were not mutually adjusted. Analysis for models 1 and 2 was repeated with minutes of moderate to vigorous physical activity as the outcome. We repeated analyses in children who did not report swimming or cycling during the period of measurement. Analyses were carried out on boys and girls combined. To test for an effect modification of sex we introduced interaction terms (sex×exposure variable) into model 1. When evidence of an interaction existed we did the analyses separately for boys and girls. Moderate skewness was found in the activity variables. We did not transform data for the analyses but we did use robust standard errors. Such errors allow derivation of confidence intervals and standard errors on the basis of the actual distribution of the outcome variable in the dataset, rather than on an assumed underlying probability distribution.[25] We present the results for continuous variables as standardised regression coefficients, adjusted for the standard deviation of cpm for each model. Thus the regression coefficient for continuous variables is the difference in cpm associated with a 1 standard deviation change in the exposure variable. We present the results for categorical variables as normal regression coefficients.

RESULTS

A total of 11 952 children from the Avon longitudinal study of parents and children were invited to participate in study clinics at age 11 years. Of these, 7159 (59.9%) attended the clinic and 6622 (92.5%) agreed to wear an actigraph accelerometer. Of the children who agreed to participate, 5595 (84.5%) returned actigraphs that satisfied the validity criteria.[16] Children from multiple births, totalling 144, were excluded from the analyses to rule

Table 4 | Associations between prenatal characteristics and counts per minute of physical activity in children aged 11-12 years from Avon longitudinal study of parents and children

	Model 1			Model 2		
Variable	No of children	Regression coefficient (95% CI)	P value	No of children	Regression coefficient (95% CI)	P value
Maternal body mass index (kg/m^2)*	4657	−3.2 (−8.3 to 1.9)	0.214	4394	−5.2 (−10.4 to 0.1)	0.053
Maternal smoking status during pregnancy:						
Non-smoking	3827	28.0 (14.2 to 48.1)	<0.001	3757	19.0 (4.7 to 333.3)	0.009
Smoking	698			664		
Partner's smoking status during the pregnancy:						
Non-smoking	3360	20.1 (10.0 to 30.2)	<0.001	3200	14.2 (3.4 to 25.0)	0.010
Smoking	1610			1456		
Maternal age at birth (years)	5127	−11.5 (−16.1 to −6.8)	<0.001	4739	−7.9 (−13.1 to −2.7)	0.003
Maternal brisk walking during pregnancy (never as baseline):	1113			1041		
<1 h/wk	1384	−2.0 (−15.1 to 11.2)	0.022†	1339	5.0 (−8.5 to 18.5)	0.009†
≥2 h/wk	2199	12.4 (0.3 to 24.4)		2103	17.7 (5.3 to 30.1)	
Maternal swimming during pregnancy (never as baseline):	2538			2399		
<1 h/wk	1643	13.2 (2.8 to 23.6)	0.008†	1589	21.5 (10.9 to 32.2)	<0.001†
≥2 h/wk	498	20.0 (3.6 to 36.4)		485	24.2 (7.8 to 40.7)	
Parity (0 as baseline):	2331			2183		
1	1739	4.1 (−6.1 to 14.4)	<0.001†	1637	2.9 (−7.6 to 13.4)	0.012†
≥2	905	26.1 (12.6 to 39.6)		828	21.2 (7.1 to 35.3)	
Season of birth‡ (spring as baseline):	1174			1089		
Summer	1522	15.7 (3.2 to 28.1)	0.013	1420	16.7 (4.0 to 29.5)	0.010
Autumn	1469	31.9 (19.1 to 44.7)	<0.001	1337	34.1 (20.8 to 47.5)	<0.001
Winter	962	33.4 (20.0 to 46.8)	<0.001	893	34.7 (21.0 to 48.5)	<0.001

Model 1 adjusted for age and sex. Model 2 adjusted for age, sex, parental social class by occupation, and mother's education.
*Standardised regression coefficient: change in counts per minute per standard deviation (3.7) of variable.
†P for linear trend.
‡Winter=December to February; spring=March to May; Summer=June to August; Autumn=September to November. Additionally adjusted for season of measurement.

out non-independence in the data. The sample consisted of 5451 children (2593 boys and 2858 girls), mean age 11.8 years. Some small differences were found between the characteristics of children who provided valid data on physical activity and those who did not (table 2).

Tables 3-7 show the associations between variables and cpm for each model for each of the critical developmental periods. Results were similar after excluding children who reported swimming or cycling during the measurement period (data not shown). Results from model 3 were similar to those of model 1 (data not shown). Results for models 1 and 2 with moderate to vigorous physical activity as the outcome showed a similar pattern to cpm as the outcome. Therefore, only the results for counts per minute (cpm) are shown.

None of the birth outcomes was associated with physical activity at ages 11-12 years and this remained unchanged after adjustment for confounders (table 3).

Few of the prenatal characteristics were associated with physical activity (table 4). Mother's body mass index before pregnancy, parents' smoking status during pregnancy, mother's age at birth of the child, mother's physical activity, parity, and season of birth showed modest associations with physical activity. The associations for parents' smoking and maternal age attenuated after adjustment for socioeconomic status, whereas the associations for maternal physical activity during pregnancy strengthened slightly. Partner's body mass index, obesity in the mother and her partner, partner's age at birth, partner's physical activity, and presence of the mother's partner at home were not associated with later physical activity (data not shown).

Table 5 shows the associations between characteristics in childhood from age 0-2 years and physical activity. These associations tended to be modest and remained after adjustment. Parental activity was associated with later physical activity in the child.

Of the characteristics in preschool aged children, only television viewing at 38 and 54 months' follow-up showed any clear associations, although these were small. Little evidence was found that the other proxy measures of physical activity, time spent outside at 38 and 54 months, were associated with later physical activity.

Evidence was found of an interaction in only two of the variables so the results are presented for the analyses of boys and girls combined. Sex×brisk walking and sex×motor coordination showed evidence of effect modification (P=0.020 and P=0.008). Table 7 shows the analyses for boys and girls separately when the exposure variable was modified by sex.

DISCUSSION

Few of the early life factors studied were associated with later physical activity in 11-12 year olds and for those that were the associations were modest.

Birth outcomes and prenatal exposures

None of the birth outcomes was associated with physical activity. A recent study found that children of low birth weight (<2500 g) reported slightly fewer minutes of activity per week at age 10-12 than their peers of higher birth weight. The same study, however, reported no difference in sedentary lifestyle by birth weight.[8]

Table 5 | Associations between early exposures in childhood (0-2 years) and counts per minute of physical activity in children aged 11-12 years from Avon longitudinal study of parents and children

	Model 1			Model 2		
Variable	No of children	Regression coefficient (95% CI)	P value	No of children	Regression coefficient (95% CI)	P value
Activity at 6 months*	4574	−2.13 (−6.99 to 2.72)	0.389	4303	−1.49 (−6.49 to 3.50)	0.558
Motor coordination at 6 months*	4736	5.33 (0.12 to 10.54)	0.045	4452	5.77 (0.25 to 11.29)	0.041
With partner at 8 months:						
Yes	4675	23.6 (−3.4 to 50.5)	0.086	4422	9.5 (−21.5 to 40.5)	0.547
No	138			103		
Parents activity at 21 months (neither active as baseline):	917			866		
Either active	1968	29.4 (16.2 to 42.5)	<0.001†	1876	28.5 (15.2 to 41.8)	<0.001†
Both active	881	31.5 (16.1 to 46.8)		844	33.5 (17.8 to 49.3)	
Time outside at 24 months (<7 h/wk as baseline):	1026			946		
7-13 h/wk	1284	−15.5 (−29.1 to −1.8)	0.085†	1224	−12.9 (−27.1 to 1.2)	0.196†
>13 h/wk	2349	−8.5 (−21.0 to 3.9)		2211	−6.6 (−19.5 to 6.4)	
Breast fed at 6 months (still breast feeding as baseline):	1703			1629		
Yes	2309	7.2 (−3.3 to 17.7)	0.238†	2157	−1.3 (−12.4 to 9.8)	0.749†
Never	817	10.9 (−3.2 to 25.0)		749	−5.9 (−21.5 to 9.6)	

Model 1 adjusted for age and sex. Model 2 adjusted for age, sex, parental social class by occupation, and mother's education.
*Standardised regression coefficient: change in counts per minute per standard deviation of variable: activity at 6 months 6.3 and motor coordination at 6 months 5.2.
†P for linear trend.

Table 6 | Associations between exposures in preschool children (2-5 years) and counts per minute of physical activity in children aged 11-12 years from Avon longitudinal study of parents and children

	Model 1			Model 2		
Variable	No of children	Regression coefficient (95% CI)	P value	No of children	Regression coefficient (95% CI)	P value
Time outside at 38 months (<7 h/wk as baseline):	1916			1810		
7-13 h/wk	1101	−4.1 (−16.8 to 8.5)	0.588*	1043	−4.4 (−17.4 to 8.6)	0.230*
>13 h/wk	1569	−5.6 (−16.8 to 5.5)		1464	−10.2 (−21.8 to 1.5)	
Time outside at 54 months (<14 h/wk as baseline):	952			894		
14-20 h/wk	1531	14.2 (0.7 to 27.6)	0.112*	1439	9.0 (−4.9 to 22.9)	0.436*
>20 h/wk	1956	10.6 (−2.4 to 23.5)		1849	4.6 (−8.8 to 17.9)	
Television viewing at 38 months:						
<10 h/wk	3566	−6.1 (−18.0 to 5.9)	0.318	3367	−12.4 (−24.9 to 0.1)	0.051
>10 h/wk	1037			967		
Television viewing at 54 months:						
<10 h/wk	1432	−4.7 (−15.0 to 5.7)	0.375	1354	−11.0 (−21.8 to −0.2)	0.046
>10 h/wk	3035			2853		
Sleep at 30 months (hours per night)†	4589	3.0 (−1.8 to 7.8)	0.218	4310	−0.55 (−5.8 to 4.7)	0.837

Model 1 adjusted for age and sex. Model 2 adjusted for age, sex, parental social class by occupation, and mother's education.
*P for linear trend.
†Standardised regression coefficient: change in counts per minute per standard deviation (0.96) of variable.

Body mass index of the mother before pregnancy but not her partner was weakly associated with physical activity. Previous studies have been inconsistent. One reported no relation between parental obesity and physical activity, assessed by heart rate monitor in 101 prepubescent girls.[26] A systematic review found that parental obesity was positively associated with physical activity in 4-12 year olds.[13]

Smoking in the mother and her partner were both positively associated with physical activity. This is surprising because maternal smoking during pregnancy is associated with childhood obesity.[9] The association we have shown was similar for smoking in both the mother and the partner and attenuated after adjustment, so may be a result of the social patterning of smoking behaviour. We have previously shown a negative association between physical activity and socioeconomic status.[24]

Previous studies have reported a positive association between parental activity and children's activity although there is some inconsistency. Eleven of 29 studies in a systematic review showed a positive association between parental physical activity and children's physical activity whereas findings in the remainder were equivocal.[13] In our study, maternal activity during pregnancy (specifically brisk walking and swimming) was positively associated with physical activity in the children. It is unlikely that this is due to biological factors in utero but is more likely that physical activity during pregnancy is a marker for later maternal physical activity and that this in turn influences children's physical activity.

Parity is also a measure of the number of older siblings and we found that physical activity was positively associated with parity. This confirms the findings of a previous study, which reported that birth order was positively associated with physical activity and negatively associated with a sedentary lifestyle in 10-12 year olds.[8]

The association with season of birth is difficult to explain. Children born during summer to winter were more active than those born in spring. Season of birth is associated with a range of mental and physical disorders.[27] It is possible that season of birth has an effect through the age at which children start school. In this study some children were measured while at primary school and some while at secondary school,

Table 7 | Associations between exposure and counts per minute of physical activity when evidence existed of effect modification by sex, adjusted for age

	Boys			Girls		
Variable	No of children	Regression coefficient (95% CI)	P value	No of children	Regression coefficient (95% CI)	P value
Maternal brisk walking during pregnancy (never as baseline):	517			596		
<1 h/wk	671	−0.1 (−21.5 to 21.2)	0.998*	713	−4.1 (−20.1 to 12.0)	<0.001*
≥2 h/wk	1074	−0.6 (−19.9 to 18.7)		1125	24.4 (9.4 to 39.4)	
Motor coordination†	2266	−1.55 (−9.57 to 6.45)	0.703	2470	11.63 (4.86 to 18.40)	0.001

*P for linear trend.
†Standardised regression coefficient: change in counts per minute per standard deviation (5.24) of variable.

WHAT IS ALREADY KNOWN ON THIS TOPIC

Identifying factors that influence physical activity in childhood may help develop better intervention strategies

Little is known about whether factors in early childhood might influence later physical activity

WHAT THIS STUDY ADDS

Factors in early life have limited influence on later physical activity in 11-12 year olds

Parental physical activity is associated with modest increases in children's activity

Encouraging activity among parents may help children to be active

where the environments may provide different opportunities for physical activity. It was not, however, possible to control for school type in this analysis. It is also known that a month of birth bias exists in many competitive sports, with those born earlier in the sports' season more likely to succeed at competitive sport[28] and it may be that early involvement in organised sport leads to increased physical activity in later life.[29]

Early childhood (0-2 years) and preschool (2-5 years)

None of the indicators of physical activity at age 0-2 years (activity at six months or time outside at 24 months) was associated with later physical activity. Tracking of physical activity tends to be weak to moderate[21 30] and it may be that the early measures of physical activity we chose lacked precision to detect an association with later physical activity. Parental physical activity at 21 months was associated with children's physical activity when two non-active parents were compared with either or both parents being active. Studies have reported that physical activity tends to aggregate in families.[31] A review, however, reported that the evidence for an association between parental and child's physical activity is limited.[32] A small association was found with motor coordination at six months. This is in agreement with a recent study that found a weak association between physical activity and motor skills.[11]

Few of the characteristics in preschool aged children (2-5 years) were associated with later physical activity. A small association was found, after adjustment, with television viewing at 38 and 54 months. One study recently reported no cross sectional association between television viewing and objectively measured physical activity.[33] A meta-analysis that included mainly cross sectional studies reported a weak relation between television viewing and physical activity (Pearson's coefficient $r=-0.096$, 95% confidence interval -0.080 to -0.112).[34] The modest associations we report here may result from the length of time between measures for television viewing and assessment of physical activity, as other factors may have had a greater influence before follow-up at 11 to 12 years.

Effect modification by sex

We found little evidence of effect modification by sex on most of the variables. Owing to the large number of tests for interaction it is possible that those showing evidence of effect modification did so by chance. We did find strong evidence of an association between maternal brisk walking during pregnancy and physical activity in girls but not in boys. A previous review reported that maternal physical activity is associated with physical activity in daughters more than in sons.[32]

Strengths and limitations of the study

The use of an objective measure of physical activity is a major strength of this study as it provides a more precise and accurate estimate than self report of the level of physical activity. The detailed measures available and the large sample size allowed us to test for associations of several potential determinants and allowed adequate exploration of the role of potential confounders.

Some of the variables were based on single questions therefore not validated questionnaires. This may have resulted in attenuated associations with children's physical activity owing to imprecision of measurement.[14] It is also possible that cohort attrition and biased participation in study resulted in an unrepresentative sample, which may limit generalisability. Children who participated in this study were more likely to be from socially advantaged backgrounds,[16] although the magnitude of social patterning in physical activity is small.[24] Several of the characteristics were based on questionnaires in which the questions changed slightly over time, making comparisons difficult.

Conclusions

We have shown that early life factors have limited influence on later physical activity in 11-12 year olds. This may have implications when developing guidelines for interventions to increase physical activity, as focusing on modifiable early life factors may have only a modest effect on later levels of physical activity. We have shown that children are slightly more active if their parents are active early in the child's life. This suggests that encouraging physical activity in parents may also influence their children to become more active, with the added advantage that physically active parents are healthier. Although we report few associations between early life factors and physical activity, future research should re-examine these associations in later adolescence when physical activity declines, particularly in girls.

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Contributors: CM organised the daily data collection tasks; was in charge of clinic organisation, preparation of activity monitors, and supporting documentation for each child; and carried out statistical analyses. He is guarantor. CR was the lead applicant for grant funding; was responsible for the overall design of measurement protocols, data collection, and analysis; organised the ethical procedures; and liaised with the funding body. KD participated in daily collection tasks, helped prepare the activity monitors and supporting documentation for each child, and provided input on drafts of this paper. KT was an applicant for grant funding, had overall responsibility for statistical analyses, and provided input on drafts of this paper. SL assisted with statistical analyses and provided input on drafts of this paper. SNB was a collaborator on the grant; provided scientific input on all aspects of the study design, analysis, and reporting; and provided input on drafts of this paper. AN was an applicant for grant funding; provided input on all aspects of the study design and drafts of this paper; and was responsible for the management of data collection on physical activity.

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1 Department of Health. *At least five a week: evidence on the impact of physical activity and its relationship to health*. London: DoH, 2004.
2 Strong WB, Malina RM, Blimkie CJR, Daniels SR, Dishman RK, Gutin B, et al. Evidence based physical activity for school-age youth. *J Pediatr* 2005;146:732-7.
3 Twisk JW. Physical activity guidelines for children and adolescents: a critical review. *Sports Med* 2001;31:617-27.
4 Hallal PC, Victora CG, Azevedo MR, Wells JCK. Adolescent physical activity and health: a systematic review. *Sports Med* 2006;36:1019-30.
5 Brage S, Wedderkopp N, Ekelund U, Franks PW, Wareham NJ, Andersen LB, et al. Features of the metabolic syndrome are associated with objectively measured physical activity and fitness in Danish children: the European youth heart study (EYHS). *Diabetes Care* 2004;27:2141-8.
6 Nassis GP, Papantakou K, Skenderi K, Triandafillopoulou M, Kavouras SA, Yannakoulia M, et al. Aerobic exercise training improves insulin sensitivity without changes in body weight, body fat, adiponectin, and inflammatory markers in overweight and obese girls. *Metabolism* 2005;54:1472-9.
7 Andersen LB, Harro M, Sardinha LB, Froberg K, Ekelund U, Brage S, et al. Physical activity and clustered cardiovascular risk in children: a cross-sectional study (the European youth heart study). *Lancet* 2006;368:299-304.
8 Hallal PC, Wells JCK, Reichert FF, Anselmi L, Victora CG. Early determinants of physical activity in adolescence: prospective birth cohort study. *BMJ* 2006;332:1002-7.
9 Reilly JJ, Armstrong J, Dorosty AR, Emmett PM, Ness A, Rogers I, et al. Early life risk factors for obesity in childhood: cohort study. *BMJ* 2005;330:1357.
10 Hebestreit H, Bar-Or O. Exercise and the child born prematurely. *Sports Med* 2001;31:591-9.
11 Fisher A, Reilly JJ, Kelly LA, Montgomery C, Williamson A, Paton JY, et al. Fundamental movement skills and habitual physical activity in young children. *Med Sci Sport Exerc* 2005;37:684-8.
12 Thorburn AW, Proietto J. Biological determinants of spontaneous physical activity. *Obes Rev* 2000;1:87-94.
13 Sallis JF, Prochaska JJ, Taylor WC. A review of correlates of physical activity of children and adolescents. *Med Sci Sport Exerc* 2000;32:963-75.
14 Wareham NJ, Rennie KL. The assessment of physical activity in individuals and populations: why try to be more precise about how physical activity is assessed? *Int J Obes* 1998;22(suppl 2):S30-8.
15 Golding J, Pembrey M, Jones R. ALSPAC—the Avon longitudinal study of parents and children. I. Study methodology. *Paediatr Perinat Epidemiol* 2001;15:74-87.
16 Mattocks C, Ness A, Leary S, Tilling K, Blair SN, Shield J, et al. Use of accelerometers in a large field based study of children: protocols, design issues and effects on precision. *J Phys Act Health* 2008;5 (suppl 1): S94-107.
17 Ekelund U, Sjostrom M, Yngve A, Poortvliet E, Nilsson A, Froberg K, et al. Physical activity assessed by activity monitor and doubly labeled water in children. *Med Sci Sport Exerc* 2001;33:275-81.
18 Mattocks C, Ness A, Leary S, Tilling K, Deere K, Kirkby J, et al. Calibration of an accelerometer during free-living activities in children. *Int J Pediatr Obes* 2007;doi: 10.1080/17477160701408809.
19 Riddoch CJ, Bo Andersen L, Wedderkopp N, Harro M, Klasson-Heggebo L, Sardinha LB, et al. Physical activity levels and patterns of 9- and 15-yr-old European children. *Med Sci Sport Exerc* 2004;36:86-92.
20 Tremblay MS, Barnes JD, Copeland JL, Esliger DW. Conquering childhood inactivity: is the answer in the past? *Med Sci Sport Exerc* 2005;37:1187-94.
21 Kristensen PL, Moller NC, Korsholm L, Wedderkopp N, Andersen LB, Froberg K. Tracking of objectively measured physical activity from childhood to adolescence: the European youth heart study. *Scand J Med Sci Sport* 2007;doi: 10.1111/j.1600-0838.2006.00622.x.
22 Fisher A, Reilly JJ, Montgomery C, Kelly L, Williamson A, Jackson DM, et al. Seasonality in physical activity and sedentary behavior in young children. *Pediatr Exerc Sci* 2005;17:31-40.
23 Office of Population and Census Surveys. *Standard occupational classification*. London: HMSO, 1991.
24 Riddoch C, Mattocks C, Deere K, Saunders J, Kirkby J, Tilling K, et al. Objective measurement of levels and patterns of physical activity. *Arch Dis Child* 2007;92:963-9.
25 Kirkwood BR, Sterne JAC. *Essential medical statistics*. 2nd ed. Oxford: Blackwell, 2003.
26 Treuth MS, Butte NF, Puyau M, Adolph A. Relations of parental obesity status to physical activity and fitness of prepubertal girls. *Pediatr* 2000;106:E49.
27 Kihlbom M, Johansson SE. Month of birth, socioeconomic background and development in Swedish men. *J Biosoc Sci* 2004;36:561-71.
28 Helsen WF, Hodges NJ, Van Winckel J, Starkes JL. The roles of talent, physical precocity and practice in the development of soccer expertise. *J Sport Sci* 2000;18:927-36.
29 Pfeiffer KA, Dowda M, Dishman RK, McIver KL, Sirard JR, Ward DS, et al. Sport participation and physical activity in adolescent females across a four-year period. *J Adolescent Health* 2006;39:523-9.
30 Malina RM, Bouchard C, Bar-Or O. *Growth, maturation and physical activity*. Champaign, IL: Human Kinetics, 2004.
31 Simonen RL, Perusse L, Rankinen T, Rice T, Rao DC, Bouchard C. Familial aggregation of physical activity levels in the Quebec family study. *Med Sci Sport Exerc* 2002;34:1137-42.
32 Gustafson SL, Rhodes RE. Parental correlates of physical activity in children and early adolescents. *Sports Med* 2006;36:79-97.
33 Ekelund U, Brage Sor, Froberg K, Harro M, Anderssen SA, Sardinha LB, et al. TV viewing and physical activity are independently associated with metabolic risk in children: the European youth heart study. *PLoS Med* 2006;3:e488.
34 Marshall SJ, Biddle SJ, Gorely T, Cameron N, Murdey I. Relationships between media use, body fatness and physical activity in children and youth: a meta-analysis. *Int J Obes* 2004;28:1238-46.

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