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A Prospective Study of Sedentary Behavior in a Large Cohort of Youth

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Abstract

Purpose—To describe longitudinal patterns of objectively measured sedentary behavior from age 12 to 16.

Methods—Children participating in the Avon Longitudinal Study of Parents and Children wore accelerometers for one week at age 12, 14 and 16. Participants included boys (n=2591) and girls (n=2845) living in a single geographic location in the U.K. (Bristol). Total minutes per day spent in sedentary behavior, and time spent in blocks of sedentary behavior lasting 10–19 minutes, 20–29 minutes and 30+ minutes are described. Growth curve models were used to determine the rate of change in sedentary behavior from age 12 to 16.

Results—At age 12 the boys and girls, on average, were sedentary for 418.0 (67.7) and 436.6 (64.0) minutes per day respectively, and sedentary behavior increased over time to 468.0 (74.3) and 495.6 (68.9) minutes per day at age 14, and to 510.4 (76.6) and 525.4 (67.4) minutes per day at age 16. Growth curve analyses found that total sedentary behavior increased at a rate of 19.5 (0.7) and 22.8 (0.7) minutes per day per year for the boys and girls respectively. The absolute mean increase in total sedentary behavior (+92.4 min/d and +88.8 min/d for the boys and girls respectively) closely matched the mean decrease in light physical activity (–82.2 min/d and –82.9 min/d for the boys and girls respectively, from age 12 to 16. Time spent in continuous sedentary behavior lasting 30+ minutes increased by 121% from age 12 to 16.

Conclusions—Sedentary behavior increased with age, at the expense of light physical activity. The increase in sedentary behavior lasting 30+ minutes in duration contributed greatly to the increase in total sedentary behavior.

Keywords

Children; adolescents; longitudinal; patterns; descriptive

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Introduction

It is possible for an individual to spend a large proportion of time in sedentary behavior, even if they meet physical activity guidelines (5, 21). Interestingly, higher levels of sedentary behavior have been associated with obesity and metabolic risk factors in children and adults, and with early mortality in adults, independent of physical activity levels (6, 10, 13, 24). Those studies provide support for the contention that reduction of time spent in sedentary behavior should be adopted as a public health goal. However, few studies have objectively quantified the time spent in sedentary behavior.

Cross-sectional studies have described the time children and adults spend in sedentary behavior using accelerometers (15, 19, 23, 24). An important observation from the National Health and Nutrition Examination Survey (NHANES) 2003–2004 data was that adolescents (16 to 19 years) spent approximately 2 hours more per day in sedentary behavior compared to children (6 to 11 years) (15). This indicates that childhood and adolescence are key developmental periods during which time spent in sedentary behavior increases; however, this needs to be confirmed by analyzing longitudinal accelerometer data. In addition, it is important to consider if any factors influence time spent in sedentary behavior. For example, children from lower socioeconomic backgrounds tend to spend more time in screen-based sedentary behaviors (2).

The purpose of this paper is to describe longitudinal patterns of sedentary behavior, as measured by accelerometry, in a sample of children when aged 12, 14 and 16. Maternal socioeconomic factors will be studied as predictors of sedentary behavior from age 12 to 16.

Methods

Study population

The Avon Longitudinal Study of Parents and Children (ALSPAC) has been described in detail elsewhere (8). From April 1991 to December 1992, pregnant women residing in the former county of Avon in the UK were recruited into the study (n=14 541). Recruitment occurred through poster advertisements at parent and child care facilities, and advertisements placed in the local and national press, radio and television. Participants were also recruited directly by ALSPAC staff when attending routine ultrasound examinations, and community midwives informed pregnant women of the study. Ethical approval for the study was obtained from the ALSPAC Law and Ethics Committee (approved as an institutional review board) and local research ethics committees. Since the age of 7-years the children have been invited to research clinics for psychometric and physiological measurements. The children provided written assent and the parents provided written informed consent for participation in the research clinics.

Accelerometry protocol

The 12-year clinic visit was the first time the participants were issued with accelerometers; the protocol below was repeated at the 14-year and 16-year clinic visits (17, 20). The participants wore an accelerometer (AM7164, 2.2, & GTM1, ActiGraph LLC, Fort Walton Beach, FL, USA) for seven days at the right hip to detect movement in the vertical plane. Accelerations and decelerations associated with movement frequency and intensity leads to the accrual of count data. A 60 second sampling period was used throughout, and the count data are expressed in counts per minute (cpm). The participants were instructed to wear the accelerometer during their waking hours, but to remove the accelerometer when bathing, showering or participating in water sports. Participants included in the study had to provide data for at least 10 hours per day, over a minimum of 3 days. Periods of continuous zeros lasting more than 10 minutes were considered non-wear time (18).

Sedentary behavior definitions

Accelerometer cutpoints between <100cpm and <500cpm have been used to define sedentary behavior in the past (7, 24, 26). In the current study, total sedentary behavior reflects the average minutes per day spent at <200cpm, during waking hours. The macro used in the present study cleaned the raw count data in blocks of 200cpm, and so the sedentary behavior cutpoint is the lowest possible (17). To the best of our knowledge no studies have measured breaks in sedentary behavior in children. This is important since a study in adults found that breaks in sedentary behavior were associated with improved metabolic health (10). In the current study, continuous blocks of sedentary behavior lasting for 10–19 minutes, 20–29 minutes and 30 minutes in duration are described. The continuous blocks reflect more-to-less frequent breaks in sedentary behavior during waking hours. The average number of times each sedentary block occurred per day was determined, and the average minutes accrued within each sedentary block per day was determined.

Physical activity definitions

It is expected that any change in sedentary behavior over time will be substituted with time spent in light physical activity and/or moderate-to-vigorous physical activity (MVPA). Total moderate-to-vigorous intensity physical activity (MVPA) is defined as the average minutes per day spent at 3600cpm. This accelerometer cutpoint is based on results from a calibration study in a subsample of ALSPAC participants that corresponds to an energy expenditure of 4 metabolic equivalents (METs) (17). Given that light physical activity lies between sedentary behavior and MVPA, the average minutes per day spent between 200-to-3599cpm defines light intensity physical activity.

Anthropometric measures

Anthropometric measures are included in the present study for the purpose of describing the development of the children over time. At each research clinic visit the participants were measured for height and weight, using a stadiometer (Harpenden, Holtain, Crymych, Pembrokeshire, UK) and electronic scale (Tanita TBF 305, www.tanita.co.uk) respectively, with shoes and socks removed. From the height and weight measures, body mass index was calculated (BMI, kg/m²).

Social predictors of sedentary behavior

Previous studies using accelerometer measured sedentary behavior have found girls to be more sedentary than boys (15, 19), and all analyses in the current study will be performed by gender. Having an older mother was associated with higher accelerometry measured sedentary behavior in a cross-sectional study of 7-year-olds (14), so maternal age will be included as a covariate in the current study. Previous studies have also reported levels of sedentary behavior, as assessed by television viewing, to be higher in children from lower socioeconomic status groups (2). In the current study, social class, maternal education, and maternal smoking status will be included as covariates to provide a measure of socioeconomic status. Social class was determined from parental occupation at 32-weeks gestation (1=Professional, 2=Managerial/Technical, 3=Skilled non-manual, 4=Skilled manual, 5=Partly skilled, and 6=Unskilled)(12), and maternal education self-reported at 32-weeks gestation [1=none/Certificate of Secondary Education, 2=vocational, 3=O-level (national school exam at 16-years), 4=A-level (national school exam at 18-years), or 5=university degree]. Maternal smoking status while pregnant was determined from a questionnaire at 18-weeks (smoking habits during the first trimester) and 32 weeks (number cigarettes smoked per day) gestation. Finally, maternal obesity (BMI >30kg/m²) at enrolment has been associated with obesity in their children in previous ALSPAC studies (22). This association is likely explained by both genetic and environmental influences, and

it is possible that maternal obesity may influence levels of sedentary behavior in their children. Therefore, maternal obesity will be included as a covariate in the current study.

Statistical procedures

Descriptive statistics were calculated for cross-sectional samples of children at each age, and for a cohort of children providing accelerometer data and social factor data at all three ages. The reason for presenting data on the cohort of children relates to the tracking analysis, which requires participants to have provided three consecutive data points. The means and standard deviations (SD) for the anthropometric measures, sedentary variables and physical activity variables are presented. For the social factors, the frequencies and percents are presented.

In order to determine the trajectory of sedentary behavior over time, and to determine if the social factors affect the trajectory over time, growth curve models were constructed. The growth curve models provide both a mean trajectory of sedentary behavior and an estimation of individual trajectories of sedentary behavior. First an unconditional linear growth model was fitted to provide a baseline model for comparison, followed by a conditional growth curve model that additionally included accelerometer wear time, the social factors and social factor \times age interaction terms. If the interaction term did not contribute to the model fit then it was removed. Age was centered at baseline age and therefore the rate of change in sedentary behavior can be interpreted as *per year*. The growth curve models were performed using PROC MIXED (SAS, version 9.2) (25). Tracking of sedentary behavior was assessed using logistic regression, to determine the odds of remaining in the top quartile of sedentary behavior at 16-years, given that a child was in the top quartile for sedentary behavior at 12-years and 14-years (SAS, version 9.2) (1, 28).

Results

Totals of 11 952, 11 267, and 10 692 children were invited to the 12-, 14- and 16-year clinics respectively; and of those invited 7159, 6147 and 5509 attended. Compared to non-attendees, those attending the 12-, 14- and 16-year clinics were more likely to be girls, have a higher birth weight, be from a higher social class, have older and taller mothers, and have mothers with a higher level of education. The cross-sectional samples providing valid accelerometry data at age 12, 14 and 16 included 5436, 3488 and 1974 children respectively. Compared to all those who attended the research clinics, the children who wore accelerometers were more likely to be girls, have higher birth weight, be from higher social class, have older and taller mothers, and have mothers with a higher level of education (this was the case for all three clinics). The cohort of children (n=1342) had mothers with a higher level of education and of a higher level of social class compared to the cross-sectional samples (Table 1). There were no differences with regard to anthropometric measures over time between the cross-sectional samples and the cohort of children.

The data in Table 1 describe the anthropometric changes with increasing age. Boys became taller and heavier than the girls by age 16, but the BMI of the girls is slightly higher than the boys across all three ages. In addition, 1 in 20 mothers were obese prior to pregnancy and almost 1 in 5 mothers smoked while pregnant. The distribution of maternal education levels and social class levels are such that a wide range of socioeconomic backgrounds are included in the study.

The sedentary behavior variables are presented in Table 2. Total sedentary behavior, the frequency of sedentary blocks, and the time spent within sedentary blocks increased with age for both boys and girls. The time spent sedentary in blocks lasting \geq 30 continuous minutes increased by 133% and 121% for boys and girls respectively, from age 12 to 16.

The increases in time spent in sedentary blocks lasting 20–29 minutes and 10–19 minutes were less pronounced from ages 12 to 16 (48% and 20% increase respectively). These patterns were similar in the cross-sectional samples and in the cohort of children.

Data in Table 2 also describe physical activity levels. Levels of MVPA remained relatively constant from age 12 to 16, but light intensity physical activity levels declined by approximately 25% for both boys and girls. The absolute decline in light intensity physical activity closely matches the absolute increase in time spent in sedentary behavior. These patterns were similar for the cross-sectional samples of children and for the cohort of children (Table 2). The increase in sedentary behavior and the decrease in light intensity physical activity are plotted in Figure 1 to provide a visual presentation of these results. In addition to the absolute times spent in sedentary behavior and physical activity, the percent of time spent in sedentary behavior and physical activity are also provided (see Table, Supplementary Digital Content 1).

In support of the descriptive data in Table 2, the unconditional growth curve models found that total sedentary behavior increased by 16.3 (0.6) minutes per day per year and 19.6 (0.6) minutes per day per year for the boys and girls respectively; and the time spent in daily sedentary blocks lasting 30 or more minutes increased by 15.6 (0.5) minutes per day per year and 17.4 (0.5) minutes per day per year for the boys and girls respectively. The conditional growth curve models are presented in Table 3. Total sedentary behavior increased by 19.5 (0.7) minutes per day per year for the boys and 22.8 (0.7) minutes per day per year for the girls after adjusting for covariates. The time spent in sedentary blocks lasting 30 or more minutes increased by 16.0 (0.5) minutes per day per year and 18.1 (0.5) minutes per day per year for boys and girls respectively after adjusting for covariates. Children spent more time sedentary if born to older mothers and to mothers with a higher level of education.

The data related to tracking of sedentary behavior over time are presented in Table 4. From logistic regression analyses the odds of being in the top quartile of sedentary behavior at 16-years, increased by approximately 2-fold if previously classified in the top quartile of sedentary behavior at both 12-years and 14-years.

Discussion

At age 12 our sample of children spent more than 7 hours per day engaged in sedentary behavior, and this increased over time. Interestingly this increase was largely at the expense of light intensity physical activity while MVPA remained relatively constant. Specifically, the time spent engaged in daily sedentary behavior increased at a rate of 20 and 23 minutes per day per year for boys and girls respectively. In absolute terms sedentary behavior increased by approximately 90 minutes per day from age 12 to 16. In addition to total sedentary behavior, patterns of sedentary behavior by continuous blocks are described and notably the time spent sedentary in blocks lasting 30 minutes more than doubled from age 12 to 16. Our tracking analyses found that high levels of sedentary behavior tended to be maintained over time, indicating that a high risk group of children exists that consistently have high levels of sedentary behavior.

There is evidence from cross-sectional accelerometer studies that time spent in sedentary behavior is higher among older children (15). To the best of our knowledge the present study is the first to describe longitudinal changes in sedentary behavior, as measured by accelerometry, in both boys and girls during childhood. We identified one study that described changes in accelerometry measured sedentary behavior in a sample of U.S. children (27). However, that study only covered two time points from age 12 to 14 and only

included girls (27). In that study the time spent in sedentary behavior increased from 7.7 to 8.5 hours per day from age 12 to 14 in the girls, and the increase in sedentary behavior was in parallel with a decrease in light physical activity (27). No studies have described time spent in continuous blocks of sedentary behavior during childhood, and replication of our findings related to the continuous blocks of sedentary behavior from age 12 to 16 is needed.

With the growing consensus that time spent in sedentary behavior increases during childhood, it is important to investigate the potential health implications of such an increase. Several studies have reported associations between sedentary behavior and early mortality from cardiovascular disease and metabolic risk factors in adults (4, 11, 13). However, a recent review of longitudinal studies concluded that there was insufficient evidence of a relationship between sedentary behavior and metabolic risk factors in childhood (3). Only one of the longitudinal studies used accelerometry measured sedentary behavior, and more research using accelerometry measured sedentary behavior is needed to study the association between sedentary behavior and metabolic health in childhood (3, 27). Furthermore, there is evidence from a study of adults that single minute breaks in sedentary behavior are associated with improved metabolic health (10). We observed that increased time spent in sedentary behavior from age 12 to 16 was largely a result of more prolonged periods of sedentary behavior, indicating fewer breaks in sedentary behavior with age. This may be of particular importance given the findings by Healy et al.(10).

Having an older mother and a mother with a higher level of education was associated with more time spent in sedentary behavior in the current study. It is speculated that parents with higher levels of education are likely to place more importance on their child's academic achievement, resulting in more sitting time while studying. Older mothers may be less inclined to participate in physical activity with their children, leaving more time for the child to be sedentary. No other social factors included in the current study were associated with time spent in sedentary behavior from age 12 to 16. Future studies are needed to confirm these findings and more research is needed to explore the potential effect of other social and physical environmental factors that could influence time spent in sedentary behavior in childhood (14, 29).

A major strength of the current study is the repeated measures of sedentary behavior, as assessed by accelerometry, during an important developmental time period in a large sample of children. In addition, unique descriptions of sedentary behavior patterns by continuous time blocks are of importance given the findings by Healy et al. (10). The current study also has some limitations. First, a linear growth curve model was used and at some point the rate of increase in sedentary behavior would be expected to slow, and ultimately plateau in later life. A polynomial age variable was considered, but the curvilinear relationship was minimal over the three data points. Second, our sample of children was recruited from a single geographic location in the UK. While the demographics of the sample closely matched UK wide census data at recruitment, the generalizability of our results needs to be considered given that not all children wore accelerometers. Third, attrition may have biased our findings and it is possible that sedentary behavior may have been different among those missing. Fourth, more than seven days of accelerometer wear may be required to reliably measure sedentary behavior in children (16). However, participant burden and the likelihood of wearing accelerometers for more than seven days have to be taken into consideration. Finally, accelerometers do not capture the context in which sedentary behavior occurs, or the specific sedentary behaviors taking place. Knowing these latter details would help understand the specific sedentary behaviors underlying the increase in accelerometry measured sedentary behavior (9).

In conclusion, sedentary behavior increased from age 12 to 16, at the expense of light intensity physical activity, and tracked over time. The time spent in continuous blocks of sedentary behavior lasting 30 or more minutes, an indicator of more prolonged sedentary behavior, markedly increased.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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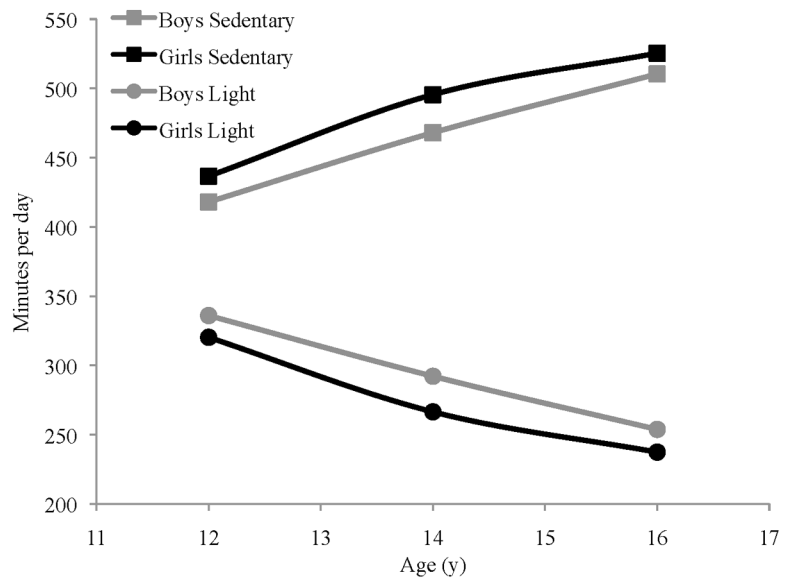


Figure 1. Average times spent in sedentary behavior and light intensity physical activity at age 12, 14 and 16 for boys and girls.

Table 1
Descriptive statistics of children participating in the Avon Longitudinal Study of Parents and Children (ALSPAC) at ages 12, 14 and 16

	Cross-Sectional Samples			Tracking Cohort		
	Total	Boys	Girls	Total	Boys	Girls
Sample Size, No.						
- 12-years	5436	2591	2845	1342	599	743
- 14-years	3488	1625	1863	1342	599	743
- 16-years	1974	890	1084	1342	599	743
Anthropometry						
Height, mean (SD), cm						
- 12-years	150.7 (7.2)	149.9 (7.1)	151.4 (7.3)	150.6 (7.3)	150.0 (7.0)	151.1 (7.4)
- 14-years	163.3 (7.7)	164.8 (8.8)	162.0 (6.3)	163.3 (7.7)	165.1 (8.8)	161.9 (6.4)
- 16-years	168.8 (8.3)	174.0 (7.7)	164.5 (6.1)	168.8 (8.2)	174.0 (7.6)	164.6 (6.1)
Weight, mean (SD), kg						
- 12-years	43.5 (9.8)	42.4 (9.5)	44.5 (10.1)	43.0 (9.5)	42.3 (9.3)	43.6 (9.6)
- 14-years	54.3 (10.9)	54.2 (11.5)	54.5 (10.3)	54.1 (10.7)	54.3 (11.5)	53.9 (10.0)
- 16-years	60.8 (11.3)	63.2 (11.8)	58.9 (10.5)	60.6 (11.0)	63.2 (11.6)	58.6 (10.1)
BMI, mean (SD), kg/m ²						
- 12-years	19.0 (3.4)	18.7 (3.2)	19.3 (3.4)	18.8 (3.1)	18.7 (3.1)	19.0 (3.2)
- 14-years	20.3 (3.4)	19.8 (3.2)	20.7 (3.5)	20.2 (3.3)	19.8 (3.2)	20.5 (3.3)
- 16-years	21.3 (3.5)	20.8 (3.2)	21.7 (3.6)	21.2 (3.3)	20.8 (3.1)	21.6 (3.5)
Maternal Pregnancy Factors ^a						
Maternal Age, mean (SD), y	29.1 (4.5)	29.2 (4.6)	28.9 (4.5)	29.3 (4.4)	29.8 (4.3)	28.9 (4.5)
Maternal Obesity, No. (%)						
- No	4454 (94.9)	2131 (94.5)	2332 (95.1)	1278 (95.3)	568 (94.8)	710 (95.7)
- Yes	242 (5.1)	123 (5.5)	119 (4.9)	63 (4.7)	31 (5.2)	32 (4.3)
Maternal Smoking, No. (%)						
- No	3712 (79.9)	1778 (79.9)	1939 (79.8)	1119 (83.4)	501 (83.6)	618 (83.3)
- Yes	937 (20.1)	448 (20.1)	492 (20.2)	222 (16.6)	98 (16.4)	124 (16.7)
Maternal Education, No. (%)						
- None/CSE	639 (12.8)	304 (12.6)	337 (13.0)	102 (7.6)	43 (7.2)	59 (8.0)

	Cross-Sectional Samples			Tracking Cohort		
	Total	Boys	Girls	Total	Boys	Girls
- Vocational	417 (8.3)	219 (9.1)	200 (7.7)	83 (6.2)	41 (6.8)	42 (5.7)
- O level	1800 (36.0)	857 (35.4)	943 (36.3)	483 (36.0)	204 (34.1)	279 (37.6)
- A level	1334 (26.6)	646 (26.7)	691 (26.6)	397 (29.6)	185 (30.9)	212 (28.6)
- University degree	817 (16.3)	394 (16.3)	424 (16.3)	276 (20.6)	126 (21.0)	150 (20.2)
Social Class, No. (%) ^b						
- 1	182 (3.8)	86 (3.7)	96 (3.8)	79 (5.9)	35 (5.8)	44 (5.9)
- 2	1239 (25.9)	616 (26.8)	624 (25.0)	358 (29.4)	176 (29.4)	182 (24.5)
- 3	1303 (27.3)	626 (27.2)	681 (27.3)	389 (29.0)	167 (27.9)	222 (29.9)
- 4	1275 (26.6)	612 (26.6)	664 (26.7)	318 (23.7)	146 (24.4)	172 (23.2)
- 5	643 (13.4)	291 (12.7)	354 (14.2)	165 (12.3)	64 (10.7)	101 (13.6)
- 6	147 (3.1)	67 (2.9)	80 (3.2)	32 (2.4)	11 (1.8)	21 (2.8)

Abbreviations: BMI, body mass index; CSE, certificate of secondary education

^aMaternal pregnancy factor data based on the 12-year sample. Missing data in the 12-year cross-sectional sample: maternal age (n=259), maternal obesity (n=733), maternal smoking (n=780), maternal education (n=422), and social class (n=640).

^bSocial class based on occupation (1=Professional, 2=Managerial/Technical, 3=Skilled non-manual, 4=Skilled manual, 5=Partly skilled, and 6=Unskilled)

Table 2
Sedentary behavior and physical activity patterns at ages 12, 14 and 16 among children participating in the Avon Longitudinal Study of Parents and Children (ALSPAC)

	Cross-Sectional Samples					
	Boys			Girls		
	12-years (n=2589)	14-years (n=1625)	16-years (n=889)	12-years (n=2840)	14-years (n=1861)	16-years (n=1082)
Total sedentary, mean (SD), min/d	418.0 (67.7)	468.0 (74.3)	510.4 (76.6)	436.6 (64.0)	495.6 (68.9)	525.4 (67.4)
Freq of sedentary blocks, mean (SD)						
- 10–19 min	8.1 (2.1)	9.0 (2.2)	9.5 (2.2)	8.3 (1.9)	9.3 (2.1)	9.9 (2.1)
- 20–29 min	2.0 (0.9)	2.5 (1.1)	2.9 (1.1)	2.0 (0.9)	2.7 (1.0)	3.0 (1.1)
- 30 min	1.2 (0.8)	1.9 (1.2)	2.5 (1.3)	1.3 (0.9)	2.2 (1.1)	2.7 (1.3)
Time in sedentary blocks, mean (SD), min/d						
- 10–19 min	107.1 (28.1)	119.5 (29.3)	127.9 (29.6)	109.6 (25.8)	124.4 (29.1)	132.2 (28.2)
- 20–29 min	46.9 (22.2)	58.2 (25.4)	69.3 (25.8)	48.3 (20.8)	63.5 (24.3)	71.1 (25.2)
- 30 min	47.9 (36.6)	79.8 (53.4)	111.4 (63.9)	53.6 (38.0)	91.9 (52.2)	118.7 (61.2)
Total light PA, mean (SD), min/d	336.0 (59.2)	292.2 (61.0)	253.8 (62.3)	320.3 (56.6)	266.5 (54.1)	237.4 (59.5)
Total MVPA, mean (SD), min/d	28.4 (16.9)	29.1 (18.7)	29.8 (20.4)	18.3 (11.7)	19.7 (14.9)	18.3 (15.3)
Total cpm, mean (SD), average/d	662.7 (185.2)	600.9 (201.0)	535.2 (197.4)	551.8 (150.9)	487.9 (163.9)	431.9 (143.4)
ACC wear time, mean (SD), min	4636.8 (1037.5)	4118.6 (1435.3)	3935.7 (1521.6)	4546.6 (1007.5)	3933.0 (1473.0)	3757.4 (1487.7)
				Tracking Cohort		
		Boys (n=599)			Girls (n=742)	
		12-years	14-years	12-years	14-years	16-years
Total sedentary, mean (SD), min/d	429.5 (60.4)	475.9 (67.5)	512.7 (74.8)	442.3 (61.5)	503.5 (64.7)	529.0 (65.6)
Freq of sedentary blocks, mean (SD)						
- 10–19 min	8.4 (1.9)	9.1 (2.1)	9.6 (2.1)	8.5 (1.9)	9.5 (1.9)	9.9 (2.0)
- 20–29 min	2.1 (0.9)	2.5 (1.0)	3.0 (1.0)	2.1 (0.9)	2.7 (0.9)	3.0 (1.0)
- 30 min	1.2 (0.8)	1.9 (1.1)	2.5 (1.3)	1.3 (0.8)	2.2 (1.1)	2.8 (1.2)
Time in sedentary blocks, mean (SD), min/d						
- 10–19 min	111.3 (25.4)	121.5 (27.9)	128.7 (28.7)	112.2 (25.3)	126.8 (26.2)	133.5 (27.9)
- 20–29 min	49.6 (20.4)	60.2 (22.9)	70.2 (23.8)	49.9 (21.0)	65.0 (22.8)	72.1 (24.7)
- 30 min	51.6 (37.7)	82.9 (51.4)	112.0 (61.9)	54.3 (36.6)	95.7 (50.5)	121.5 (59.3)
Total light PA, mean (SD), min/d	333.2 (55.5)	288.9 (57.5)	253.3 (59.4)	316.9 (54.3)	265.6 (51.3)	235.3 (62.2)

	Cross-Sectional Samples					
	Boys			Girls		
	12-years (n=2589)	14-years (n=1625)	16-years (n=889)	12-years (n=2840)	14-years (n=1861)	16-years (n=1082)
Total MVPA, mean (SD), min/d	26.3 (15.4)	28.3 (17.6)	30.0 (20.3)	18.0 (11.3)	19.4 (14.9)	18.7 (15.5)
Total cpm, mean (SD), average/d	631.6 (165.1)	584.4 (186.4)	536.4 (198.6)	543.8 (151.4)	477.5 (156.9)	430.4 (141.5)
ACC wear time, mean (SD), min	4938.3 (881.5)	4446.0 (1250.5)	4083.9 (1442.6)	4778.6 (937.0)	4305.0 (1289.8)	3834.3 (1472.8)

Abbreviations: ACC, accelerometer; cpm, counts per minute; IQ, interquartile range; MVPA, moderate-to-vigorous physical activity; PA, physical activity; SD, standard deviation

Table 3

Conditional growth curve models describing change in sedentary behavior from age 12 to 16 among children participating in the Avon Longitudinal Study of Parents and Children (ALSPAC)

	Boys (n=1970)		Girls (n=2189)	
	Total Sedentary (min/d)	Time in 30min blocks (min/d)	Total Sedentary (min/d)	Time in 30min blocks (min/d)
Intercept	349.0 (13.7) ***	35.2 (8.4) ***	364.8 (11.6) ***	35.1 (7.7) ***
Age ^d	19.5 (0.7) ***	16.0 (0.5) ***	22.8 (0.7) ***	18.1 (0.5) ***
Accelerometer wear time	0.009 (0.001) ***	0.002 (0.001) **	0.009 (0.001) ***	0.002 (0.001) ***
Maternal age	1.5 (0.3) ***	0.4 (0.2) *	1.1 (0.3) ***	0.4 (0.2) *
Maternal obesity				
- Obese	-5.8 (6.0)	-2.6 (3.6)	-3.3 (5.5)	-4.6 (3.6)
- Non-Obese	Referent	Referent	Referent	Referent
Smoked during pregnancy				
- Yes	-3.6 (3.6)	-1.7 (2.1)	-3.0 (3.1)	-2.3 (2.0)
- No	Referent	Referent	Referent	Referent
Maternal education				
- None/CSE	-28.4 (6.0) ***	-14.6 (3.6) ***	-11.7 (5.0) *	-9.5 (3.3) **
- Vocational	-32.6 (6.1) ***	-17.4 (3.7) ***	-11.7 (5.5) *	-5.8 (3.6)
- O levels	-16.7 (4.5) ***	-10.3 (2.7) **	-7.2 (3.8)	-6.5 (2.5) **
- A levels	-8.1 (4.3)	-7.1 (2.6) **	-4.6 (3.7)	-2.3 (2.4)
- Degree	Referent	Referent	Referent	Referent
Social Class ^b				
- 1	5.5 (11.1)	1.6 (6.7)	22.5 (9.1) **	17.2 (6.0) **
- 2	5.2 (9.1)	3.0 (5.5)	11.1 (7.2)	5.5 (4.7)
- 3	4.7 (8.9)	1.2 (5.4)	5.6 (7.0)	3.7 (4.6)
- 4	1.6 (8.8)	-1.7 (5.3)	4.2 (7.0)	1.7 (4.6)
- 5	2.5 (9.2)	-0.7 (5.5)	4.0 (7.3)	0.9 (4.8)
- 6	Referent	Referent	Referent	Referent
Variance Components				
- Level 1 (Within Person)	1019.1 (69.5) ***	1471.1 (66.3) ***	1297.6 (73.2) ***	1630.8 (69.1) ***

	Boys (n=1970)		Girls (n=2189)	
	Total Sedentary (min/d)	Time in 30min blocks (min/d)	Total Sedentary (min/d)	Time in 30min blocks (min/d)
- Level 2 - In initial status	2901.3 (141.9)***	-9.2 (72.1)	2184.0 (125.8)***	-109.4 (74.0)
- Level 2 - In rate of change	410.5 (38.4)***	45.5 (13.7)**	326.6 (33.1)***	42.9 (16.6)**
- Level 2 - Covariance	-279.4 (57.7)***	233.7 (25.5)***	-238.6 (50.8)***	203.4 (26.5)***

* $P < 0.05$,

** $P < 0.01$,

*** $P < 0.001$.

Abbreviations: CSE, certificate of secondary education. Data presented are β -coefficients (standard error).

^a Age variable centered on age at 12-year clinic (interpret as rate of change per year).

^b Social class based on occupation (1=Professional, 2=Managerial/Technical, 3=Skilled non-manual, 4=Skilled manual, 5=Partly skilled, and 6=Unskilled)

Tracking of sedentary behavior from age 12 to 16 and from age 14 to 16 among children participating in the Avon Longitudinal Study of Parents and Children (ALSPAC)

Table 4

	Boys (n=599)				Girls (n=742)			
	Upper Quartile 16y				Upper Quartile 16y			
	Upper Quartile 12y	Upper Quartile 14y	Upper Quartile 16y	Upper Quartile 16y	Upper Quartile 12y	Upper Quartile 14y	Upper Quartile 16y	Upper Quartile 16y
Total sedentary	OR	95% CI	OR	95% CI	OR	95% CI	OR	95% CI
	2.89	1.9, 4.3	2.19	1.5, 3.3	2.31	1.6, 3.3	2.83	2.0, 4.1
Freq of sedentary blocks								
- 10–19 min	1.48	1.0, 2.4	2.10	1.4, 3.1	1.36	0.9, 2.0	1.03	0.7, 1.5
- 20–29 min	1.94	1.3, 2.9	1.54	1.0, 2.3	1.66	1.1, 2.4	1.34	0.9, 1.9
- 30 min	2.12	1.4, 3.2	2.75	1.8, 4.1	1.92	1.3, 2.8	2.57	1.8, 3.7
Time in sedentary blocks								
- 10–19 min	1.60	1.1, 2.4	2.25	1.5, 2.4	1.41	1.0, 2.0	1.27	0.9, 1.8
- 20–29 min	1.90	1.3, 2.8	1.34	0.9, 2.0	1.72	1.2, 2.5	1.21	0.8, 1.8
- 30 min	1.75	1.2, 2.6	2.66	1.8, 4.0	1.76	1.2, 2.5	2.74	1.9, 3.9