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Correlates of objectively measured physical activity and sedentary behaviour in English children

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Background: Evidence on the correlates of objectively measured physical activity and sedentary behaviour in childhood is limited. This study aimed to identify correlates of physical activity and sedentary behaviour among 7-year-old children in England. **Methods:** Physical activity was measured using Actigraph accelerometry in 480 participants as part of the Gateshead Millennium Study during 2006–07. Twenty-two potential correlates across five domains (demographic and biological; psychological, cognitive and emotional; behavioural; social and cultural; physical environmental) were tested for associations with total volume of habitual physical activity, moderate–vigorous intensity physical activity (MVPA) and sedentary behaviour. Multiple linear regression analysis was used. **Results:** Seven correlates, including four that are potentially modifiable, were significantly associated with total physical activity, MVPA and sedentary behaviour in final models: gender, child weight status, maternal age, child interest in active play, active commuting to school, parenting practice and season. Four of these variables were significantly associated with all three constructs in final models. The final models explained 18, 18 and 24% of variance in total volume of physical activity, MVPA and sedentary behaviour, respectively. **Conclusion:** A number of potentially modifiable factors are associated with increased physical activity and/or reduced sedentary behaviour in English children. These could be valuable targets of future interventions.

Keywords: physical activity, sedentary behaviour, correlates, children, Gateshead Millennium Study

Introduction

Habitual physical activity and sedentary behaviour in childhood and adolescence are now recognized as important influences on current and future health.[1] There is growing concern that objectively measured levels of physical activity among children and youth are often lower than recommendations,[2–4] and the development of effective interventions to increase physical activity requires an improved understanding of the correlates of physical activity and sedentary behaviour.[5–7]

Reviews[8–13] have established a valuable conceptual framework to improve our understanding of the influences on physical activity in childhood and adolescence, but have focused largely on physical activity rather than sedentary behaviour to date. Furthermore, reviews of previous studies have actually identified relatively few correlates of physical activity consistently, and so have called for more research.[8–13] Although there are studies of the correlates of objectively measured habitual physical activity,[14–19] it would appear that there are no studies of the correlates of objectively measured sedentary behaviour in children. In addition, the correlates of physical activity may differ from the correlates of sedentary behaviour,[20–22] and these constructs should ideally be considered separately. Correlates of objectively measured physical activity and sedentary behaviour may also differ significantly by age group,[23] and so should ideally be studied in relatively large samples with narrow age ranges. The present study therefore aimed to identify significant correlates of objectively measured habitual physical activity and sedentary behaviour in a sample of 7-year-old children.[24]

Methods

Study participants

A total of 1029 infants had been recruited during 1999–2000 to a birth cohort study, the Gateshead Millennium Study (GMS), which is described in detail elsewhere.[24] Briefly, all babies born in pre-specified recruiting weeks between June 1999 and May

2000 to Gateshead-resident mothers were eligible to join the study. This cohort is socio-economically representative of North East England,[24] but is ethnically homogenous and is comprised almost entirely of Caucasians—the ethnic majority group in the UK. Data collection for the present study during 2006–07 involved a variety of anthropometric and lifestyle measures. All parents who had not previously indicated that they did not wish to be contacted were invited to take part. The present study was given a favourable ethical opinion from the Gateshead and South Tyneside Local National Health Service Research Ethics Committee, and all participating parents gave informed written consent to participation; all children gave assent to participation.

Objective measurement of physical activity and sedentary behaviour

Physical activity and sedentary behaviour were measured using the Actigraph 7164 and GT1M models (MTI, Fort Walton Beach, Florida). Reviews have concluded repeatedly that the Actigraph measures habitual physical activity and sedentary behaviour in children with high practical utility, reasonably high reliability, high validity relative to criterion measures (energy expenditure and direct observation of movement) and negligible reactivity.[25–27]

In the present study, the Actigraphs were attached to a waist belt and parents were asked to put the belt on when children woke up and remove it before bed, for a period of 7 consecutive days. Parents were also asked to note periods when the Actigraph was removed in a log sheet. Accelerometry data were reduced manually as described previously.[28] In brief, long periods of consecutive 'zeros' in the accelerometry record were checked for entries in the log sheet. These periods were rare and usually corresponded to log-sheet records (e.g. showering) which explained the zeros satisfactorily. Accelerometer records which consisted of at least 3 days were included (2 week days plus 1 week end day; days of <6 h excluded), on the *a priori* grounds that reliability of this amount of Actigraph accelerometry in UK children is adequate.[29] Analyses confirmed that for the data from the present study, reliability was high for total volume of physical activity, moderate–vigorous intensity physical activity (MVPA) and sedentary behaviour for the minimum period of accelerometry.[28]

The Actigraph Accelerometers in the present study were set to summarize activity data in 15 s sampling intervals (epochs), but data were collapsed to 60 s epochs when summarized to allow use of cut-points in accelerometry output as described below. Objectively measured physical activity was measured using two commonly-used constructs: total volume of physical activity [expressed as the mean counts per minute (cpm) over the duration of accelerometry monitoring[19]] and percent of time spent in MVPA. The epoch chosen does not affect measurements of total volume of activity,[25] but tends to misclassify vigorous intensity physical activity as moderate intensity.[25] Measurement of the amount of time spent in sedentary behaviour is largely unaffected by epoch.[25]

In order to express accelerometry output in terms of intensity of activity, it is necessary to apply cut-points to the accelerometry data.[25] A recent review found a moderately large body of high quality and consistent evidence from paediatric validation and calibration studies, which suggests that the appropriate cut-point to measure MVPA with the Actigraph lies in the range 3100–3600 cpm.[25] The cut-point of Puyau *et al.*[30] (3200 cpm) was used to define MVPA. The Actigraph GTIM model has been shown to have a consistent bias of −9% relative to the older Actigraph model[31] and so a +9% correction to GTIM data was made before applying any cut-point to define MVPA and sedentary behaviour. A body of high quality and consistent evidence from paediatric calibration and validation studies suggests that an Actigraph cut-point of around 1100 cpm will measure sedentary behaviour with optimal accuracy,[32,33] across a wide paediatric age range.[25] The cut-point of 1100 cpm was, therefore, used in the present study to define sedentary behaviour.

Anthropometrics

Height and weight were measured by trained researchers according to standard protocols using a Leicester portable height measure and a TANITA TBF 300MA body fat analyser (both Chasmors, London UK). Body mass index (BMI) was calculated in the usual way [weight (kg)/height $(m)^2$]. For children, BMI *z*-scores relative to UK 1990 reference data were calculated to define healthy weight (*z*-score <1.04); overweight (BMI *z*-score $1.04 \leq 1.64$); obese (BMI *z*-score >1.64). For parents, weight status was assigned as healthy weight (BMI ≤ 25.0), overweight (BMI $25.0 \leq 30.0$), obese (BMI >30.0) (table 1).

Potential correlates of physical activity and sedentary behaviour

Reviews of the correlates of physical activity in youth[8–13] were considered when identifying potential correlates to be considered in the present study. The literature on the correlates of objectively measured sedentary behaviour in childhood is much more limited, and the topic is complicated by variations in the definitions of sedentary behaviour, which are discussed below. All potential correlates were supported by *a priori* hypotheses of associations with physical activity, sedentary behaviour or both. The social ecologic framework has dominated the literature on correlates of physical activity, with five domains widely accepted:[8–13] (i) demographic and biological; (ii) psychological, cognitive and emotional; (iii) behavioural; (iv) social and cultural; (v) physical environmental. In the present study, potential correlates were grouped according to this conceptual framework and measured using a variety of methods as described in table 1.

Data that were collected from the main carer in the form of questionnaires have been described in detail by Parkinson *et al.*[24] Further information on individual questionnaire items is available in the Supplementary Data.

The variables studied for each domain were:

Demographic and biological: gender; child weight status; socio-economic status (SES); maternal age; maternal weight status; main carer works outside the home.

Psychological, cognitive, and emotional: child interest in physically active play.

Behavioural: child active commuting to school; outdoor play; participation in after school clubs.

Social and cultural: permissive/authoritarian/authoritative parenting practice in relation to physical activity (authoritative subdomains: praise and encouragement in relation to physical activity; rationale in relation to physical activity; modelling parenting behaviour); parental-perceived importance of active play; parental habitual physical activity; parental habitual TV viewing and screen time; parental regular use of active transport.

Physical environment: perceived availability of safe local places for play; season.

Statistical analysis and power

All questionnaire data were double entered to minimize errors in data entry. Participants and non-participants were

Table 1 Potential correlates of objectively measured habitual physical activity and sedentary behaviour[a]

Domain, variable (s)	Measurement method	Use in analysis
Demographic and biological		
Gender		Binary variable: female, male
Child weight status	Researcher measured height, weight. BMI *z*-score relative to UK 1990 reference data	Ordered categorical variable (0–2): healthy weight, overweight, obese
Socio-economic status	Maternal education, four categories (no qualifications; school qualifications to age 16; post-16 school education; higher education)	Ordered categorical variable (1–4): lowest to highest education
Maternal age	Calculated via self-reported birthday	Ordered categorical variable (1–4): youngest to eldest age quartile
Maternal weight status	Researcher measured height, weight. BMI	Ordered categorical variable (0–2): healthy weight, overweight, obese
Main carer works outside home	Parent self-report	Binary variable: no, yes
Psychological, cognitive and emotional		
Child interest in physically active play	Parent questionnaire	Continuous variable (1–5): least to most
Behavioural domain		
Child active commuting to school	Parent report of usual frequency of walking or cycling vs. car use	Ordered categorical variable (1–5): least to most frequent
Outdoor play	Parent questionnaire	Continuous variable (1–5): least to most frequent
Participation in after school clubs	Parent questionnaire	Binary variable: no, yes
Social and cultural		
Permissive parenting practice in relation to physical activity	Parent questionnaire, adapted from Vereecken *et al.*[39]	Continuous variable (1–5): least to most
Authoritarian parenting practice in relation to physical activity	Parent questionnaire, adapted from Vereecken *et al.*[39]	Continuous variable (1–5): least to most
Authoritative parenting practice in relation to physical activity	Parent questionnaire, adapted from Vereecken *et al.*[39]	Continuous variable (1–5): least to most
Praise and encouragement in relation to physical activity[b]	Parent questionnaire, adapted from Vereecken *et al.*[39]	Continuous variable (1–5): least to most
Rationale[c] in relation to physical activity[b]	Parent questionnaire, adapted from Vereecken *et al.*[39]	Continuous variable (1–5): least to most
Modelling[d] physical activity behaviour[b]	Parent questionnaire, adapted from Vereecken *et al.*[39]	Continuous variable (1–5): least to most
Parental perceived importance of active play	Parent questionnaire, adapted from Vereecken *et al.*[39]	Continuous variable (1–5): least to most
Parental habitual physical activity	Parent recent physical activity questionnaire (RPAQ)[40]	Ordered categorical variable (1–4): least to most active quartile
Parental habitual TV viewing and screen time	Parent RPAQ[40]	Ordered categorical variable (1–4): least to most sedentary quartile
Parental regular use of active transport	Parent RPAQ[40]	Binary variable: non-active, active
Physical environment		
Perceived availability of safe local places for play	Parent questionnaire	Continuous variable (1–5): least to most
Season	Date of physical activity measurement Winter (January, February, November, December) Spring/fall (March, April, September, October) Summer (May, June, July, August)	Ordered categorical variable (1–3): winter, spring/fall, summer

a: Individual questionnaire items are provided in the Supplementary Data
b: Subdomains of the authoritative parenting practice
c: Example of 'rationale' questioning: How often do you tell your child that active play and games are good for them?
d: Example of 'modelling' questioning: I try to be more active so my child is more active

compared using chi-squared tests for categorical variables and two sample *t*-tests for continuous variables.

No formal power calculation was carried out, as sample size for the present study was fixed by the size of the GMS cohort. Previous studies of the correlates of objectively measured physical activity in youth have generally been able to identify correlates successfully with samples of <300 participants.[14–19] For the present study, the sample size was expected to exceed 400, and was deemed likely to be adequate to carry out the analyses detailed below, with >30 study participants per explanatory variable in the multiple regression models.

Minitab release 15.1 was used for all analyses. Physical activity and BMI data were skewed, and the median and the interquartile range (IQR) were calculated for these variables. Mean and standard deviation (SD) are presented for normally distributed data. Simple univariate linear regression analysis was used to examine individual relationships between potential correlates listed in table 1 and the three separate outcome variables (total volume of physical activity; percentage of monitored time in MVPA; percentage of monitored time spent sedentary). As the relationship was considered linear among ordered categorical variables, they were treated as continuous for this analysis. In order to meet the assumptions of linear regression, namely that residuals should be normally distributed, two of the outcome variables required transformation (percentage of time spent in MVPA, square root transformation; total physical activity expressed as mean accelerometer cpm, $\log_{10}$ transformation).

To build the final models, stepwise multiple linear regression was used. All explanatory variables associated

significantly with each outcome ($P < 0.05$) in the univariate analysis were considered. Those variables which remained associated significantly (at $P < 0.05$) in the final model were considered to be significant correlates of physical activity and sedentary behaviour in the present study.

Results

Characteristics of study participants

A total of 607 children were followed up during 2006–07, and all were invited to participate in physical activity and sedentary behaviour measurements. The remaining children were either untraceable or the family had opted out of the study. One hundred children did not wear (or return) the Actigraphs and/or did not complete accelerometer log sheets, and 27 did not meet the minimum accelerometry requirement, leaving 480 eligible children (244 boys; 236 girls). Mean duration of accelerometry monitoring was 6.4 days (SD 0.9) with mean duration of 11.1 h (SD 1.1) per day. Total physical activity was similar for boys and girls, median (IQR) cpm was 739 (624–888) for boys and 717 (595–855) for girls ($P = 0.102$).

Questionnaires for the present analysis were completed by the child's birth mother in 450 (of 467) (96%), by the child's birth father in 5, and by grandparents and others in 12 cases.

Table 2 summarizes characteristics from those children included in the present study and provides a comparison with non-participants. Sample attrition produced a final sample characterized by slightly higher SES than the initial sample, but left a sample for the present study, which was representative of North East England in terms of SES. At the inception of the birth cohort from which the present study sample was recruited in 2000, lower SES families were slightly overrepresented (data not shown) and so the slightly differential sample attrition by the time of the present study in 2007 led to a more socio-economically representative sample.[24]

Levels of objectively measured physical activity were relatively low, and levels of objectively measured sedentary behaviour relatively high. Median (IQR) time spent in MVPA was 3.9% (2.6–5.8), equivalent to 20–30 min MVPA per day. Median (IQR) monitoring time spent sedentary was 77.8% (73.7–81.7) equivalent to $>9\,\mathrm{h\,day^{-1}}$ sedentary (no trunk movement as defined by accelerometry). The remaining time (1–2 h of accelerometry wear time during the waking day) was categorized as light intensity physical activity, defined as physical activities with an energy cost below approximately three times resting energy expenditure.[25]

Correlates of objectively measured total volume of habitual physical activity (accelerometry cpm)

The results of the univariate analysis are shown in table 3. Of seven variables significantly associated with total volume of physical activity in the univariate analysis, four remained significant in the final model (table 4). In the final model, total volume of physical activity was significantly lower in: the overweight and obese; those with parent-perceived low interest in physically active play; those who used non-physically active methods of transport to school; and in winter and spring/fall compared to summer. A total of 18.1% of variance in total volume of physical activity was explained in the final model.

Correlates of objectively measured MVPA

The results of the univariate analysis are shown in table 3. Of seven variables significantly associated with MVPA in univariate analysis, five remained significantly associated with MVPA in the final model (table 4). MVPA was significantly lower among: girls; overweight and obese children; in spring/fall and winter compared to summer; in those who used non-active means of transport to school, and children perceived by their parents to have low interest in physically active play. A total of 17.8% of the variance in MVPA was explained in the final model.

Correlates of objectively measured sedentary behaviour

Results of the univariate analysis are shown in table 3. Eleven variables were significantly associated with sedentary behaviour in univariate analyses; seven remained significant in the final model (table 4). Levels of objectively measured sedentary behaviour were significantly higher among: girls; overweight and obese children; those with older mothers; in spring/fall and winter compared to summer; those with low interest in physically active play; those using modelling parenting practices towards physical activity; those who did not use active forms of commuting to school. In the final model, 24.0% of variance in objectively measured sedentary behaviour was explained.

Table 2 Characteristics of study participants and non-participants, mean (SD), median (IQR) or number (%)

Variable	Included in analysis	Excluded from analysis	*P* for difference
N	480	127	
Gender (%)			0.254
Male	244 (51)	54 (45)	
Female	236 (49)	66 (55)	
Body mass index	16.3 (15.2–17.8)	16.4 (15.2–18.3)	0.092
Body mass index *z*- score	0.32 (−0.34 to 1.06)	0.40 (−0.30 to 1.28)	0.299
Weight status (%)			0.192
Overweight	57 (12%)	10 (8)	
Obese	63 (13%)	24 (20)	
Socio-economic status, from maternal educational attainment (%)			<0.001
1 (no qualifications)	57 (12)	41 (32)	
2 (education to age 16)	254 (53)	53 (42)	
3 (post-16 education)	62 (13)	24 (19)	
4 (higher education)	107 (22)	9 (7)	

Table 3 Univariate analysis of correlates associated with total physical activity, MVPA and sedentary behaviour[a]

Variable	*n*	Total volume of physical activity (cpm) *P*	Percentage of monitored time in MVPA *P*	% Monitored time in sedentary behaviour *P*
Demographic and biological domain				
Gender	480	0.100	0.003	<0.001
Child weight status	476	0.003	<0.001	0.020
Socio-economic status	475	0.169	0.632	0.125
Maternal age	466	0.049	0.138	0.045
Maternal weight status	428	0.564	0.414	0.675
Main carer works outside home	460	0.063	0.368	0.039
Psychological, cognitive and emotional domain				
Child interest in physically active play	467	<0.001	<0.001	<0.001
Behavioural domain				
Active commuting to school	466	<0.001	<0.001	<0.001
Outdoor play	467	<0.001	0.001	<0.001
Participation in after school clubs	463	0.036	0.062	0.125
Permissive parenting practice	467	0.646	0.844	0.938
Authoritarian parenting practice	467	0.286	0.426	0.172
Authoritative parenting practice	467	0.569	0.633	0.614
Praise and encouragement		0.327	0.294	0.371
Rationale		0.286	0.208	0.642
Modelling behaviour		0.092	0.178	0.045
Parental perceived importance of active play	467	0.129	0.230	0.141
Parental habitual physical activity	425	0.273	0.490	0.836
Parental habitual TV viewing and screen time	441	0.310	0.374	0.587
Parental use of active transport method	445	0.073	0.128	0.011
Physical environment domain				
Availability of safe places for play	467	0.074	0.052	0.022
Season	480	<0.001	<0.001	<0.001

a: Numbers for analysis ranged from 428 to 480, due to missing data on individual independent variables

Discussion

We present data in the under-researched area of correlates of objectively measured physical activity in children, including novel data on the correlates of objectively measured sedentary behaviour. The present study found four variables that were significantly associated in final models with all three constructs of habitual total physical activity, habitual MVPA and habitual sedentary behaviour; namely active commuting to school; child interest in physical activity; child weight status; season. This suggests that at least some common factors may influence all three constructs in English children.

While the two constructs of physical activity might have been expected to have similar correlates, empirical evidence on this issue is scarce since studies have generally not considered objectively measured total physical activity and MVPA as separate constructs, and older studies which used more traditional subjective methods were unable to consider the data in this manner due to limitations in subjective methodology. In the current study, while gender remained significant in the final model for MVPA, it did not remain in the final model for total volume of physical activity. This distinction may reflect gender-specific differences in activity patterns and may imply that analysis using more than one construct may lead to a more informed picture of behaviour. It is widely accepted that sedentary behaviour should be considered separately from physical activity,[20–22] as the correlates of physical activity and sedentary behaviour may differ. In the present study, correlates of objectively measured habitual physical activity and sedentary behaviour were broadly similar. However, maternal age and parental modelling in the present study were significant correlates only of sedentary behaviour and not physical activity. This may simply reflect a decrease in activity of older mothers, or be a reflection of family size, with the potential for younger children requiring more parental involvement.

Informal subgroup analysis, in the present study, showed the three final regression models to be fairly robust. In addition to those variables, which remained significant in the final models, the subgroup analysis also indicated that outdoor play may be associated with physical activity and negatively associated with sedentary behaviour in some subgroups. This relationship was strongest among boys.

Identifying correlates of objectively measured physical activity and sedentary behaviour should inform future interventions aimed at promotion of physical activity, promotion of reduction in sedentary behaviour and prevention of obesity.[5,8] In the present study, some significant correlates of physical activity and sedentary behaviour were non-modifiable (gender, season, maternal age), though some are at least potentially modifiable (active vs. non-active commuting to school; child-perceived interest in physically active play; weight status).

Previous comparable studies are scarce. In the UK, for example, the current authors are aware of only one previous study of the correlates of objectively measured physical activity (not sedentary behaviour), in 11- to 13-year-old children,[34] an older group than those recruited to the present study. The explanatory variables included in the present study explained relatively little of the variation in objectively measured physical activity, but this was consistent with other evidence. Previous studies which have used objective measures of physical activity have typically explained <20% of variation in physical activity in their final models.[19–23] Studies of correlates of objectively measured physical activity may tend to find fewer correlates than studies of subjectively measured physical activity, in part because of correlated error in studies which depend on subjective methods to derive both explanatory and outcome variables.[19,35] However, the higher accuracy of objective measurements is essential for studies of the amount and intensity of

Table 4 Final models: associations between total physical activity, MVPA and sedentary behaviour

Variable	Total physical activity (cpm)			Percentage of monitored time in MVPA			Percentage of monitored time in sedentary behaviour		
	β-coeff.	95% CI	*P*-value	*β*-coeff.	95% CI	*P*-value	*β*-coeff.	95% CI	*P*-value
Gender	–	–	–	0.150	(0.054 to 0.246)	0.002	−1.961	(−2.948 to −0.974)	<0.001
Child weight status	−0.021	(−0.035 to −0.006)	0.005	−0.150	(−0.217 to −0.082)	<0.001	0.764	(0.071 to 1.456)	0.031
Maternal age	–	–	–	–	–	–	0.550	(0.107 to 0.992)	0.015
Child perceived interest in physically active play	0.041	(0.025 to 0.058)	<0.001	0.228	(0.149 to 0.306)	<0.001	−2.371	(−3.175 to −1.567)	<0.001
Child active commuting to school	0.012	(0.005 to 0.018)	0.001	0.052	(0.020 to 0.085)	0.001	−0.600	(−0.929 to −0.272)	<0.001
Modelling behaviour	–	–	–	–	–	–	1.025	(0.133 to 1.917)	0.025
Season	0.046	(0.033 to 0.058)	<0.001	0.147	(0.087 to 0.208)	<0.001	−2.296	(−2.907 to −1.684)	<0.001
(Constant)	2.579	(2.508 to 2.650)		0.642	(0.304 to 0.980)		89.214	(84.733 to 93.695)	
Adjusted R^2			18.1%			17.8%			24.0%

physical activity.[25] As our data on correlates of objectively measured sedentary behaviour are novel, comparison is made with a study from the USA, which made subjective measures of sedentary behaviour.[20] They identified correlates of subjectively measured sedentary time that were different to those of physical activity,[20] and tended to be non-modifiable, socio-demographic factors such as low maternal education or lower family income,[20] neither of which were in the final model in our analyses. Correlates of both sedentary behaviour and physical activity are likely to differ between such varied geographic regions, as well as potential differences between studies which use different approaches to the measurement of physical activity.

The present study is consistent with many recent studies of objectively measured physical activity in finding that gender was significantly associated with both physical activity (MVPA) and sedentary behaviour. The finding that SES was not significantly associated with habitual physical activity supports recent evidence from all of the objective measurement studies in the UK: all four studies to date, which all used accelerometry, have found no marked differences in total volume of physical activity between socio-economic groups in UK children and adolescents.[25] Socio-economic differences in physical activity in UK children and adolescents in the 'expected' direction (lower physical activity in lower SES groups) has been observed in studies using subjective methods only[25] and it is likely that such variation is not real, but arises from biases inherent in subjective methodology. Seasonality in objectively measured physical activity is understudied, and probably varies markedly by geographic location, but in the UK similar seasonal variations have been shown: increased physical activity during summer months has been reported in both younger and older British children than those studied here.[3,36] The present study therefore supports the hypothesis that there are a few core influences (e.g. gender, seasonality) on objectively measured physical activity in the UK which are consistent in their associations across a wide age range from preschool to adolescence.[3,25,36] Active commuting to school was shown to be strongly associated with increased overall physical activity and MVPA (and decreased sedentary behaviour) in the present study. This lends further support to existing evidence regarding children who walk or cycle to school[37] and emphasizes the potential value of active commuting as a potential target of future interventions.

The principal strengths of the present study were: the recruitment of a sample which was socio-economically representative of North East England;[24] the use of validated objective measurements; the inclusion of three constructs (two of physical activity, plus sedentary behaviour); the inclusion of a large number of potential correlates across all domains in the social-ecological model; the relatively large and homogenous (narrow age range; almost exclusively from the majority ethnic group) sample.

The present study was designed prospectively with a number of aims; one of these was to examine the correlates of habitual physical activity and sedentary behaviour in childhood. There are limitations to the present study, in that it was cross-sectional in design, and thus can make no firm claims regarding the causal nature of relationships observed. Generalisability of study findings to other settings or other age groups is unclear and requires further study, but as noted above some correlates do appear to be consistently associated with objectively measured volume of physical activity across a wide paediatric age range in the UK, and others do not (e.g. SES). One limitation of the present study was the inability to examine whether correlates of physical activity differed by subgroup. Exploratory analyses of differences in associations between subgroups (defined by

weight status and by gender) were undertaken, but these were probably underpowered. Future larger studies might consider whether associations between exposure and outcome variables vary between subgroups within the population. Practical constraints meant that it was not possible to measure all of the potential correlates of physical activity and sedentary behaviour: correlates which are identified in any study may depend on the precise construct of sedentary behaviour which is being measured. In the present study, sedentary behaviour was defined as time spent with no trunk movement.[26,34] As previously mentioned, family size may explain the impact of maternal age on sedentary behaviour and would be a valuable inclusion in future analyses. For future studies of determinants of physical activity and sedentary behaviour there is also value in analysing the data more comprehensively, according to a social ecological approach, as discussed by Spence and Lee,[38] but this type of approach was beyond the scope of this manuscript. Future follow-up of the cohort will allow us to track the children and see how the correlates of physical activity and sedentary behaviour change, for example, as interest in active play declines, or weight status changes.

Conclusions

The present study identified a number of correlates of physical activity and sedentary behaviour in English children. Four variables were associated with both habitual physical activity and sedentary behaviour (child's weight status, child's-perceived interest in active play, child's active commuting to school and season). Future interventions aimed at increasing physical activity, and decreasing sedentary behaviour, in mid-childhood should be informed by the evidence of the present study.

Supplementary data

Supplementary data are available at *EURPUB* online.

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Conflicts of interest: None declared.

Key points

- Some factors influence both physical activity and sedentary behaviour among children—four were conserved across all three constructs.
- Several modifiable or potentially modifiable correlates were identified which will help to identify children most at risk of high levels of sedentary behaviour.
- Public health professionals could use the correlates identified by the present study to design interventions to increase physical activity and reduce sedentary behaviours in children.

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