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Correlates of intensity-specific physical activity in children aged 9–11 years: a multilevel analysis of UK data from the International Study of Childhood Obesity, Lifestyle and the Environment

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ABSTRACT

Objectives Physical activity (PA) can provide numerous physical and psychological health gains, yet a low proportion of children in England are sufficiently active to accrue benefit. Analysing the correlates of PA from a socioecological perspective may help to identify factors that promote versus discourage PA. The purpose of the present study was to: (1) assess the relationships between a wide range of potential correlates and intensity-specific PA and (2) explore which correlates are associated with meeting government PA guidelines.

Design, setting and participants Cross-sectional study on children aged 9–11 years from the South West of England (n=425; 183 males).

Outcome measures A mixture of self-reported and objective measures (eg, body mass index (BMI), accelerometer-derived PA, self-reported sport participation, etc) were collected from child participants, parents and school teachers. After adjusting for covariates (ie, age, sex and accelerometer wear time), multilevel modelling techniques were employed to examine the relationships between potential correlates and light-intensity, moderate-intensity and vigorous-intensity PA, as measured with an ActiGraph GT3X+ accelerometer. Generalised linear mixed modelling was used to analyse the correlates associated with government-recommended levels of PA.

Results Computer use shared a negative association whereas parent support for PA showed a positive relationship with light-intensity PA. In terms of moderate-intensity PA, computer use and BMI z-score shared a negative association whereas positive relationships were found for sport participation, active transport and for outdoor time after school. Children at schools with 25%–49% of pupils attending school sport/PA clubs did more moderate-intensity PA than those attending schools with lower participation rates. For vigorous-intensity PA, a negative relationship was observed for BMI z-score, and positive associations for self-efficacy, active transport, parent support and the presence of crossing guards on routes to school. Correlates associated with meeting the PA guidelines were BMI z-score (negative), sport participation, active transport and outdoor time after school (all positive).

Conclusion Results demonstrate that factors pertaining to the individual, home and school environment may play an important role in understanding the correlates of differing PA intensities in children.

Trial registration number NCT01722500.

Strengths and limitations of this study

- ► Objective measures of physical activity were employed, and data were simultaneously collected from multiple levels of influence.
- ► This study is limited by its cross-sectional design, and as such the direction of causality cannot be inferred.
- ► Data were collected from the South West region of the UK, and the majority of participants were white British which may limit the generalisability of our findings.

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INTRODUCTION

Physical activity (PA) is essential for healthy development in children and youth as it provides a number of physiological and psychological health benefits.[1] Evidence supports the notion that PA is associated with a lower risk of obesity[2–4] and clustered risk factors for cardiovascular disease.[5 6] Further, PA can improve bone mineral density,[7] and enhance emotional health and cognitive functioning in children and youth.[8 9] It is therefore concerning that PA levels in England are critically low, with 79% of boys and 84% of girls (aged 5–15 years) not meeting the UK guidelines[10] of 60 min moderate-to-vigorous PA (MVPA) per day.[11]

Exploring the correlates of PA, and particularly those that are potentially modifiable, is necessary to aid our understanding of how to increase PA levels among children.[12]

Yet, this area of research is complex given the number of settings likely to influence children's PA behaviour (eg, home, school and neighbourhood environments), as illustrated by socioecological model approaches.[13] It is therefore important to consider a wide range of correlates from multiple domains, given that focusing on a single domain may give rise to inaccurate conclusions.[12] Despite this, there is a lack of studies simultaneously exploring a range of potential correlates from multiple domains.[14]

There has also been a lack of specificity in terms of how PA is defined. For example, measures of total PA[15] or self-reported leisure time PA[16] have typically been explored. Such approaches can contribute to a loss of important information given that PA consists of different behaviours. Accordingly, Atkin *et al*[17] have called for a more contextual approach on correlates of particular PA behaviours in order to improve future intervention design. However, PA also requires different levels of exertion, and greater health benefits may be gleaned from more intense PA.[7] Yet, light PA contributes the most to overall PA levels and could appeal more to inactive children looking to become physically active.[18] It is therefore important from both a research and applied perspective (eg, shaping health-enhancing interventions that are tailored to specific groups) to explore how correlates differ for specific intensities of PA. Furthermore, examining correlates that are associated with government-recommended levels of MVPA will aid our understanding of the typical behaviours and mediators that ought to be targeted in order to increase compliance with these guidelines.

There were two purposes to the present study. First, to analyse the correlates of objectively measured intensity-specific PA: namely, light-intensity PA (LPA), moderate-intensity PA (MPA) and vigorous-intensity activity (VPA), across several domains of the socioecological model in a sample of children aged 9–11 years. Second, to explore which correlates are associated with meeting the MVPA guidelines.

METHODS

Study design

UK-specific data from the International Study of Childhood Obesity, Lifestyle and the Environment (ISCOLE) were analysed. A detailed account of the methodology employed within ISCOLE has been provided elsewhere.[19] Children aged 9–11 years were recruited from schools in Bath and North East Somerset and West Wiltshire. A target sample size of 500 children was set based on a power calculation described by Katzmarzyk *et al*.[19] Data collection took place during term time from September 2011 to January 2013. Informed parental consent and child assent were obtained from all participants. Data collection for the UK site of ISCOLE received ethical approval from the University of Bath 'Research Ethics Approval Committee for Health'.

Outcome variables

Each participant wore an ActiGraph GT3X+ accelerometer (ActiGraph, Pensacola, Florida, USA) attached to an elastic belt, on the right hip, for up to seven full days.[19] A 24-hour monitoring protocol was implemented in order to improve compliance; thus, participants were encouraged to wear the monitor at all times except during water-based activities.[19 20] A detailed explanation of how the data were treated has been provided elsewhere.[20] Briefly, time spent sleeping was identified using a published fully automated algorithm,[21] and a subsequent algorithm was run to identify periods of non-wear (20 consecutive minutes of zero activity counts[22]).[20] All remaining minutes were therefore identified as waking wear time.[20] Data were considered acceptable if participants wore the device for at least 4 days including 1 weekend day and had ≥10 hours of waking wear time per day.[20] Accelerometer cut-points developed by Evenson *et al*[23] were used to quantify LPA (26–573 counts/15 s), MPA (574–1002 counts/15 s) and VPA (≥1003 counts/15 s) as these are recommended over other cut-points.[24] For the second objective, participants were classified as 'meeting the MVPA guidelines' if their mean amount of time spent in MVPA (≥574 counts/15 s[23]) per day was ≥60 min, in accordance with the UK PA recommendations.[11] Children not achieving this were classified as 'not meeting the MVPA guidelines'.

Potential correlates

As children's PA can be influenced by numerous factors as demonstrated in the socioecological model,[13] it was important to choose potential correlates carefully, while considering parsimony. Those who were chosen for this study were selected a priori based on previous research.[15 25–27] First, it was deemed important to cover several domains of the socioecological model,[13] and correlates were subsequently grouped accordingly: demographic/biological, psychological, behavioural, home and school environment factors. Second, correlates that have had indeterminate relationships in past research were included, and we chose to incorporate multiple activity-related behaviours (ie, active transport, sport participation, sedentary behaviours) given that only one or two have been assessed in isolation, in past research. A similar premise was applied to the school environmental correlates as they were chosen to reflect different PA behaviours that can be influenced by this domain (ie, sport participation, active transport and informal PA).

Demographic/biological

During a visit to the school, participants' stature was measured using a seca 213 portable stadiometer (Seca, Hamburg, Germany), and their body mass was measured using a portable Tanita SC-240 Body Composition Analyser (TANITA, Tokyo, Japan).[19] Children were asked to remove shoes and outer clothing, and all measurements were taken by trained ISCOLE staff.[19] Each measurement was repeated twice, or three times if the first two measurements were >0.5 cm or 0.5 kg apart, and the average of the two closest measurements was used for analysis.[19] Body mass index (BMI) was calculated (body mass (kg)/height (m)^2), and their BMI *z*-score was derived using WHO growth reference data.[28]

Information was also collected from the participant's main caregiver pertaining to their sex and date of birth. Decimal age at the time of data collection was then calculated.

Psychological

A Diet and Lifestyle Questionnaire was administered to all participants. The children were asked how much they agreed/disagreed with a number of statements (eg, 'I can be physically active during my free time on most days') to measure their self-efficacy for PA, using a validated questionnaire.[29] There were eight items in total, and responses were coded on a scale of 0 (disagree a lot) to 4 (agree a lot). The mean of all items was computed to create a composite self-efficacy score. Internal consistency for the self-efficacy scale was good: Cronbach's alpha coefficient was 0.82.

Behavioural

Participants were also asked about how much time they spent in specific behaviours. First, they were asked how many hours they had spent watching television (TV) on both school and weekend days in the past week, choosing from seven options coded as: I did not watch any hours of TV (0); <1 hour (0.5); 1 hour (1); 2 hours (2); 3 hours (3); 4 hours (4); ≥5 hours (5). Using this information, a weighted mean score of TV viewing was calculated using the formula: (school day TV×5+weekend TV×2)/7. The same question was asked for computer use, including the same response options (I did not play video/computer games or use a computer other than for school work; <1 hour; 1 hour; 2 hours; 3 hours; 4 hours; ≥5 hours). Computer use across the week was also calculated using the aforementioned formula. These items were taken from the US Youth Risk Behavior Surveillance System,[30] which possess sufficient reliability and validity.[31] Second, participants were asked if they had participated in sports teams during the past year with a simple 'yes' or 'no' question. Third, questions regarding participants' active transport to school were adapted from the Canadian Health Behaviour in School-Aged Children study.[32] The children were asked how they travelled to school in the last week for the main part of their journey. The following were considered active transport modes: walking, bicycle, rollerblade, skateboard and scooter. Passive forms of transport included: bus, train, tram, underground, boat, car, motorcycle or moped.

Home environment

Parents/guardians were asked to provide information on their socioeconomic status (SES), ascertained from the combined annual income for their household (before taxes) and their highest level of education. Due to a large amount of missing data on family income, parental education was used as an indicator of SES. Data were collapsed into the following three categories: low (General Certificate of Secondary Education/equivalent, some secondary school or less); middle (A levels/equivalent); high (bachelor's degree or graduate/professional degree).

Items from the Neighborhood Impact on Kids Survey[33] were used to assess parent support. Parents/guardians were asked how often in a typical week (never, 1–2 days, 3–4 days, 5–6 days or everyday) they (1) encourage their child to do sport/PA, (2) provide transport to sports/PA clubs, (3) watch their child participate in such activity and (4) how often they do sport or PA with their child. Responses were coded on a scale of 0 (never) to 4 (everyday), and the mean score was computed. Additionally, parents were asked if their child owned a mobile phone or two-way radio/walkie-talkie with a simple 'yes' or 'no' question.

Data on outdoor time after school were collected from the children. Participants were asked 'On a school day, how much time did you spend outside after school before bedtime?' They could choose from the following options: <1 hour, 1 hour, 2 hours, 3 hours, 4 hours and ≥5 hours. Responses were coded on a scale of 0–5, and this was treated as a continuous variable.

School environment

School administrators also completed a questionnaire which included items that were adapted from the Healthy School Planner,[34] employed in the Canadian School Health Action, Planning and Evaluation System.[35] First, they were asked 'What percentage of pupils participate in school sports or PA clubs (including dance) offered by your school: Not available, <10%, 10%–24%, 25%–49%, or ≥50%'. All participating schools had these clubs on offer, and only one had <10% of pupils doing such activities. Responses for both <10% and 10%–24% were therefore collapsed into one category (≤24%). Second, school administrators were asked whether there are safe walk-to-school routes present via the following yes/no/don't know question: 'Does your school provide crossing guards at intersections to encourage safe walk-to-school routes?'; all schools responded either yes or no. Third, administrators were asked: 'How much of a problem is heavy traffic in the neighbourhood where this school is located: a major problem, moderate problem, minor problem, not a problem, don't know'. No schools selected 'don't know', thus results were collapsed into two categories: problematic (major or moderate) and not problematic (minor and not a problem).

Statistical analysis

All analyses were conducted in SAS Studio V.3.5 (SAS Institute, 2012–2016). Participants were included in the analysis if they had complete data for all potential correlates and valid accelerometry data. Descriptive statistics were computed and compared between included and excluded participants. To address the first objective, simple multilevel linear regression was conducted first to analyse associations between each independent variable and the PA outcomes (LPA, MPA and VPA) using the MIXED procedure. Age and sex were included as covariates in all models, given their consistent relationships with PA reported in the literature.[15] The mean waking wear time per day was computed and also included as a covariate, and schools were treated as random effects in all models. Variables associated with PA at P<0.10 were included in multiple multilevel linear regression models. This less-stringent criterion was used in order to avoid important variables from being excluded.[36] Variables were entered in the following order: biological and psychological, followed by behavioural, then home and finally school-level correlates. Variables with a P value >0.05 were removed before the next set of variables were entered, and if more than one was non-significant, the variable with the highest P value was removed first. This process was continued until only significant variables (P<0.05) were left; these were considered to be correlates of PA.[37] Generalised linear mixed modelling using the GLIMMIX procedure was employed to examine the second objective pertaining to which variables were associated with meeting the MVPA guidelines. In model 1, simple associations between each potential correlate and the dependent variable (ie, meeting the MVPA guidelines vs not meeting the MVPA guidelines) were conducted, adjusting for covariates only and with schools treated as random effects. In model 2, all significant variables (P<0.05) from model 1 were included, and those that remained significant in model 2 were considered to be correlates associated with meeting the MVPA guidelines. Checks for normality, multicollinearity and linearity were performed, and unless stated, no problems regarding these assumptions were identified.

RESULTS

In total, 1114 consent forms were distributed, from which 541 students consented to take part in the study (recruitment rate=49%). After withdrawals (n=8), and excluding those without complete data, the analytical sample for this study was 425 participants. Excluded participants were more likely to be male, have a higher mean BMI z-score, and have lower PA on average. The intraclass correlation revealed that approximately 23%, 18% and 6% of the variation for LPA, MPA and VPA, respectively, were explained by school-level factors, whereas 7% of the variation in being classified as meeting/not meeting the MVPA guidelines were explained at the school level. The remaining proportion of the variability in each outcome was therefore explained by individual or unknown factors. Descriptive characteristics of the analytical sample for child-level and school-level variables are provided in tables 1 and 2, respectively.

Correlates of LPA, MPA and VPA

Table 3 shows the simple associations between potential correlates and each outcome variable, adjusting for covariates. Computer use, ownership of a mobile phone (both negative), sport participation, parent support and outdoor time after school (all positive) were associated with LPA (P<0.10), and subsequently included in multiple regression analyses. As for MPA and VPA, positive relationships were found for self-efficacy, sport participation, active transport, parent support, outdoor time after school and for presence of school crossing guards, whereas a negative association was found for BMI z-score with both outcomes. In addition, computer use (negative) and the proportion of pupils attending school sport/PA clubs were related to MPA; a significant difference between the middle and lowest groups was found for the latter. No significant associations were found for TV viewing, SES or heavy traffic in the school neighbourhood for either outcome. Due to a slight positive skew in VPA (skewness=1.2), a square root transformation was applied, but the same patterns were observed. As such, results using the original scale are presented for ease of interpretation.

Results from the final models are displayed in table 4. Only computer use (negative) and parent support (positive) were associated with LPA. Computer use was also negatively associated with MPA. The other behavioural variables, sport participation and active transport, displayed significant positive relationships with MPA. A positive association was also observed between outdoor time after school and MPA. The proportion of children attending school sport/PA clubs remained significant in the multiple regression analysis for MPA. Other factors held constant, children who attended schools with 25%–49% of pupils doing sport/PA clubs did 6.0 more minutes of MPA per day than those at schools with fewer pupils participating in such activities; no significant difference was found between the highest (≥50%) and lowest (≤24%) categories. In contrast, BMI z-score was negatively associated with MPA, and the same relationship was observed for VPA. Whereas, self-efficacy, parent support and the presence of school crossing guards were positively associated with VPA. Active transport was also included in the model for VPA given that it verged on significance (P=0.050), and because this variable was significantly associated with the transformed data (P=0.029) in the same direction (positive). No differences in the results were found whether this variable was included or excluded from the model, and all other results for the transformed data followed the same patterns (ie, providing confidence in the raw metric of the data).

The analyses were repeated using the Treuth cut-points[38] as a sensitivity analysis. The same results were found for LPA for both the unadjusted and final multiple regression models. The same results were found for MPA in the unadjusted analysis. Results for the final model differed in that computer use and outdoor time after school were removed, though the latter approached significance (P=0.066), whereas self-efficacy and the presence of school crossing guards were included, and relationships were in expected directions. All other correlates (ie, BMI z-score,

Table 1 Descriptive characteristics of the analytical sample for all child-level variables (n=425)

Variable	Mean (SD) or n (%) Total	Boys	Girls
Demographic/biological			
Age (years)	10.9 (0.4)	10.9 (0.4)	10.9 (0.5)
Sex (% male)	183 (43.1)	–	–
BMI z-score*	0.4 (1.1)	0.4 (1.0)	0.4 (1.1)
Psychological			
Self-efficacy score (0–4)†	2.5 (0.8)	2.5 (0.8)	2.5 (0.8)
Behavioural			
TV viewing (hours/day)	1.8 (1.0)	1.8 (1.1)	1.7 (1.0)
Computer use (hours/day)	1.2 (1.1)	1.6 (1.2)	0.9 (0.8)
Sport participation (% yes)	292 (68.7)	144 (78.7)	148 (61.2)
Transport mode to school (% active)	276 (64.9)	121 (66.1)	155 (64.1)
Home environment			
SES (highest parental education level)			
University degree	199 (46.8)	93 (50.8)	106 (43.8)
A levels or equivalent	105 (24.7)	47 (25.7)	58 (24.0)
GCSEs or less	121 (28.5)	43 (23.5)	78 (32.2)
Parent support score (0–4)†	1.6 (0.8)	1.6 (0.7)	1.6 (0.8)
Ownership of a mobile phone (% yes)	243 (57.2)	86 (47.0)	157 (64.9)
Outdoor time after school (hours/day)	1.7 (1.3)	1.7 (1.3)	1.7 (1.4)
Outcome variables			
LPA (min/day)	286.3 (45.2)	285.5 (43.3)	286.9 (46.7)
MPA (min/day)	43.3 (13.0)	48.0 (13.9)	39.8 (11.0)
VPA (min/day)	20.9 (11.5)	26.1 (12.6)	17.0 (8.7)
Meeting the MVPA guidelines (% yes)‡	224 (52.7)	131 (71.6)	93 (38.4)
Mean accelerometer waking wear time (min/day)	845.7 (49.7)	853.5 (50.3)	839.7 (48.4)

*BMI z-score was derived from WHO growth reference data.[28]
†Higher scores denote greater levels of self-efficacy and parent support.
‡% of children with a mean of at least 60 min of MVPA per day.[11]
BMI, body mass index; GCSE, General Certificate of Secondary Education; LPA, light-intensity physical activity; MPA, moderate-intensity physical activity; MVPA, moderate-to-vigorous physical activity; SES, socioeconomic status; TV, television; VPA, vigorous-intensity physical activity.

sport participation, active transport and the proportion of pupils attending school sport/PA clubs) remained significant in the final model. As for VPA, only self-efficacy and parent support were included in final models, and BMI z-score approached significance (P=0.057). The differences in results compared with the Evenson cut-points are likely because the mean levels of MPA (26.8 min/day) and VPA (4.7 min/day) were much lower according to the Treuth cut-points, whereas the mean amount of LPA recorded per day was higher (412.2 min/day).

Table 2 Descriptive characteristics of the school-level variables (n=26)

Variable	n (%)
Proportion of pupils attending school sport/physical-activity clubs	
≤24%	8 (30.8)
25%–49%	10 (38.5)
≥50%	8 (30.8)
Presence of crossing guards on routes to school (% yes)	15 (57.7)
Heavy traffic in school neighbourhood (% problematic)	17 (65.4)

Correlates associated with meeting the MVPA guidelines

As shown in table 5, BMI z-score (negative), and self-efficacy, sport participation, active transport, parent support and outdoor time after school (all positive) displayed a significant relationship in model 1. All these variables were included in model 2. A higher BMI z-score was associated with reduced odds of being classified as active whereas more time spent outdoors after school was associated with increased odds of meeting the MVPA guidelines. Children who engaged in sport participation and

Table 3 Simple associations between potential correlates and intensity-specific physical activity (LPA, MPA, VPA), adjusting for age, sex and mean accelerometer wear time: β-coefficients and 95% CIs (n=425)

	LPA (min/day)		MPA (min/day)		VPA (min/day)	
	β (95% CI)	P value	β (95% CI)	P value	β (95% CI)	P value
BMI z-score	0.52 (–2.88 to 3.92)	0.764	–1.52 (–2.51 to –0.53)	**0.003**	–1.99 (–2.89 to –1.08)	**<0.0001**
Self-efficacy (0–4)*	1.63 (–3.25 to 6.50)	0.513	2.91 (1.51 to 4.31)	**<0.0001**	2.85 (1.57 to 4.14)	**<0.0001**
TV viewing (hours/day)	1.93 (–1.61 to 5.46)	0.284	–0.28 (–1.32 to 0.75)	0.590	–0.09 (–1.05 to 0.87)	0.854
Computer use (hours/day)	–4.83 (–8.58 to –1.09)	**0.012**	–1.48 (–2.58 to –0.38)	**0.008**	–0.54 (–1.55 to 0.48)	0.301
Sport participation (ref=no sport)	7.51 (–0.45 to 15.47)	**0.064**	3.47 (1.15 to 5.79)	**0.004**	2.64 (0.48 to 4.80)	**0.017**
Active transport (ref=passive transport)	–6.05 (–14.01 to 1.91)	0.136	5.62 (3.34 to 7.90)	**<0.0001**	2.42 (0.30 to 4.55)	**0.025**
SES (parental education level)						
University degree	Ref	0.422	Ref	0.635	Ref	0.343
A levels	6.15 (–3.05 to 15.34)	0.189	–0.39 (–3.09 to 2.32)	0.779	–0.48 (–2.97 to 2.00)	0.703
GCSEs or less	2.71 (–6.58 to 11.99)	0.567	1.00 (–1.72 to 3.73)	0.470	1.45 (–1.02 to 3.92)	0.249
Parent support (0–4)*	6.24 (1.67 to 10.81)	**0.008**	1.94 (0.60 to 3.28)	**0.005**	1.80 (0.55 to 3.04)	**0.005**
Ownership of a mobile phone (ref=no mobile)	–7.95 (–16.12 to 0.21)	**0.056**	–1.65 (–4.05 to 0.76)	0.179	–1.80 (–3.98 to 0.39)	0.107
Outdoor time after school (hours/day)	2.66 (–0.11 to 5.42)	**0.060**	1.53 (0.73 to 2.33)	**0.000**	0.79 (0.05 to 1.53)	**0.038**
Proportion of pupils attending school sport/PA clubs						
≤24%	Ref	0.740	Ref	**0.008**	Ref	0.224
25%–49%	5.64 (–18.12 to 29.39)	0.641	6.18 (0.63 to 11.73)	**0.029**	1.88 (–1.85 to 5.62)	0.322
≥50%	–3.69 (–29.18 to 21.81)	0.776	–2.36 (–8.38 to 3.66)	0.441	–1.50 (–5.66 to 2.66)	0.479
Presence of school crossing guards (ref=none)	–8.23 (–27.80 to 11.33)	0.409	5.60 (0.47 to 10.72)	**0.032**	3.63 (0.52 to 6.75)	**0.023**
Heavy traffic around school (ref=not a problem)	–4.76 (–25.20 to 15.68)	0.647	–0.96 (–6.65 to 4.73)	0.740	–1.99 (–5.26 to 1.27)	0.231

Schools were treated as random effects in all models.
Bold font indicates significant results (P<0.10).
*Higher scores denote greater levels of self-efficacy and parent support.
BMI, body mass index; GCSE, General Certificate of Secondary Education; LPA, light-intensity physical activity; MPA, moderate-intensity physical activity; PA, physical activity; ref, reference category; SES, socioeconomic status; TV, television; VPA, vigorous-intensity physical activity.

active transport were 1.73 and 2.38 times more likely to be sufficiently active, respectively, than those who did not. The relationships for self-efficacy and parent support were no longer significant in model 2.

Only self-efficacy was significantly associated with meeting the MVPA guidelines according to the Treuth cut-points. However, only 7.8% of participants were classified as meeting the MVPA guidelines using these cut-points which could explain the lack of significant findings compared with the main analysis using the Evenson cut-points.

DISCUSSION

The aims of this paper were (1) to explore correlates of intensity-specific PA and (2) to analyse correlates associated with meeting the MVPA guidelines. Potential correlates from multiple domains of the socioecological model were chosen to provide a broader indication of the correlates associated with different intensities of children's PA.

Computer use was negatively associated with lighter-intensity PA (LPA and MPA) in the current study, while TV viewing was not significantly associated with any of the PA outcomes. According to a recent meta-analysis, evidence that sedentary behaviour displaces PA is weak, and the two may instead coexist.[39] Specific sedentary behaviours were assessed, and a significant negative, although small, relationship was found between TV viewing and PA, whereas computer use was not significantly associated with PA.[39] These findings contrast with our results which could be due to differences in the study populations that were assessed, but another possible explanation for these differences is that the authors pooled together all PA outcomes and did not distinguish between specific PA intensities.[39] In another meta-analysis, TV viewing displayed a significant negative relationship with VPA but this association disappeared when computer use was

Table 4 Final models showing correlates of LPA, MPA and VPA: β-coefficients and 95% CIs

	β (95% CI)	P value
LPA (min/day)		
Computer use (hours/day)	−4.31 (−8.06 to −0.57)	0.024
Parent support (0–4)*	5.65 (1.07 to 10.22)	0.016
MPA (min/day)		
BMI z-score	−1.35 (−2.28 to −0.42)	0.005
Computer use (hours/day)	−1.22 (−2.28 to −0.15)	0.025
Sport participation (ref=no sport)	2.97 (0.73 to 5.21)	0.009
Active transport (ref=passive transport)	5.63 (3.44 to 7.81)	<0.0001
Outdoor time after school (hours/day)	1.55 (0.79 to 2.30)	<0.0001
Proportion of pupils attending school sport/PA clubs		
≤24%	Ref	0.006
25%–49%	5.97 (0.53 to 11.41)	0.032
≥50%	−2.75 (−8.65 to 3.16)	0.361
VPA (min/day)		
BMI z-score	−1.60 (−2.51 to −0.69)	0.001
Self-efficacy (0–4)*	1.89 (0.56 to 3.22)	0.006
Active transport (ref=passive transport)	2.05 (0.00 to 4.10)	0.050
Parent support (0–4)*	1.36 (0.12 to 2.60)	0.032
Presence of school crossing guards (ref=none)	3.21 (0.34 to 6.07)	0.028

All models were adjusted for age, sex and mean accelerometer wear time, with schools treated as random effects.
*Higher scores represent greater self-efficacy and parent support.
BMI, body mass index; LPA, light-intensity physical activity; MPA, moderate-intensity physical activity; PA, physical activity; ref, reference category; VPA, vigorous-intensity physical activity.

added to form a composite measure of screen time.[40] Taken together, it is possible that there may be contrasting effects for different screen-based behaviours depending on how they are defined and according to the type or intensity of PA in question. Further research is needed to gain a better understanding of these differences and to explore the role of other sedentary pursuits in relation to children's PA, given the increased use of new screen-based leisure technologies.[41]

The activity-related behaviours of sport participation and active transport were both positively associated with PA of at least a moderate intensity. Evidence from other research has shown that both sport participation and active transport can make a significant contribution to children's MVPA,[42–47] but for active transport, the further the distance travelled, the greater the contribution.[45 48] A significant positive relationship was also observed for time spent outdoors after school with MPA and compliance with the MVPA guidelines. This finding concurs with a review[49] and a UK study[50]; the latter reporting that children who spent longer outdoors were more active than those residing indoors, as measured by GPS) technology.[50] There is arguably more space outside and subsequently a greater opportunity for higher intensity activity, whereas more opportunities to engage in sedentary-based pursuits are available inside the home.[49] Encouraging more time outdoors or promoting participation in at least one specific PA behaviour (eg, active transport or sport participation) could provide benefits, given that each behaviour was independently associated with meeting the MVPA guidelines.

BMI z-score was negatively associated with MPA, VPA and meeting the MVPA guidelines. These findings are consistent with the negative relationship between MVPA and markers of adiposity generally reported.[2 3 25 51–53] However, a review of reviews reported an inconsistent relationship between BMI and PA among children.[15] While some studies report no association between total PA and BMI,[52 54] others have found a negative relationship.[3 53] Previous research suggests this inconsistency could partly be due to a different association between BMI and LPA than with total PA (ie, positive for LPA vs negative for total PA).[53] Abbott and Davies[55] suggested that there may be an intensity threshold required for a significant reduction in body composition to take place. These findings provide support for the benefits of higher intensity PA in relation to adiposity, but strategies aimed at increasing such PA among those with an unhealthy body weight are needed. This is particularly important given that reverse causality may be at play, in that children with excess body weight may find it difficult to undertake PA of a high intensity.

Self-efficacy was also associated with MPA, VPA and meeting the MVPA guidelines in the simple models, but in the multiple regression analysis it remained

Table 5 Correlates associated with meeting the MVPA guidelines (≥60 min of MVPA per day): OR and 95% CIs

	Model 1, OR (95% CI)	Model 2, OR (95% CI)
BMI z-score	0.71 (0.58 to 0.87)*	0.71 (0.57 to 0.88)*
Self-efficacy (0–4)†	1.49 (1.12 to 1.98)*	1.06 (0.77 to 1.46)
TV viewing (hours/day)	0.90 (0.74 to 1.11)	
Computer use (hours/day)	0.86 (0.69 to 1.07)	
Sport participation (ref=no sport)	1.75 (1.10 to 2.79)*	1.73 (1.04 to 2.88)*
Active transport (ref=passive transport)	2.22 (1.40 to 3.52)*	2.38 (1.46 to 3.87)*
SES (parental education level)		
University degree	Ref	
A levels/equivalent	1.12 (0.66 to 1.90)	
GCSEs or less	1.49 (0.88 to 2.54)	
Parent support (0–4)†	1.40 (1.06 to 1.83)*	1.22 (0.90 to 1.64)
Ownership of a mobile phone (ref=no mobile)	0.89 (0.56 to 1.41)	
Outdoor time after school (hours/day)	1.32 (1.12 to 1.56)*	1.32 (1.11 to 1.58)*
Proportion of pupils attending school sport/PA clubs		
≤24%	Ref	
25%–49%	1.21 (0.55 to 2.67)	
≥50%	0.60 (0.25 to 1.46)	
Presence of school crossing guards (ref=none)	1.90 (0.95 to 3.79)	
Heavy traffic around school (ref=not a problem)	0.71 (0.35 to 1.41)	

OR for continuous variables are expressed as a one unit increase from the mean.
Model 1=adjusted for age, sex and mean accelerometer wear time, with schools treated as random effects.
Model 2=mutually adjusted model with significant correlates from model 1 entered simultaneously, adjusting for covariates (age, sex, mean accelerometer wear time) and schools treated as random effects.
*P<0.05.
†Higher scores denote greater levels of self-efficacy and parent support.
BMI, body mass index; GCSE, General Certificate of Secondary Education; MVPA, moderate-to-vigorous intensity physical activity; PA, physical activity; ref, reference category; SES, socioeconomic status; TV, television.

significantly positively associated with VPA only. Such a finding concurs with past work showing a positive relationship between self-efficacy and VPA and no relationship with MPA.[56 57] However, both studies are dated with more recent research reporting positive relationships between self-efficacy and MVPA.[58–60] It is unclear as to why self-efficacy was not associated with MPA or the MVPA guidelines in our study, yet it is pertinent to refer to Bandura's self-efficacy theory,[61] which hypothesises that an individual's perception of his/her ability to undertake an activity will govern his/her persistence during times of difficulty. As VPA requires more physical exertion than MPA, it may be that a higher level of perceived self-efficacy is warranted to execute activities of this kind. Given the potentially superior benefits associated with VPA,[7] intervention efforts which aim to enhance perceptions of self-efficacy, particularly for strenuous activity, might therefore be important. Such efforts will likely require a steady increase in the intensity of the activity and opportunities for children to engage in fun and enjoyable PA with others of similar ability.

Parent support was positively associated with all outcomes in the simple models, but in the mutually adjusted models it only remained a significant correlate of both LPA and VPA. Reasons for this are unclear, yet parent support was identified as a consistent correlate of PA in a review of reviews,[26] and it may mediate positive associations between parent's and children's activity levels.[62] It is worth noting that parent support has previously been associated with organised PA, not free-time PA,[63] and the items used in our study may have been more relevant to organised activities, such as sport. Future research would do well to explore specific types of PA as well as intensity-specific PA. Furthermore, it is possible that some of the other variables included in the multiple regression analyses, such as sport participation, likely play a role in the causal pathway between parent support and PA. Nevertheless, encouraging parents to support their children's PA in general, by facilitating active transport to school and participation in sport/PA clubs, as well as allowing informal PA outdoors in the neighbourhood, should be a key focus of future intervention efforts.

School environmental variables were also analysed. A positive relationship between the presence of crossing-guards on routes to school and VPA was found. Those who went to schools where this was in place did approximately three more minutes of VPA than those attending schools without such a policy, holding other variables constant. This may simply be due to a higher number of children actively commuting to school where crossing-guards are provided. Alternatively, it may be that schools that have this in place may have other strategies and policies which support PA at school, thus promoting an increase in VPA overall. Despite this, the specific reasons for such a finding are unknown, and further work is needed to explore this in more detail. In a study of school-level correlates among children aged 9–10 years from Norfolk, having a school crossing guard was positively associated with MPA.[27] In their study, 40.7% of schools had this in place,[27] whereas 57.7% of schools did so in our work. As such, there are still a number of schools which do not provide crossing guards, and we agree with the authors that such a strategy may be worth implementing and evaluating at schools where this is currently not in place.[27]

While controlling for other correlates in the model, children who went to schools with 25%–49% of pupils attending PA/sport clubs did approximately six more minutes of MPA than those at schools with fewer students engaging in such activity. Schools with higher levels of sport participation rates might have a positive ethos towards PA, which could explain their higher activity levels because the more children taking part, the more likely that their friends will join in as well. Indeed, past work has shown children tend to have similar PA levels to that of their school peer groups.[64] However, this does not explain why there was no significant difference between the lowest and highest categories (ie, ≤24% vs ≥50%). It is plausible that schools with high participation rates may struggle to provide time spent in actual PA for all children if there is inadequate space, coaching provision or time to cater for the larger number of pupils taking part. Consequently, other environmental factors such as school size, provision of facilities and available space may have interacting effects, and further research is required to delve into the specific relationships at play.

The use of objectively measured PA is a major strength of this study, providing a more robust assessment than self-reported measures. However, accelerometers do not capture cycling adequately nor water-based PA such as swimming. Data on such behaviours were not collected so as to avoid participant burden; consequently, children's PA may have been underestimated in this study. Although intensity-specific PA was analysed, which provides new information beyond total PA alone, we realise that each outcome was based on mean daily values. This does not provide specific contextual information on the PA type or time when PA is undertaken. Furthermore, as we used the mean value of children achieving at least 60 min of MVPA per day as a method for classifying those who were meeting the MVPA guidelines, it is likely that some of these participants will not have been achieving this amount of MVPA on all 7 days of the week as stipulated within the UK PA guidelines.[11] However, given that objective estimates of children's PA typically show that very few are meeting these guidelines (eg, only 9% of boys and 2% of girls recorded at least 60 min of MVPA on all valid days that were measured in the International Children's Accelerometry Database study[65]), it can be argued that using mean values allow appropriate analysis to be performed while still capturing those who are likely the most active, versus the least active children within the sample. Another limitation associated with accelerometry data is that different results can be found depending on the choice of cut-points used to assess PA, as shown in the current study. We recommend focusing on the main results using the Evenson cut-points[23] based on the work conducted by Trost *et al*,[24] but wide consensus regarding which cut-points to use in the literature is needed.

It is also important to note that some of the self-reported measures employed in this study have not been validated. For example, the item measuring time spent outdoors after school was developed by the ISCOLE team,[19] and this is also likely to vary according to the time of year (ie, the season) when data were collected. Yet, we did not adjust for seasonal differences in the current study. In addition, the direction of causality cannot be inferred due to the cross-sectional study design, and the majority of participants were white British, so it was not possible to assess the role of ethnicity, and our findings may not generalise to other regions of the UK. Previous research has shown that PA levels may differ according to both children's sex and weight status, involving some interesting interactions.[66] It was beyond the scope of the current study to explore interactions or differences by sex, and this is an area that requires further research. However, we recommend that others follow the guidelines provided by Atkin *et al*[17] in relation to testing interactions by demographic factors, such as sex, when assessing potential correlates of PA. Although a power calculation was performed for the ISCOLE study as a whole, no formal power calculation was carried out for this particular study. As such, we cannot be certain if this study was adequately powered and given that a number of statistical tests have been performed, it is possible that some of our findings may have been due to chance.

In conclusion, a number of correlates from multiple domains were associated with PA, and it would appear that some may only apply to specific intensities (eg, computer use and self-efficacy), though more research is required to confirm this. According to the results of our study, interventions which promote physically active behaviours such as sport, active transport and outdoor time after school may help to promote compliance with PA guidelines, and particular attention for children with an unhealthy body weight is needed. Interventions targeting this group of children that aim to address any barriers they may face with regard to PA participation (eg, weight-related fears and low perceived competence) need to be addressed. Multicomponent interventions which involve both schools and the home environment that incorporate simple changes, including the provision of school crossing guards or raising parent's awareness on how they can support their children's PA, may prove effective.

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