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Childhood predictors of adolescent behaviour: The prospective association of familial factors with meeting physical activity guidelines

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There were no competing interests arising from this study.

Abstract

Little is known about the longitudinal association of familial socio-demographic factors, behaviours, attitudes, or home environment with meeting physical activity guidelines. Our objective was to a) describe 4-year change in the prevalence of meeting guidelines, and characteristics of participants across categories of physical activity maintenance, and b) identify familial factors in childhood that are longitudinally associated with meeting guidelines in adolescence.

Data on 17 parent- and child-reported family variables and objectively measured physical activity (ActiGraph GT1M) were available from 406 children (10.3±0.3 years, 53.5% female) participating in the SPEEDY study. Average duration of week- and weekend day moderate-to-vigorous physical activity (MVPA, ≥2000 counts/min) at baseline and follow-up (14.3±0.3 years) were calculated to determine whether participants met 60min MVPA/day guidelines at each assessment. Descriptives were calculated across four MVPA change categories. Multi-level logistic regression examined the association of baseline familial factors with meeting guidelines at follow-up, adjusting for sex, baseline physical activity, family socio-economic position and school clustering.

At follow-up, 51.5% and 36.1% of adolescents met guidelines on weekdays and weekend days, respectively (baseline: 68.0%, 67.2%). Girls were less likely than boys to remain sufficiently active, particularly on weekdays. Family social support was positively associated with adolescents meeting guidelines at weekends (OR 1.2; 95%CI 1.0–1.4). The presence of play equipment at home was negatively associated with meeting guidelines on weekdays (OR 0.5; 95%CI 0.3–0.8).

Interventions that foster parent's facilitation of physical activity may help to encourage the upkeep of healthy behaviours during the transition from childhood to adolescence.

Keywords: Physical activity, family, home environment, longitudinal, predictors, maintenance

Background

The World Health Organisation cites inactivity as the fourth leading risk factor for global mortality.[1] In children, physical activity is associated with improved cardiovascular risk factors,[2] anthropometric indicators (particularly body composition, waist circumference and fat mass)[3,4] and bone health.[5] It is also suggested that regular engagement in physical activity is beneficial for young people's mental health and self-esteem, and for improved cognitive performance and scholastic achievement.[6–8] However, data from several countries suggest that the majority of children are insufficiently active to confer such health benefits.[9,10] Understanding the modifiable influences of physical activity in young people is therefore a public health priority.

The family, as the primary unit of socialisation during childhood, is central in shaping engagement in health behaviours, including physical activity.[11,12] There is substantial evidence that parenting behaviours and family processes also play a critical role in adolescent well-being.[13] Familial factors, such as logistical support (e.g. provision of transport or covering cost), co-participation, or encouragement, have been consistently and positively correlated with physical activity in children and adolescents.[14,15] For example, a recent meta-analysis demonstrated a moderate-sized positive, cross-sectional association between parental modelling and child physical activity (especially pertinent for fathers and sons).[16] However, the reliance upon cross-sectional data in this review and within the evidence base more broadly is a key limitation that hinders our capacity to draw causal inferences. Longitudinal studies are required to better characterise familial and home influences on changes in children's activity with age. This is especially important given that levels of physical activity decline substantially throughout childhood and into adolescence.[17,18]

In keeping with the socio-ecological model,[19] influences on behaviour may be location and time-specific. Evidence suggests that declines in physical activity during late childhood are not evenly spread across the day and week, with larger decreases observed on weekend days[20] and during leisure time on weekdays.[21] Previous work in the SPEEDY (Sport, Physical activity and Eating behaviour: Environmental Determinants in Young people) cohort, also analysed here, indicated that family support was associated with 1-year change in physical activity at weekends, but not weekdays.[22] In contrast, peer support was only associated with change in weekday physical activity. As this has implications for intervention design, stratification of analyses by week- and weekend-day is pertinent to inform context-specific intervention strategies.

The objectives of the current study are therefore to:

a) Describe 4-year change in the prevalence of meeting guidelines over the transition from primary to secondary school, and demographic characteristics of participants across four categories of physical activity maintenance:

(1) Maintained below physical activity guidelines

(2) Maintained above physical activity guidelines

(3) Decreased from above to below physical activity guidelines

(4) Increased from below to above physical activity guidelines;

b) Identify family factors in childhood that are longitudinally associated with meeting physical activity guidelines at week and weekend days in adolescence.

Methods

Study design and participants

The SPEEDY study was conducted in Norfolk (UK) to examine individual and collective factors associated with (changes in) physical activity and dietary behaviour in schoolchildren. Ethical approval was obtained from the University of East Anglia Faculty of Health Ethics Committee. The longitudinal analyses presented here use data collected between April and July 2007 (SPEEDY-1), and May and July 2011 (SPEEDY-3). Full details on participant recruitment, study procedures and sample representativeness for the wider SPEEDY study have been described elsewhere.[23] Briefly, at baseline primary schools in Norfolk were purposively sampled to achieve heterogeneity in urban and rural locations; 92/157 schools approached participated in measurement sessions. All Year 5 children (aged 9-10 year, N=3619) at participating schools were invited to participate; parents of 2064 children provided written informed consent (57% response rate) at baseline. Participants with an active postal address (and who had not withdrawn from the study) were contacted four years later (Year 9; aged

13-14 years). Due to ethical restrictions, we were unable to track individual participants through the school system, and re-recruitment was therefore only possible via the home address. At both time points, measurements were conducted during the school Summer term (April -July), with all variables assessed using the same methods. At follow-up, measurements were conducted at secondary schools with at least five responding participants; remaining participants were offered home visits.

Data collection

At baseline, trained staff conducted measurement sessions in schools, comprising physical measurements and the distribution of questionnaires (children completed questionnaires under supervision at school, parents at home) and accelerometers.[23] Height was measured to the nearest millimetre using portable Leicester height measures, and weight to the nearest 0.1 kg using a non-segmental bio impedance scale (Tanita, type TBF- 300A). Body mass index (kg/m2) was calculated and children's weight status was derived using established protocols.[24] Age and gender were self-reported during the baseline measurement session, and ethnicity was parent-reported using the UK standard classification.[25]

Physical activity

Physical activity was measured using waist-mounted ActiGraph accelerometers (GT1M, ActiGraph LCC, Pensacola, FL, USA), validated for the assessment of children's energy expenditure in free-living conditions.[26,27] Children were instructed to wear the accelerometer continuously on their right hip throughout waking hours for seven consecutive days, except when participating in water-based activities. The accelerometer was set to record activity counts in five-second epochs. Data were cleaned using specially designed software (MAHUFFE Processing Software, available at: http://www.mrc-epid.cam.ac.uk/Research/Programmes/Programme_5/index.html) to remove the first day of data collection and any days with <500 min of recording (defined as a valid day).[28] To be included in the weekday analysis, at least three valid weekdays were required (for weekend analysis, at least one weekend day was required); this cut-off was based on previous research in British schoolchildren.[28] Periods of ≥10 min continuous zero counts were coded as non-wear time.[28] Data recorded after 11pm and before 6am were excluded, to ensure a focus on daytime activity. Average daily minutes of moderate-to-vigorous physical activity (MVPA), MVPA defined as ≥2000 counts/minute, corresponding to a walking pace of about 4 km/h in children.[29] Those obtaining an average of 60 or more minutes of MVPA per day were labelled as 'meeting physical activity guidelines',[30] and this binary variable (at follow-up) was treated as the primary outcome for longitudinal analysis. Using the same criteria and based on physical activity guidelines; (2) Maintained above physical activity guidelines; (3) Decreased from above to below physical activity guidelines; (4) Increased from below to above physical activity guidelines.

Family and home environment variables

Seventeen family and home environment variables, all questionnaire-reported and assessed at baseline, were included in this analysis (see Table 1 for a detailed description of the assessment and construction of variables). These included physical activity levels of parents, home and family environment variables (e.g. availability of play equipment and social support for physical activity). Parent-reported level of education was used as a proxy for family socio-economic status (SES), and, together with child sex and meeting physical activity guidelines at baseline (yes or no), included as confounders in all analyses.

Variable		Description and coding
Mother	Age †	Mother's age, in years
	Body Mass Index (BMI) †	Mother's BMI, calculated from self-reported height and weight (kg/m^2)
	Physical Activity (PA) level †	Previously validated index[31] based on leisure time PA and PA at work; collapsed to: inactive or active
Father	Age †	Father's age, in years
	Body Mass Index (BMI) †	Father's BMI, calculated from self-reported height and weight (kg/m^2)
	Physical Activity (PA) level †	Previously validated index[31] based on leisure time PA and PA at work; collapsed to: inactive or active
	Education level of responding parent	Collected in 14 categories, coded as: low (did not finish secondary school), medium (left school between 16-18 years), high (continued education beyond secondary school)
Home and family environment	Number of parents living at home	Number of parents reported living at home; coded as: one or two
	Play equipment at home	Presence of play equipment in the garden; coded as: yes or no
	Dog as pet	Presence of dog as pet at home; coded as: yes or no
	Family encouragement †	Sum of responses (never/hardly ever to everyday) to questions on how often family members encourage child PA, tell child PA is good for their health and that they're doing well at PA. Child-reported. Score range: 3–12 (α 0.69).
	Family social support †	Sum of responses (never/hardly ever to everyday) to questions on how often during a typical week family members do PA with child, watch child do PA, take child to PA places. Child-reported. Score range: 3–12 (α 0.65).
	Family activities †	Sum of responses (0–4+) to nine questions on how many times during a typical week family members do various activities together (e.g. eat meals, watch TV, go to the park). Parent-reported. Score range: 9–27.
	Children allowed to play anywhere in neighbourhood	Frequency parents typically allow child to play out anywhere in neighbourhood; coded as: score 1 (never) to 5 (very often), collapsed to: never, rarely, sometimes, often or very often. Parent-reported.
	Children prevented from playing outside	Frequency child is typically restricted from playing outside; coded as: never/rarely, sometimes, often/very often (latter two categories combined and NA coded to missing due to small numbers). Parent-reported.
	Children prevented from walking/cycling to friends' houses	Frequency child is typically restricted from playing outside; coded as: never, rarely, sometimes, often/very often (latter two categories combined and NA coded to missing due to small numbers). Parent-reported.
	Belief of agent responsible for child PA	Parent-reported view of who should take main responsibility for children's PA; coded as: parents or other (composite of school, child, and other).

Statistical analysis

Descriptive statistics were calculated for the demographic characteristics of the total sample, and for the four categories of physical activity maintenance. Multinomial logistic regression was conducted to identify significant differences in demographic factors between maintenance categories, and relative risk ratios presented. Relative risk ratios (RRR) demonstrate the probability of one group compared with another (e.g. boy vs. girls (reference group)) meeting physical activity guidelines at follow-up. A relative risk ratio of 4.2, for example, would indicate that boys are 4.2 times more likely to meet guidelines at follow-up than the girls. Using 'meeting MVPA guidelines at follow-up' as the outcome variable, multi-level logistic regressions were conducted for each exposure variable in turn, adjusting for sex, meeting physical activity guidelines at baseline, SES, and school-level clustering. Exposure variables associated at p<0.1 in simple models were taken forward to be examined simultaneously in a multivariable model.[32] In the single models, interactions by sex were also explored. If the p-value for the interaction term was ≤0.1, the analysis for that variable was stratified by sex, and if any subsequent stratified results met significance criteria (≤0.05), the interaction term was taken forward to the multivariable model. An odds ratio, indicating the relative odds of meeting physical activity guidelines at SPEEDY-3, is presented for each exposure variable in the final multivariable model, along with confidence intervals and p-values. To avoid selection bias of restricting the sample to those living in a two parent household, a secondary multivariable model was run additionally including the father-related variables taken forward. Further exploratory analysis examined the individual components of 'family social support' following the same procedures (three individual items: 'During a normal week, someone in my family… a) does a physical activity or plays sports with me; b) takes me to a place where I can do activities or play sports, or c) watches me take part in physical activities or sports').

Results

489 participants of the original 2064 were re-assessed at 4-year follow-up (approximately 24%). Of these, 406 (83%) provided sufficient questionnaire data and at least three days of physical activity data, and were included in weekday analyses (fewer participants were included for weekend analyses: 312 provided an adequate response to questionnaires, and at least one day of weekend data). Participants included for longitudinal analysis reported a slightly higher parental education

score (included: 2.3 ± 0.7, not included: 2.1 ± 0.2; $p<0.001$) but were similar to those not included on other baseline variables (sex and meeting physical activity guidelines). Table 2 shows participant characteristics of the total sample (n=406); the mean age of participants at baseline was 10.2 ± 0.3 years, (follow-up: 14.3 ± 0.3 years) and 53.5% were female (follow-up: 47.6%). At baseline, on weekdays, 68.0% of participants met physical activity guidelines, and 67.2% at weekends. At follow-up, on weekdays, 51.5% of participants met physical activity guidelines (compared with 36.1% on weekend days). At baseline, mothers (n=386) were aged 40.1 years (± 5.2) and were of a healthy weight (mean BMI value 24.9 (± 4.9)). Father data was mostly reported by mothers (only 12% of questionnaire respondents were men). Fathers (n=333) were reported to be aged 43.2 years (± 6.8) and with an average BMI of 26.4 (± 15.4). Education level was self-reported for one parent only (the questionnaire respondent); approximately 41% left school before age 16, 23% continued their education aged 16-18 years, and 36% completed school beyond age 18. The majority of families comprised two parents living at home at baseline (approximately 82%). Most families had play equipment at home; approximately 77% reported having a slide, swing etc. in the back garden, whilst only 35% reported having a dog as a family pet. Table 2 also displays demographic characteristics of participants across the four physical activity maintenance categories. Across the maintenance categories, girls were significantly less likely than boys to remain sufficiently active, particularly during the week (of those who maintained below threshold, 76.8% were girls).

Table 2: Characteristics of participants included for analysis, stratified by maintenance category

		Sex (% female)		Age (mean years, SD)		BMI (mean z-score, SD)	
Total sample	N = 406	53.5		10.2 ± 0.3		0.3 ± 1.1	
Maintenance categories:							
Weekday	**N = 406**		RRR (95% CI)		RRR (95% CI)		RRR (95% CI)
Maintained below threshold†	N = 82 (20%)	76.8	-	10.3 ± 0.3	-	0.5 ± 1.3	-
Maintained above threshold	N = 161 (40%)	**42.2**	**0.2 (0.1 – 0.4)*** **	10.3 ± 0.3	0.9 (0.4 – 2.1)	0.3 ± 1.0	0.9 (0.7 – 1.1)
Decreased from above to below threshold	N = 115 (28%)	**49.6**	**0.3 (0.2 – 0.6)*** **	**10.2 ± 0.3**	**0.4 (0.1 – 0.9)***	0.2 ± 1.1	0.8 (0.6 – 1.0)
Increased from below to above threshold	N = 48 (12%)	**60.4**	**0.5 (0.2 – 1.0)***	10.3 ± 0.3	0.8 (0.3 – 2.7)	0.5 ± 1.2	1.0 (0.7 – 1.4)
Weekend	**N = 312**						
Maintained below threshold†	N = 72 (23%)	69.4	-	10.3 ± 0.3	-	0.3 ± 1.3	-
Maintained above threshold	N = 82 (27%)	**45.8**	**0.4 (0.2 – 0.7) ****	10.2 ± 0.3	0.4 (0.3 – 1.9)	0.3 ± 1.0	1.0 (0.8 – 1.3)
Decreased from above to below threshold	N = 124 (40%)	**49.2**	**0.4 (0.2 – 0.8)****	10.2 ± 0.3	0.4 (0.2 – 1.1)	0.3 ± 1.1	1.0 (0.8 – 1.3)
Increased from below to above threshold	N = 34 (10%)	55.9	0.6 (0.2 – 1.3)	10.2 ± 0.3	0.5 (0.1 – 1.9)	0.3 ± 1.3	1.0 (0.7 – 1.4)

† Reference category; RRR = relative risk ratio; 95% CI = 95% confidence interval

*p<0.05, **p<0.01, ***p<0.001

Predictors of change in meeting activity guidelines on weekdays

In the simple analyses, the presence of play equipment at home, the frequency that a child was allowed to play anywhere in the neighbourhood, and the frequency that a child was prevented from playing outside, were all negatively associated with meeting physical activity guidelines on a weekday at age 14 years (see Table 3). No significant interactions with sex were observed. In the multivariable model, only the presence of play equipment at home remained significantly negatively associated (see Table 4), indicating that those reporting having play equipment at home at age 10 years, had lower odds of meeting physical activity guidelines at age 14 years.

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Variable (reference category)	Weekday (N = 406) Odds ratio (95% CI)	Weekend day (N = 312) Odds ratio (95% CI)
Age of mother	1.0 (0.9 – 1.0)	1.0 (0.9 – 1.1)
BMI of mother	1.0 (1.0 – 1.1)	1.0 (1.0 – 1.1)
PA level of mother (inactive)	1.0 (0.7 – 1.3)	0.9 (0.7 – 1.4)
Age of father	1.0 (1.0 – 1.1)	1.0 (1.0 – 1.1)
BMI of father	**1.1 (1.0 – 1.3)*** [$]	**1.2 (1.0 – 1.3)*** [$]
PA level of father (inactive)	0.9 (0.7 – 1.2)	0.8 (0.6 – 1.2) [$]
Play equipment at home (none)	**0.6 (0.3 – 1.1)**	1.0 (0.5 – 2.3)
Presence of dog as a pet at home (none)	1.1 (0.6 – 2.0)	0.8 (0.4 – 1.6)
Family encouragement	1.0 (0.9 – 1.2)	1.1 (1.0 – 1.2)
Family social support	1.0 (0.8 – 1.2)	**1.2 (1.0 – 1.4)***
Family activities	1.0 (0.9 – 1.1)	1.0 (0.9 – 1.1)
Children allowed to play anywhere in neighbourhood (never)		
% rarely	**0.5 (0.3 – 1.1)**	0.7 (0.2 – 3.2)
% sometimes	1.0 (0.5 – 2.1)	1.1 (0.5 – 2.5)
% often or very often	1.6 (0.7 – 3.5)	1.1 (0.4 – 2.7)
Children prevented from playing outside (never or rarely)		
% sometimes	0.8 (0.4 – 1.6)	0.6 (0.3 – 1.4)
% often or very often	**0.4 (0.2 – 1.0)****	1.1 (0.4 – 3.2)
Children prevented from walking/cycling to friends' houses (never or rarely)		
% sometimes	1.3 (0.7 – 2.4)	1.4 (0.6 – 3.2)
% often or very often	1.1 (0.5 – 2.2)	1.7 (0.7 – 4.0)
Belief that others (e.g. school) responsible for child PA (parent)	0.9 (0.5 – 1.5)	1.3 (0.6 – 2.7)

NB: All analyses adjusted for child sex, SES, and meeting MVPA guidelines at baseline. N for analyses including father variables are N=330 for weekdays, and N=260 for weekend days. p < 0.1 identified in **bold** (threshold for progression to multivariable model) *p<0.05, **p<0.01, [$] interaction with sex at p<0.1.

Table 4. Results of multivariable logistic regression analysis between baseline family/home factors and meeting MVPA guidelines on weekdays at follow-up

	Weekday physical activity (n=406)
Variable	Odds ratio (95% CI)
Play equipment at home	**0.5 (0.3 – 0.8)****
Children prevented from playing outside (never or rarely)	
% sometimes	0.8 (0.5 – 1.3)
% often or very often	0.8 (0.4 – 1.5)
Children allowed to play anywhere in neighbourhood (never)	
% rarely	0.7 (0.4 – 1.4)
% sometimes	1.4 (0.8 – 2.5)
% often or very often	1.1 (0.6 – 1.9)

NB: Analyses additionally adjusted for child sex, SES, and meeting MVPA guidelines at baseline. *p<0.05, **p<0.01, ***p<0.001

Predictors of change in meeting activity guidelines at the weekend

In the simple analysis, one variable was identified as a significant predictor of adolescent's meeting physical activity guidelines at the weekend (see Table 3). Family social support was positively associated with meeting guidelines at follow-up; those reporting higher levels of support at baseline (e.g. family members often watch the child play sports) had a higher odds of meeting activity guidelines at age 14 years. No evidence of effect modification by sex was observed. Further exploratory analysis of the family social support variable examined participating in physical activity with the child, facilitating the physical activity of the child, and watching the child do physical activity as separate exposures. Results indicated that of the three individual items only *facilitating* physical activity was significantly positively associated with children accruing sufficient activity at weekends (OR 2.7, 95% CI 1.1 – 6.6, $p<0.01$).

Father-level predictors of change in meeting activity guidelines

In the sub-sample of children with two parents in the household, only fathers' BMI was significantly associated with meeting physical activity guidelines in univariate models (Table 3). In addition, three interactions with child sex were identified (meeting physical activity guidelines on weekdays: father's BMI*child sex (OR 0.88, 95%CI 0.77-1.01, $p<0.1$); meeting physical activity guidelines on weekend days: father's BMI*child sex (OR 0.84, 95%CI 0.73-0.97, $p<0.05$) and father's physical activity*child sex (OR 1.56, 95%CI: 0.92-2.62, $p<0.1$)). Inclusion of the father data did not substantially affect the associations observed for the other exposure variables included in the final multivariable model. In stratified models, father's BMI was positively associated with meeting physical activity guidelines on weekdays for boys but not for girls (boys: OR 1.12, 95%CI 1.00-1.25, $p=0.05$; girls: OR 0.97, 95%CI 0.88-1.07, $p>0.05$). A similar pattern was observed for meeting physical activity guidelines on weekend days (boys: OR 1.17, 95%CI 1.04-1.33, $p<0.05$; girls: OR 0.96, 95%CI 0.86-1.08, $p>0.05$). Despite a significant interaction, father's level of physical activity was not associated with either boys' or girls' odds of meeting guidelines on weekend days in stratified analyses (boys: OR 0.89, 95%CI 0.57-1.40, $p>0.05$; girls: OR 1.34, 95%CI 0.87-2.07, $p>0.05$).

Discussion

Understanding modifiable influences on context- and time-specific activity in children may help inform the design of interventions to improve physical activity levels. We used data from the SPEEDY study to describe maintenance of physical activity over the transition from primary to secondary school, and to explore family factors in childhood that predicted meeting physical activity guidelines in adolescence.

Our data mirror previous evidence on the prevalence of child physical activity and suggest similar patterns of age-related decline in physical activity to that currently reported in the literature.[17,18] There was a positive association between physical activity at age 9-10 years, and physical activity at age 13-14 years. Approximately 28% of children dropped below the threshold for meeting guidelines as they progressed to adolescence, and this figure increased to 40% for weekend activity. We showed that only 50% of 13-14 year olds were sufficiently active on weekdays. At weekends, even fewer adolescents met physical activity guidelines (approximately 36%). We also observed some sex differences in these patterns of behaviour change. Boys were more likely to remain sufficiently active than girls, despite previous analyses of the SPEEDY cohort indicating the boy's physical activity levels decrease more rapidly than girls over this period.[33] This may be explained by elevated MVPA at baseline, allowing for a steeper decline in activity whilst still meeting activity guidelines. There was also a small group (approximately 12% of all 'increasers') of girls who improved their physical activity levels between childhood and adolescence. Given that barriers to physical activity reported by girls (e.g. perceived lack of support and opportunities, difficulties with body image and skills development) tend to be exacerbated as girls move through adolescence,[34] efforts to further understand this group, and therefore enhance and maintain girls' physical activity participation during the transition to secondary school are critical.[35] We did not, however, see any significant differences across the maintenance categories for other variables, such as ethnicity and weight status.

Greater family social support at baseline (aged 10-11 years) predicted meeting physical activity guidelines at secondary school (aged 13-14 years), even when taking baseline values into account. Those reporting high social support had 20% higher odds of meeting national guidelines at weekends. Family social support was assessed using a scale assessing family co-participation, facilitation, and encouragement. The prospective association observed here echoes the findings of extant studies.[16] As previous work has indicated that the different components may be differentially associated with children's behaviour,[21] we conducted further exploratory analysis of the family social support variable. Results indicated that of the three individual items, only facilitating child physical activity was significantly positively associated with them accruing sufficient activity at weekends. This is consistent with data from previous studies suggesting that logistical support (e.g. driving child to sports practice) is critical.[36] This is a modifiable facet of family life, and may therefore be a potential target for those developing interventions to increase or maintain physical activity over the transition into adolescence.

We observed an association between fathers' weight status and the later physical activity levels of their children; a higher BMI of the father at baseline was associated with greater odds of their child meeting activity guidelines whilst at secondary school. This was the case for both week and weekend days, and is counter to studies suggesting that the weight status and health behaviours of parents correlate directly with that of their child.[37,38] Further exploration of interactions by sex identified that this association was only significant for boys, not girls. We hypothesise that those sons whose fathers are overweight may seek to avoid unhealthy weight themselves, and may therefore engage in more physical activity during adolescence. This is supported by evidence that boys identify more strongly with their fathers, compared with girls,[39,40] which may exacerbate feelings of comparison.

Data from this study also indicated an unexpected inverse association between the presence of play equipment at home (e.g. a trampoline, slide, or swing) aged 10-11 years and meeting physical activity guidelines at week days aged 13-14 years. Those with play equipment at baseline were half as likely to be sufficiently active at follow-up. An explanation for this may be that children with equipment at home are more likely to play at home and thus have limited freedom to roam. In that more restricted environment, play equipment in the home may be beneficial at younger ages. However, when moving into adolescence, this may lead to a steeper reduction in their activity levels, particularly if the equipment at home is no longer of interest to them. This is consistent with the significant negative associations we additionally observed in the simple models for the variables regarding the children's freedom to play in the neighbourhood and whether they are prevented from playing outside. This may also be reflective of a larger move toward independence that adolescents experience as they progress to secondary school; for example, becoming less reliant on family members to facilitate or provide transport to physical activity opportunities. Family support may also differ over time, due to changing resources or even family structure. We conducted an analysis of family factors predicting change in physical activity, but did not investigate change in the family factors themselves, so as to maintain our longitudinal study design. To further understand the importance of independence on physical activity during this critical transition period, qualitative work focused on specific factors in the home environment that are protective or restrictive for maintaining sufficient physical activity levels may be required.

Despite prior evidence to suggest a relationship between a host of family factors and sustaining adequate levels of physical activity, our data indicated no association between meeting guidelines in adolescence and the baseline home environment. The presence of a dog as a pet did not predict physical activity maintenance. Parental rules restricting active travel, or outdoor play, were also not shown to be associated with physical activity at follow-up. Furthermore, there were no significant associations reported between family psycho-social factors (e.g. co-participation in physical activity, encouragement for physical activity) and maintenance of physical activity. Given the increasing autonomy that adolescents experience, it may be that the influence of parents diminishes at secondary school, apart from the logistical support they can provide. Although beyond the scope of this manuscript, it may be important to examine other settings within which young people spend time that may be more important in shaping health behaviours; for example, there is increasing policy interest in the role of the school environment in supporting physical activity.[41,42]

Strengths and limitations

Key strengths of the SPEEDY study include the use of an objective measure of activity intensity and a population-based sampling strategy. We were able to examine data from two time points to comprehensively assess which home and family factors were predictive of sufficient physical activity levels during adolescence, both during the week and at weekends. Examining longitudinal data provides a stronger basis for making causal inferences. Our analyses may therefore offer important insight into how policy makers and practitioners might support the maintenance of physical activity during the transition from childhood to adolescence. However, limitations should be noted. The demographic profile of Norfolk, and hence our sample, is not representative of the wider United Kingdom (i.e. 97% of participants identified as being of white ethnic background). The SPEEDY study also experienced relatively high attrition rates. Of 2064 children originally recruited, only 489 participants were re-assessed at 4-year follow-up and of these, only 83% provided sufficient data for inclusion in our analyses. These limitations combined may limit our ability to generalise the results of these analyses to the original study sample, and to other population groups. Further, the exposure variables were self-reported, and thus may be susceptible to social desirability bias.

Conclusion

This work answers an urgent call for analyses focused on the family environment, particularly given that recent publications state that *without* the involvement of family members it is unlikely that long term change in children's physical activity levels is possible.[43] Further, we offer much-needed longitudinal research in this field.[21] Our data indicate that contrary to what we might expect, the presence of home play equipment is negatively prospectively associated with meeting physical activity guidelines during the week; further work is needed to explain this and to explore the specific factors that may support healthy behaviour on weekdays. Our results also suggest that family social support (particularly, logistical support) appears essential in attenuating the age-related decline in physical activity at weekends. Interventions that foster parent's facilitation of health behaviours may therefore be most promising in increasing and maintaining physical activity as children progress to adolescence.

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Highlights

- Girls were less likely than boys to maintain sufficient levels of PA
- Childhood family support was positively associated with weekend PA in adolescents
- Encouraging parents to facilitate child PA (e.g. transport) may support maintenance