



The Effects of Socioeconomic Status on Parent and Child Moderate-to-Vigorous Physical Activity and Body Mass Index

Samantha Donnelly, Duncan S. Buchan, Gillian McLellan & Rosie Arthur

To cite this article: Samantha Donnelly, Duncan S. Buchan, Gillian McLellan & Rosie Arthur (2022) The Effects of Socioeconomic Status on Parent and Child Moderate-to-Vigorous Physical Activity and Body Mass Index, *Research Quarterly for Exercise and Sport*, 93:4, 758-768, DOI: [10.1080/02701367.2021.1918322](https://doi.org/10.1080/02701367.2021.1918322)

To link to this article: <https://doi.org/10.1080/02701367.2021.1918322>



© 2021 The Author(s). Published with license by Taylor & Francis Group, LLC.



Published online: 28 Oct 2021.



Submit your article to this journal [↗](#)



Article views: 4066



View related articles [↗](#)



View Crossmark data [↗](#)



Citing articles: 2 View citing articles [↗](#)

The Effects of Socioeconomic Status on Parent and Child Moderate-to-Vigorous Physical Activity and Body Mass Index

Samantha Donnelly , Duncan S. Buchan , Gillian McLellan , and Rosie Arthur 

The University of the West of Scotland

ABSTRACT

Purpose: Physical inactivity and overweight status has been linked to low socioeconomic status (SES) in youth. Parents are known to influence both their child's weight and physical activity (PA). The relationship between parent and child PA is of interest to many researchers; however, previous research typically relies on self-reported measures. The purpose of this study was to examine the relationship between parent and child moderate-to-vigorous PA (MVPA) and body mass index (BMI) in a sample of children (4–11 years old) using wrist-worn accelerometers and to explore mediating processes by which SES influences child MVPA and BMI through their parents MVPA and BMI. **Methods:** Parent and child dyads ($n = 174$) wore an ActiGraph GT3X+ accelerometer on their non-dominant wrist for 7 days. Mediation analyses were conducted to understand the indirect relationships between SES and child MVPA and BMI. **Results:** Weekend parent and child MVPA was significantly related ($p < .01$). Parent and child BMIs were also significantly related ($p < .001$). There was a significant negative direct effect of SES on child BMI ($p < .05$). Additionally, we observed a significant negative indirect effect of SES on child BMI via their parents BMI ($B = -.04$, $SE .02$, 95% CI = $-.07$ to $-.01$). **Conclusions:** Whilst parent and child MVPA were significantly related during the weekend, there were no associations between SES and MVPA. Future interventions aiming to improve health outcomes in children should consider the influence SES can have as well as parental activity on children's weekend MVPA.

ARTICLE HISTORY

Received 7 October 2019
Accepted 9 February 2021

KEYWORDS

ActiGraph; accelerometer;
wrist-worn; mediation

Global obesity rates have tripled over the past four decades with 41 million children under the age of 5 and over 340 million between the age of 5–19 years being classed as overweight or obese in 2016 (World Health Organization [WHO], 2018a). Although the causes of obesity are multifactorial, the link between obesity and physical inactivity is well established (U.S. Centers for Disease Control and Prevention, 2016; WHO, 2018a). Many countries allocate considerable resources to the treatment of obesity-related disorders that can account for between 0.7% and 2.8% of a country's total healthcare expenditure (Withrow & Alter, 2011). As physical inactivity and weight status are modifiable, it is crucial to identify factors that are associated with physical activity (PA) behavior and body mass index (BMI) in order to improve upon the factors which have positive effects.

Current PA recommendations across various countries including; the United Kingdom (UK), Australia, Canada and the United States of America (USA) encourage youth to undertake at least 60 min of daily moderate-to-vigorous PA (MVPA) as a preventative measure of obesity (Australian Government, 2018; Department of Health and Social Care, 2019; Gareth, 2016; U.S. Department of Health and Human Services, 2018). Available self-reported and objective PA data published in the Lancet indicates that youths are failing to meet these recommendations on a global scale (Guthold et al., 2019; Hallal et al., 2012; Sallis et al., 2016). An important determinant of health and wellbeing is socioeconomic status

(SES) as it can influence an individual's exposure to several risk factors across the lifespan (Marmot, 2005; O'Donoghue et al., 2018). Findings suggest that children with lower SES are at a higher risk for overweight and obesity and are exposed to home and neighborhood environments that are un conducive to health-promoting behaviors (Goisis et al., 2016; Noonan et al., 2016).

Little is known about the mechanisms via which SES impacts on children's PA and BMI. It is clear that parental influence plays a major role in determining the weight of their children, with evidence from several upper-middle and high-income countries (e.g., Australia, Mexico, Norway, Germany, and the US) suggesting that parental overweight status is a risk factor for childhood overweight (Elder et al., 2010; Gibson et al., 2007; Hernández-Valero et al., 2007), existing as early as preschool age (Kitsantas & Gaffney, 2010). Additionally, parents from the Netherlands have been described as gatekeepers for PA-related opportunities with their support to be active and their own self-reported PA being shown to affect the objectively measured activity behaviors of their children (Brouwer et al., 2018). Nonetheless, studies have reported no significant relationship in parent and child PA (Erkelenz et al., 2014; Jago et al., 2010).

Multiple theories suggest that an individual's health and behavior is influenced via multidimensional environmental conditions and not solely by one factor (e.g., parents). For example, the socio-ecological model proposes that an

individual (e.g., a child) can be influenced by various systems including the microsystem (e.g., family), exosystem (e.g., school) and macrosystem (e.g., culture and social conditions such as SES) (Bronfenbrenner, 1986). Therefore, it is important to understand how parents' BMI and PA may affect children's BMI and PA. Furthermore, SES can affect the BMI and PA of adults due to; the financial resources available for food and exercise-related expenditure, the education levels and understanding of diet and exercise-related issues and the location of an individual's residence (e.g., proximity to fast food outlets, safe spaces to exercise) (Lee et al., 2019). Moreover, parents are known to play a significant role in influencing children's health behaviors via role modeling eating habits, weight status, and PA levels (Scaglioni et al., 2018; Xu et al., 2015). Therefore, it is likely that SES impacts on children's health via their parents' health behaviors.

Previous research has tended to use subjective measures of PA (Trost & Loprinzi, 2011), pedometers (Stearns et al., 2016), and differ according to the indicators of PA used (e.g., MVPA, total PA; Craig et al., 2013). The use of such methods increases the ambiguity of findings as subjective measures of PA are prone to recall bias (Chinapaw et al., 2010), whereas pedometers have been found to be inaccurate in assessing the distance covered and energy expended (Ndahimana & Kim, 2017). Considerable differences in weekday and weekend parent and child PA have been found in families from the UK (McMinn et al., 2013). Failing to examine the relationship between parent and child PA using separate analyses for weekday and weekend data is apparent in research which may therefore fail to capture the extent of this relationship (Stearns et al., 2016). Accelerometry is the gold standard for measuring free-living PA in adults and children (Esliger et al., 2011). Nevertheless, in the limited studies which employ accelerometer devices to measure PA, ambiguous wear time criteria (WTC), or failure to report WTC at all, is evident (Strutz et al., 2018).

Previous accelerometer research findings are commonly based on data derived from hip-mounted devices (Fuemmeler et al., 2011). In contrast to wrist-mounted devices, such placement can result in poor compliance (McLellan et al., 2018). Given the growing popularity of the wrist as an accelerometer placement site (Fairclough et al., 2016), it is important to establish the relationship between SES and parent and child MVPA from wrist-worn accelerometry data. Tests of the difference and direct correlations between SES and parent and child MVPA and BMI are not enough to fully understand these relationships. Statistical mediation analysis describes how SES as an independent variable "X" affects the dependent variable "Y" (Child MVPA and BMI z-score) through an indirect effect of the mediating variable "M" (Parent MVPA and BMI). Therefore, the purpose of this study was twofold. Firstly, to examine the relationship between parent and child MVPA and BMI in a sample of children (4–11 years old) using wrist-worn accelerometers. Secondly, to explore mediating processes by which SES influences a child's MVPA and BMI z-score through their parents' MVPA and BMI. Our hypotheses were that SES would be related to children's MVPA and BMI z-scores indirectly via parental MVPA and BMI.

Methods

Participants

Recruitment involved the first author visiting the parent's evenings (where parents meet with their child's teacher at school to discuss their child's progress) of six primary schools known by the first author after institutional ethical approval was granted. Children (4–11 years old) who attended the schools approached for this study ($n = 6$), and one of their parents were recruited. Each family chose which parent participated in the study during the recruitment phase. Parental attendance at these events is normally high and parents are directly contacted by teachers if they do not attend. As such, we hoped to recruit a diverse range of parents from such events, including those who may be less likely to volunteer to participate in school-based research activities. Informed consent paperwork was then handed out to parents at parent's evenings and to pupils in class by the first author. The Scottish Index of Multiple Deprivation (SIMD) decile scores of the schools ($n = 6$) ranged from 2 to 7 (4.17 ± 2.32) with a score of 1 indicating high levels of deprivation and a score of 10 indicating low levels of deprivation (Scottish Government, 2016). Data collection took place between October 2018 and May 2019.

Anthropometric measures

Objective measures of mass and stature of children and parents were undertaken at school. Mass was measured barefoot to the nearest 0.1 kg with an electronic scale (Seca Digital Scales, Seca Ltd, Birmingham, UK) whilst stature was measured barefoot to the nearest 0.1 cm using a stadiometer in accordance with standard procedures (Cole et al., 1995). BMI was then calculated as the mass in kilograms divided by the square of the stature in meters. Thereafter, BMI z-scores for each child were determined and children were classified as either healthy weight or obese/overweight relative to the UK 1990 BMI population reference data (Cole et al., 1995). Using software provided by the Child Growth Foundation (Pan & Cole, 2010), the following definitions were applied for healthy weight (BMI z-score <1.04 , below the 85th percentile) and overweight/obese (BMI z-score ≥ 1.04 , above the 85th percentile) children. Parent BMI was classified relative to the World Health Organization (WHO) classifications with BMI scores <18.5 defined as underweight, 18.5 to <25 defined as normal weight, 25 to <30 defined as overweight, excluding obese, 30 to <40 defined as obese excluding morbidly obese, and ≥ 40 defined as morbidly obese (World Health Organization, 2018b).

Socio-economic status variables

Several variables were collected via self-reported questionnaires to quantify the SES of parents. Home postcodes were collected in order to calculate residential deprivation scores. Information regarding household income, parental occupation, and the parent's highest education qualification achieved was also collected.

Residential deprivation (Area-SES)

The home postcodes were reported in order to calculate the area-SES of parent and child dyads based on residential SIMD decile scores (Scottish Government, 2016). SIMD is a measure of area-based multiple deprivations, which is centered on 31 indicators across six individual domains including current income, employment, housing, health, education, and skills and training. In order to examine the differences in MVPA and BMI based on SIMD, the median SIMD observed was 5 and from this, area SIMD was categorized as low and high based on the median split. SIMD will be referred to as area-SES hereon in.

Household income

Parents were asked to report their annual household income. The median gross salary in Scotland for all employees was £23,833 in April 2018 (Aiton, 2018) which we used to categorize high and low household income.

Occupation

Parents were asked to detail their current occupation status. From this, parent occupation was then classified into three separate categories including unemployed/stay at home parent, student/retired, and employed/self-employed.

Parent education

Parents were asked to detail their highest education qualification to date. Based on the information provided, four separate categories for parent education were created including secondary school qualification or less, UK college qualification (e.g., Higher National Certificate), UK University qualification (e.g., bachelor's degree), and UK University Postgraduate qualification.

Physical activity

Parent and child dyads were provided with two ActiGraph GT3X+ (ActiGraph, LLC, Pensacola, FL, USA) accelerometers and instructed to wear the device at all times (i.e., 24 hr per day), except during any water-based activities, for a minimum of 7 days on the non-dominant wrist (confirmed by the parent/child). Verbal and written instructions for care and placement of the devices were provided to parents. Finally, all devices were synchronized with Greenwich Mean Time and initialized to capture data at 80 Hz prior to distribution.

Accelerometry data processing

Accelerometer data were downloaded using ActiLife v6.13.3 (ActiGraph, Pensacola, FL, USA) and saved in raw format as gt3x files. The gt3x files were subsequently converted to time-stamp free .csv files which were exported into R (R Foundation for Statistical Computing, Vienna, Austria, <https://cran.r-project.org/>) and processed using the GGIR package v1.9.1. GGIR removed abnormally high values, detected non-wear time (Van Hees et al., 2013) and auto-calibrated the raw accelerometer signals using local gravity as a reference (Van Hees et al., 2014). Finally, GGIR calculated ENMO over 5 s epochs expressed in milli-gravitational units (mg). Participant files were removed from further analysis if files had a post-calibration error

≥ 0.01 g and there were less than 4 days (including one weekend day) of valid wear (defined as ≥ 10 hr per day) across the day from 6 am to 10 pm. Time spent inactive was defined as time accumulated below 50 mg for both children and adults (Rowlands et al., 2019) whereas time spent in MVPA for both children and adults was defined as the time accumulated above an acceleration of 201 mg for children and 101 mg for adults (Hildebrand et al., 2014). Time spent in light PA (LPA) was defined as time spent above 50 mg and below the relevant MVPA threshold.

Statistical analyses

All analyses were conducted using IBM SPSS Statistics v.23 (IBM, Armonk, NY). Independent samples *t* tests and one-way analysis of variance (ANOVA) and analysis of covariance (ANCOVA) were employed to assess the difference in means of MVPA and BMI based on varying factors including gender, area-SES and parent occupation. For child MVPA, age and gender were used as covariates. For child BMI z-score, gender was controlled for as a covariate. To determine the strength of the relationships between parents and their children regarding accelerometry data as well as BMI, separate Pearson correlation coefficients were conducted for variables including; parent and child MVPA on all days (i.e., the entire week), weekdays and weekend days, parent BMI, child BMI z-score, area-SES, household income, parent occupation, and parent's highest education qualification achieved. As area-SES had the greatest response rate of the SES variables collected and is based on multiple indicators including income, occupation and education, we chose to run area-SES in our mediation analyses to represent SES.

To test the indirect effects of area-SES on children's MVPA and BMI z-score via their parents MVPA and BMI, we used a regression-based package known as PROCESS (Hayes, 2012) to run mediation analyses with 10,000 bootstrap samples. Separate models were ran to examine the influence of area-SES on children's MVPA via their parents MVPA, and the influence of area-SES on children's BMI z-score via their parents' BMI. PROCESS provides the total indirect effect and the separate direct effects through each mediator whilst controlling for effects of all other mediators via bootstrapping. The beta coefficients indicate the gradient of the regression line as the strength of the relationship, and the lower and upper bound 95% confidence intervals (CI) that do not encompass zero indicate significant relationships at the .05 level. Bootstrapped CI were used to determine the significance of the indirect effect.

Results

Children ($n = 201$; $n = 103$ boys) aged 8.41 ± 1.98 years and one of their parents ($n = 151$ female) aged 38.48 ± 6.91 years consented to participate in the study. A participant flow chart is provided in Figure 1. When employing a wear time inclusion criterion in which participants must have worn the device for ≥ 16 hr per day (from 0 to 24 hr) for 4 days (including one weekend day), 79 children and parents were excluded as they did not meet these criteria. As this reduced our sample

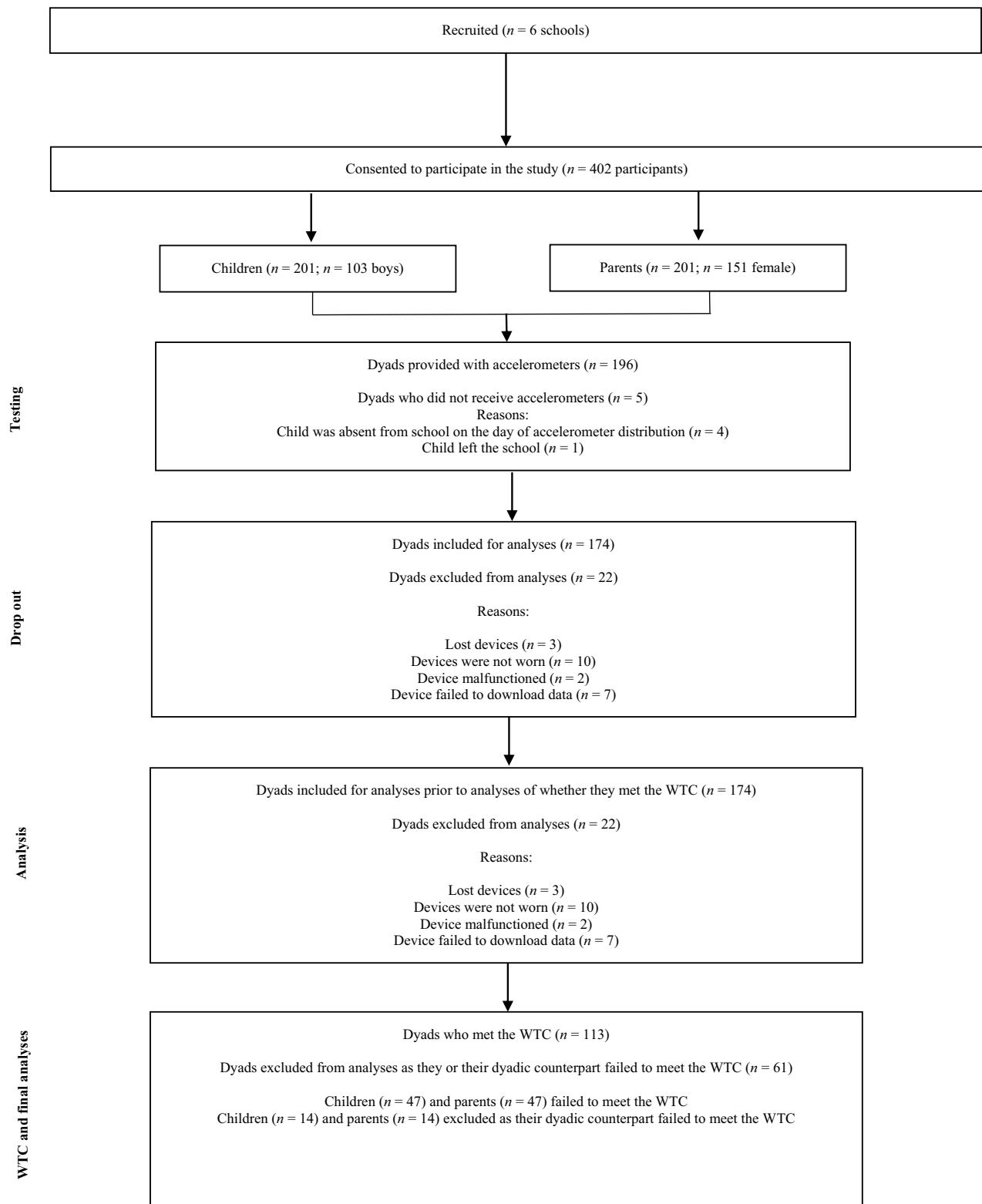


Figure 1. Consort flow diagram of the recruitment, adherence, and analysis process.

considerably, we chose to include parent and child dyads who wore the device for 4 days (including one weekend day), for ≥ 10 hr each day from 6 am to 10 pm. Subsequently, 47 children and parents failed to meet the WTC and therefore, due to the inclusion of parent and child dyads only, a further 14 adults and children were excluded as their dyad counterpart failed to meet the WTC. A final sample of 113 children (56%; $n = 58$

girls; 8.83 ± 1.78 years) and their parent ($n = 86$ female; 40.17 ± 6.61 years) was included in the MVPA analyses. Findings revealed that the average wear time for children and parents were 19.64 ± 4.92 hr and 19.98 ± 4.59 h, respectively. Children wore the device on average 5.58 ± 0.91 days during the week and 1.92 ± 0.27 days on the weekend. Parents wore the device for 5.30 ± 1.04 days during the week and 1.89 ± 0.32 days on

Table 1. Sample characteristics of child and parent participants regarding MVPA mean differences.

	MVPA min							
	Child				Parent			
Total participants (N) = 113 dyads	N (%)	AD (SD)	WD (SD)	WK (SD)	N (%)	AD (SD)	WD (SD)	WK (SD)
Characteristics								
<i>Gender</i>	113				113			
Male	55 (48.70)	63.15 (25.66)	64.50 (26.27)	60.64 (32.32)	27 (24.00)	98.65 (51.17)	101.85 (54.57)	86.81 (47.80)
Female	58 (51.30)	53.40 (20.99)	52.40 (20.61)	56.11 (30.80)	86 (76.00)	94.46 (37.87)	96.06 (39.69)	90.20 (44.27)
Confidence Int. LL–UL (95%)		1.48–18.97*	3.49–21.17**	–5.95–17.32		–17.44–25.82	–17.23–28.81	–24.32–17.54
<i>SIMD (area-SES)</i>	101				101			
< Decile 5	49 (48.50)	60.01 (26.72)	59.59 (26.00)	61.31 (36.55)	49 (48.50)	98.65 (41.34)	100.27 (43.70)	92.99 (45.65)
≥ Decile 5	52 (51.50)	56.06 (21.84)	56.24 (23.52)	56.52 (27.57)	52 (51.50)	94.77 (42.87)	96.14 (44.83)	90.53 (46.84)
Confidence Int. LL–UL (95%)		–5.57–13.37	–6.30–12.83	–7.77–17.48		–12.77–20.52	–13.37–21.62	–15.82–20.74
<i>Household income</i>	52				52			
< £23,833	8 (15.40)	62.75 (20.07)	61.17 (18.23)	66.58 (31.62)	8 (15.40)	112.30 (64.77)	118.40 (68.02)	92.47 (54.92)
≥ £23,833	44 (84.60)	59.27 (25.87)	59.39 (26.78)	58.66 (30.06)	44 (84.60)	91.67 (35.39)	91.24 (36.95)	92.32 (41.95)
Confidence Int. LL–UL (95%)		–18.74–21.16	–21.56–18.86	–16.55–32.13		–33.87–75.12	–30.06–84.38	–46.42–46.72
<i>Parent occupation</i>	105				105			
Unemployed/stay at home parent	9 (8.60)	54.15 (21.46)	53.19 (25.09)	56.74 (26.97)	9 (8.60)	88.43 (52.49)	92.93 (53.25)	73.68 (44.34)
Student/retired	5 (4.80)	67.50 (13.56)	73.53 (13.58)	51.58 (19.45)	5 (4.80)	102.08 (68.12)	110.63 (73.80)	73.23 (46.41)
Employed/self-employed	91 (86.70)	56.75 (24.24)	56.93 (24.28)	57.23 (32.19)	91 (86.70)	93.30 (37.39)	94.93 (39.58)	88.73 (44.28)
<i>Parents' highest level of education</i>	90				90			
Secondary school or less	15 (16.70)	56.60 (27.86)	55.93 (30.28)	58.03 (30.25)	15 (16.70)	93.16 (37.04)	98.01 (41.72)	81.56 (34.59)
UK college qualification	30 (33.30)	55.82 (21.76)	56.28 (23.01)	55.44 (27.09)	30 (33.30)	99.12 (45.86)	102.13 (49.13)	88.74 (43.68)
UK University Undergraduate degree	32 (35.60)	54.06 (22.47)	54.76 (23.34)	51.88 (24.63)	32 (35.60)	85.71 (32.40)	86.71 (34.85)	82.13 (37.27)
UK University Post-graduate degree	13 (14.40)	61.16 (17.66)	61.79 (15.66)	63.98 (38.72)	13 (14.40)	90.51 (39.13)	87.83 (36.23)	100.11 (52.89)

MVPA = moderate-to-vigorous physical activity; AD = all day (the entire week); WD = weekday; WK = weekend day; SIMD = Scottish Index of Multiple deprivation; SES = socioeconomic status; * $p < .05$; ** $p < .01$.

the weekend. No files were removed due to post-calibration error. LPA and inactive time were also calculated for parents and children who met the WTC. Children accumulated 695.28 ± 58.52 min of inactive time and 140.911 ± 28.89 min of LPA on average per day over the monitoring period. Parents accumulated 728.69 ± 68.93 min of inactive time and 142.18 ± 40.55 min of LPA on average per day during the monitoring period.

We found significant differences in age between parents who met the WTC and those who did not ($p < .01$), with parents who met the WTC being older (40.17 ± 6.61 years vs. 36.33 ± 6.28 years). Children who met the WTC (8.83 ± 1.87 years) were also significantly ($p < .01$) older compared to those who did not (7.89 ± 2.16 years). In relation to gender homogeneity in our sample of parent and child dyads who met the WTC, 46.9% were the same gender ($n = 53$). Descriptive statistics are presented in Table 1 for MVPA. A significant difference in children's all day MVPA was observed between boys and girls, with boys participating in more MVPA than girls on all days ($p < .05$). Boys were also more active than girls for weekday MVPA ($p < .01$). No other significant differences in children's or parents's MVPA were observed for gender or SES variables (see Table 1).

Descriptive statistics for BMI are presented in Table 2, with 185 children and 119 parents having provided objective measures of BMI. Sixteen children refused to have their mass and stature recorded whereas 64 parents self-reported their mass and stature. One mother's measures were subsequently excluded from the analysis due to pregnancy and 17 parents refused to self-report their mass and stature. Only objective measures of BMI were included in the final analyses. No significant differences were observed when comparing the BMI z-scores of children who did and did not meet the WTC

Table 2. Sample characteristics of child and parent participants with BMI/BMI-Z-score mean differences.

	BMI z-score/BMI			
	Child		Parent	
Total participants (N) = 113 dyads	N (%)	M (SD)	N (%)	M (SD)
Characteristics				
<i>Gender</i>	185		119	
Male	95 (51.40)	.83 (1.18)	29 (24.40)	28.56 (4.29)
Female	90 (48.60)	.44 (.98)	90 (75.60)	28.26 (6.00)
Confidence Int. LL - UL (95%)		.07–.71*		–1.73–2.34
<i>SIMD (area-SES)</i>	167		106	
< Decile 5	91 (54.50)	.84 (1.16)	58 (54.70)	29.59 (6.17)
≥ Decile 5	76 (45.50)	.43 (1.04)	48 (45.30)	27.02 (4.79)
Confidence Int. LL - UL (95%)		–.08–.75*		.46–4.69*
<i>Household income</i>	89		49	
< £23,833	16 (18.00)	.83 (1.21)	8 (16.30)	31.42 (7.77)
≥ £23,833	73 (82.00)	.39 (1.12)	41 (83.70)	26.78 (4.65)
Confidence Int. LL - UL (95%)		–.22–1.02		–1.91–11.18
<i>Parent occupation</i>	172		114	
Unemployed/stay at home parent	17 (9.90)	.95 (1.06)	15 (13.20)	27.85 (4.82)
Student/retired	8 (4.70)	1.00 (.86)	5 (4.40)	29.02 (5.54)
Employed/self-employed	147 (85.50)	.59 (1.12)	94 (82.50)	28.42 (5.87)
<i>Parents' highest level of education</i>	144		93	
Secondary school or less	24 (16.70)	.73 (1.25)	16 (17.20)	30.48 (6.22)
College degree	58 (40.30)	.74 (1.15)	40 (43.00)	29.55 (6.08)
Undergraduate degree	46 (31.90)	.59 (1.07)	27 (29.00)	25.90 (4.47)
Post-graduate degree	16 (11.10)	.38 (.64)	10 (10.80)	25.82 (3.10)*

BMI = body mass index; SIMD = Scottish Index of Multiple deprivation; SES = socioeconomic status; * $p < .05$.

($p = .06$). Additionally, no significant differences were found when comparing the BMI of parents who met the WTC and those who did not ($p = .90$). From objective BMI data ($n = 119$)

parents were classified as underweight ($n = 1$), normal weight ($n = 36$), overweight excluding obese ($n = 45$), obese excluding morbidly obese ($n = 32$), and morbidly obese ($n = 5$). From the objective BMI z-score of child participants ($n = 185$), 122 children were deemed healthy weight, whilst 63 were classified as being overweight/obese.

Significant differences were observed between boys' and girls' BMI z-scores, with boys having significantly higher scores than girls ($p < .05$). Additionally, children with low area-SES were found to have significantly higher BMI z-scores than those with higher area-SES ($p < .05$) when controlling for gender. Whilst no significant differences were observed for parent BMI regarding gender, significant differences were observed for area-SES, parent education, and household income (all $p < .05$). With regards to area-SES (5.03 ± 2.81 decile), parents from a lower area-SES ($< \text{Decile } 5$) had significantly higher BMIs than those from more affluent areas ($\geq \text{Decile } 5$). Additionally, there was a significant difference between parent education groups and their BMI as determined by one-way ANOVA ($F(3,89) = 4.01, p = .01$) in which a Tukey post-hoc test revealed that parent BMI was significantly higher in parents with a secondary school or less qualification when compared to parents who had a bachelor's degree ($p < .05$). Parents with a UK college qualification had a significantly higher BMI than parents with a UK University degree ($p < .05$).

Parent and child MVPA for all days was not related ($r = .14, p = .15$), and neither was parent and child MVPA on weekdays ($r = .10, p = .28$). Parent and child MVPA were significantly related on weekend days ($r = .28, p < .01$). BMI/BMI z-score and MVPA were not significantly related for either parent participants on all days ($r = -.08, p = .54$), weekdays ($r = -.08, p = .53$), and weekend days ($r = -.10, p = .41$) or child participants on all days ($r = -.11, p = .27$), weekdays

($r = -.10, p = .30$), or weekend days ($r = -.09, p = .35$). The objective BMI/BMI z-score of parent and child dyads ($n = 114$) was significantly related ($r = .40, p < .001$). Parent BMI and household income were negatively related ($r = -.45, p < .001$), as were parent BMI and area-SES ($r = -.30, p < .01$), and parent BMI and parent education ($r = -.32, p < .01$). Children's BMI z-score was negatively related to area-SES ($r = -.19, p < .05$); however, there were no significant associations between child BMI z-scores and the additional SES variables.

The regression mediation analyses used the unstandardized regression coefficients bootstrap estimates (B) of the direct and indirect effects together with bias corrected and accelerated 95% CI. Model one (see Figure 2 Model A) tested the indirect effect of area-SES on the BMI z-score of child participants via the BMI of parent participants (SIMD score as the independent variable, BMI z-score as the dependent variable and parent BMI as the mediator) which explained 47.73% of the variance in BMI z-score ($R^2 = .23, F(3, 97) = 9.54, p = .00$). Area-SES was significantly related to parent BMI ($B = -.58, SE = .19, p < .01$), which predicted child BMI z-score ($B = .06, SE = .02, p < .01$). The direct effect of area-SES on child BMI z-score was significant ($B = .08, SE = .04, p < .05$). There was also a significant negative indirect effect of area-SES on the BMI z-score of child participants via the BMI of parent participants ($B = -.04, SE .02, 95\% \text{ CI} = -.07 \text{ to } -.01$). Therefore, the higher the SIMD score of dyads (being from more affluent area-SES in Scotland) the lower the BMI z-score of child participants via their parents BMI.

Model two (see Figure 2 Model B) tested the indirect effect of area-SES on child weekday MVPA via parent's weekday MVPA (SIMD score as the independent variable, child weekday MVPA as the dependent variable and parent weekday MVPA as the mediator) which explained 31.58% of the

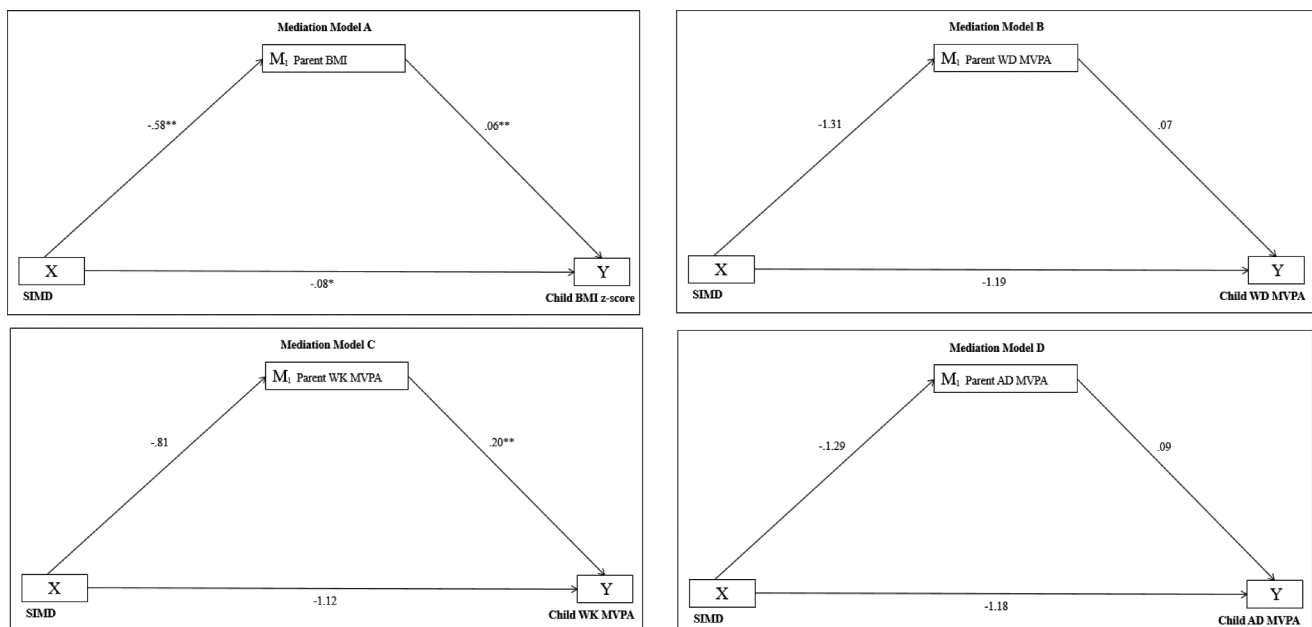


Figure 2. Mediation models examining the direct effects of SIMD on Child BMI via parent BMI, and child MVPA on weekdays, weekend days, and all days via parent MVPA on weekdays, weekend days, and all days. Model A used child gender as a covariate. Models B–D used child gender and child age as covariates. Beta unstandardized path coefficients were used. BMI = body mass index; SIMD = Scottish Index of Multiple deprivation; WD = weekday; MVPA = moderate-to-vigorous physical activity; WK = weekend; AD = all days (the entire week); $*p < .05$; $**p < .01$; $***p < .001$.

variance in child weekday MVPA ($R^2 = .10$, $F(3, 97) = 2.66$, $p < .05$). Area-SES was not related to parent weekday MVPA ($B = -1.31$, $SE = 1.58$, $p = .41$), which did not predict child weekday MVPA ($B = .07$, $SE = .05$, $p = .21$). No significant direct effect of area-SES on child weekday MVPA ($B = -1.18$, $SE = .85$, $p = .17$) or indirect effect of area-SES on child weekday MVPA via parent weekday MVPA ($B = -.09$, $SE = .14$, 95% CI = $-.43, .11$) were observed.

Model three (see Figure 2 Model C) tested the indirect effect of area-SES on child weekend MVPA via parent weekend MVPA (SIMD score as the independent variable, child weekend MVPA as the dependent variable and parent weekend MVPA as the mediator) which explained 35.63% of the variance in child weekend MVPA ($R^2 = .13$, $F(3, 97) = 3.49$, $p = .01$). Area-SES was not related to parent weekend MVPA ($B = -.81$, $SE = 1.63$, $p = .62$); however, parent MVPA on weekend days predicted child weekend MVPA ($B = .20$, $SE = .07$, $p < .01$). The direct effect of area-SES on child weekend MVPA was not significant ($B = -1.12$, $SE = 1.09$, $p = .31$), similarly to the indirect effect of area-SES on child weekend MVPA via parents' weekend MVPA ($B = -.16$, $SE = .30$, 95% CI = $-.75, .45$).

As Model four shows (see Figure 2 Model D), no significant direct or indirect effects were found between area-SES on child MVPA for all days via parent MVPA for all days (see Figure 1d). SIMD as the independent variable, child MVPA for all days as the dependent variable and parent MVPA for all days as the mediator explained 30.98% of the variance in child MVPA for all days ($R^2 = .10$, $F(3, 97) = 2.55$, $p < .05$). Area-SES was not related to parent MVPA on all days ($B = -1.29$, $SE = 1.50$, $p = .39$), which did not predict child MVPA for all days ($B = .09$, $SE = .06$, $p = .11$). The direct effect of area-SES on child MVPA on all days was not significant ($B = -1.18$, $SE = .84$, $p = .17$), similarly to the indirect effect of area-SES on children's MVPA for all days, operating via their parents' MVPA for all days ($B = -.12$, $SE = .16$, 95% CI = $-.50, .12$).

Conclusions

The findings of this study revealed that both children and parents spent a large proportion of their time during the day inactive. Parent and child MVPA were significantly related on weekend days, but not for all days or weekdays. There were no significant indirect effects of area-SES on child MVPA via their parent's MVPA. Additionally, no significant differences between parent or child MVPA when comparing those from high and low SES were observed. For BMI, we found that parents and children with low SES had higher BMIs in comparison to those with higher SES. As expected, the BMI/BMI z-score of parent and child dyads was significantly related. There were significant negative direct and indirect effects of area-SES on the BMI z-score of child participants via the BMI of parent participants. Thus, the level of deprivation where the families resided was related to parent BMI, and parent BMI was related to their child's BMI z-score. Our findings suggest that whilst child participation in MVPA is somewhat related to parental MVPA, it is not linked to SES, whereas children's BMI is related directly to SES and indirectly influenced by SES via parents' BMI. Such results may be

useful for the implementation of health interventions targeting children living in areas of deprivation.

Findings using data from the National Health and Nutrition Examination Survey (NHANES) indicates that parent and child MVPA was only found to be related on weekend days, in which children are known to accumulate the least amount of daily MVPA (Brooke et al., 2016). As children spend a considerable amount of time during their weekdays at school away from parents, parents are less likely to influence the PA levels of their children during the week in comparison to the weekend. Some studies have examined the weekday-weekend variations of parent-child PA associations in families with 4-to-16 year-old children, with the most recent evidence suggesting that this relationship is stronger during weekends when compared to weekdays (Sigmundová et al., 2018, 2020), and parent and children engage in more PA on weekend days (Dunton et al., 2012; Sigmund et al., 2015; Sigmundová et al., 2020). Nevertheless, studies examining the relationship between parent and child PA typically fail to include separate analyses for weekday and weekend data (Jago et al., 2010; Stearns et al., 2016), therefore our findings are timely. In the current study, there were no significant effects of SES in relation to parent and child MVPA. SES has been found to be negatively related to leisure time PA in adults (Bradley, 2020) and LPA in children (Stalsberg & Pedersen, 2018). Nevertheless, research has raised questions regarding this relationship (Beenackers et al., 2012; Stalsberg & Pedersen, 2018). Equivocality in this area of research may arise from a limited quantity of studies, weak research designs, the use of self-reported measures of PA (McNeill et al., 2017) and variation in the methods employed to measure SES. A cross-sectional study exploring the relationship between children's PA and family income in rural settings found that children from lower-income families engaged in more weekly PA and indicated that parents with the lowest incomes were more likely to encourage children to be active and use their immediate environment for play, whereas more affluent parents were more likely to transport their children to activity opportunities (Cottrell et al., 2015). As such, whilst children of low SES engage in different types of activity, this does not necessarily result in a reduction of activity levels when compared with children from more affluent families. Further research is warranted nonetheless to confirm this assumption.

Parents of low SES were found to have a higher BMI. We also found significant direct and indirect effects of area-SES on child BMI z-scores, indicating that residing within areas of high deprivation may influence children's BMI both directly and indirectly via parent BMI. Previous findings have found that SES is strongly associated with the occurrence of obesity in child and adult populations (Aitsi-Selmi et al., 2013). Poor dietary behaviors are associated with living in lower SES areas, and with a greater number of unhealthy food outlets located in more deprived areas, it is unsurprising that children residing in such areas are most likely to be overweight or obese (Cetateanu & Jones, 2014). Children's exposure to obesogenic family environments such as household eating habits are considered environmental factors that contribute to health inequalities (Darmon & Drewnowski, 2008). A recent Growing up in Scotland Report from the Scottish Government (Bradshaw & Hinchliffe, 2018) found that socioeconomic circumstances caused the prevalence of overweight and obesity to vary in 10 year olds, with 25% of

children living in the least deprived areas found to be overweight or obese compared to 39% of children living in the most deprived areas. Moreover, a study exploring the relationship between children's BMI, parent obesity and SES, found that the average BMI of boys whose mothers were unemployed was higher than the BMI of boys whose mothers were employed (Tchicaya & Lorentz, 2014). Nevertheless, research indicates that the co-occurrence of multiple health behaviors including PA, arises at the family level, and that interventions aiming to improve the health of children should focus on families as a whole instead of individuals (Niermann et al., 2018). When comparing settings (i.e., inside the home and outside the home) cross-sectional research from the USA has shown that associations in mother-child objectively measured MVPA were stronger when both were at home together (Song et al., 2017). Collectively, the findings of previous research and ours provide practical implications for interventions aiming to improve children's activity levels and weight status. Taken together, this research indicates the effects that SES can have on children's health outcomes via parental weight status which highlight that family-centered, home-based interventions in areas of deprivation are important avenues to health improvement.

Notable strengths of this study include the use of ActiGraph GT3X+ devices deployed on the wrist in both parents and their child to measure MVPA. Specifically, in our sample, parents and children wore the devices for a substantial and similar amount of days, and within each day, devices were worn for a significant period. As such, our findings regarding the relationship of parent and child MVPA should be confidently interpreted. The use of mediation analyses to interpret area-SES variables which indirectly effect the MVPA of parent and child dyads is a strength of this study. To the best of our knowledge, this is the first study to examine the mediating effect of area-SES on children's MVPA and BMI z-scores operating via their parents MVPA and BMI. However, this study was not without limitations including its cross-sectional design and lack of longitudinal data prohibits drawing conclusions about causality. This study was conducted between October and May in which variation in PA may occur due to seasonal change; however, a review conducted found that no conclusion can be made regarding this influence due to the lack of studies conducted and incomparable definitions of season (Rich et al., 2012). Missing accelerometry data (i.e., the participant did not wear the device) or failure to meet the WTC reduced the sample size used in subsequent analysis. Providing no financial incentives or not being able to go back into the schools to further distribute the devices may explain the failure to meet the WTC. The exclusion of multiple participants in research exploring parent and child activity is fairly common (Solomon-Moore et al., 2018) and in order to encourage continued wear of the devices, incentives may be required for parents and children. Missing data, particularly for both household income and objectively measured BMI in parents was evident. Finally, we were unable to conduct separate analyses on different genders across parent and child dyads, and longitudinal analyses on the effects of children's increasing age on parent and child PA over time due to our limited sample and study time-frame which should also be considered a limitation. Research suggests that the PA relationships are more

pronounced in mother-child dyads than father-child ones, both on weekdays and at weekends (Jacobi et al., 2011; Sigmund et al., 2015). Nevertheless, studies examining the relationship between parent and child dyads have not clearly confirmed gender-specific PA associations. Additionally, as children grow older and reach 10–11 years of age, children's cognitive decision-making abilities increase, and they begin to assert a degree of independence from their parents (Jago et al., 2009). As such, future research should aim to explore the differences between father-child and mother-child MVPA in relation to the influence of SES and the age of the child. Whilst our sample size is relatively small, and therefore may affect the generalizability of our findings across populations, we would argue that our study only included objective MVPA and BMI data. Thus, our findings may be interpreted with some confidence, especially in comparison to previous research in this field which employs both self-reported measures for PA and BMI.

What does this article add?

This study, to the best of our knowledge, is the first paper to examine the mediating effects of SES on parent and child dyads MVPA and BMI. We found a significant relationship between parent and child MVPA on weekend days only. Whilst parent and child PA is more likely to be related when parents and their child spend time together (e.g., weekends, afterschool), MVPA is known to make up a small percentage of time spent in activity which may explain the lack of significant effects related to area-SES. Our findings demonstrate both a significant negative indirect effect of area-SES on child BMI z-score via parent BMI and a significant direct effect of area-SES on child BMI z-score which has not been explored in previous research. As such, future research should look to explore the effects of area-SES on parent and child BMI and MVPA in further detail. Gaining an in-depth perspective of these relationships may inform the development of interventions which aim to improve children's health-related outcomes through the involvement of their parent.

Acknowledgments

The authors would like to thank the children and parents who participated in this study.

Funding

This study was funded by The University of the West of Scotland.

ORCID

Samantha Donnelly  <http://orcid.org/0000-0002-1735-0600>
 Duncan S. Buchan  <http://orcid.org/0000-0002-4320-4615>
 Gillian McLellan  <http://orcid.org/0000-0002-1676-4916>
 Rosie Arthur  <http://orcid.org/0000-0003-0651-4056>

References

- Aiton, A. (2018). *Earnings in Scotland: 2018*. SPICe. <https://sp-bpr-en-prod-cdnep.azureedge.net/published/2018/11/29/Earnings-in-Scotland-2018/SB%2018-80.pdf>

- Aitsi-Selmi, A., Batty, G. D., Barbieri, M. A., Silva, A. A. M., Cardoso, V. C., Goldani, M. Z., Marmot, M. G., & Bettiol, H. (2013). Childhood socioeconomic position, adult socioeconomic position and social mobility in relation to markers of adiposity in early adulthood: Evidence of differential effects by gender in the 1978/79 Ribeirão Preto cohort study. *International Journal of Obesity* (2005), 37(3), 439–447. <https://doi.org/10.1038/ijo.2012.64>
- Australian Government. (2018). *Australia's physical activity and sedentary behaviour guidelines and the Australian 24-hour movement guidelines*. <https://www1.health.gov.au/internet/main/publishing.nsf/Content/health-pubhlth-strateg-phys-act-guidelines>
- Beenackers, M. A., Kamphuis, C. B. M., Giskes, K., Brug, J., Kunst, A. E., Burdorf, A., & Van Lenthe, F. J. (2012). Socioeconomic inequalities in occupational, leisure-time, and transport related physical activity among European adults: A systematic review. *The International Journal of Behavioral Nutrition and Physical Activity*, 9(1), 116. <https://doi.org/10.1186/1479-5868-9-116>
- Bradley, J. (2020). Socioeconomic status is associated with physical activity in leisure time only. *BMJ*, 368(8228), m24. <https://doi.org/10.1136/bmj.m4>
- Bradshaw, A., & Hinchliffe, S. (2018). *Growing up in Scotland: Overweight and obesity at age 10*. Scottish Government. <https://www.gov.scot/publications/growing-up-scotland-overweight-obesity-age-10/pages/9/>
- Bronfenbrenner, U. (1986). Ecology of the family as a context for human development: Research perspectives. *Developmental Psychology*, 22(6), 723–742. <https://doi.org/10.1037/0012-1649.22.6.723>
- Brooke, H. L., Atkin, A. J., Corder, K., Ekelund, U., & Van Sluijs, E. M. F. (2016). Changes in time-segment specific physical activity between ages 10 and 14 years: A longitudinal observational study. *Journal of Science and Medicine in Sport*, 19(1), 29–34. <https://doi.org/10.1016/j.jsams.2014.10.003>
- Brouwer, S. I., Küpers, L. K., Kors, L., Sijtsma, A., Sauer, P. J. J., Renders, C. M., & Corpeleijn, E. (2018). Parental physical activity is associated with objectively measured physical activity in young children in a sex-specific manner: The GECKO Drenthe cohort. *BMC Public Health*, 18(1), 1033. <https://doi.org/10.1186/s12889-018-5883-x>
- Cetateanu, A., & Jones, A. (2014). Understanding the relationship between food environments, deprivation and childhood overweight and obesity: Evidence from a cross sectional England-wide study. *Health & Place*, 27(100), 68–76. <https://doi.org/10.1016/j.healthplace.2014.01.007>
- Chinapaw, M. J. M., Mokkink, L. B., Van Poppel, M. N. M., Van Mechelen, W., & Terwee, C. B. (2010). Physical activity questionnaires for youth: A systematic review of measurement properties. *Sports Medicine (Auckland, N.Z.)*, 40(7), 539–563. <https://doi.org/10.2165/11530770-000000000-00000>
- Cole, T. J., Freeman, J. V., & Preece, M. A. (1995). Body mass index reference curves for the UK, 1990. *Archives of Disease in Childhood*, 73(1), 25–29. <https://doi.org/10.1136/adc.73.1.25>
- Cottrell, L., Zatezalo, J., Bonasso, A., Lattin, J., Shawley, S., Murphy, E., Lilly, C., & Neal, W. A. (2015). The relationship between children's physical activity and family income in rural settings: A cross-sectional study. *Preventive Medicine Reports*, 2, 99–104. <https://doi.org/10.1016/j.pmedr.2015.01.008>
- Craig, C. L., Cameron, C., & Tudor-Locke, C. (2013). Relationship between parent and child pedometer-determined physical activity: A sub-study of the CANPLAY surveillance study. *International Journal of Behavioral Nutrition and Physical Activity*, 10(1), 8. <https://doi.org/10.1186/1479-5868-10-8>
- Darmon, N., & Drewnowski, A. (2008). Does social class predict diet quality? *The American Journal of Clinical Nutrition*, 87(5), 1107–1117. <https://doi.org/10.1093/ajcn/87.5.1107>
- Department of Health and Social Care. (2019). *UK chief medical officers' physical activity guidelines*. UK Government.
- Dunton, G. F., Liao, Y., Almanza, E., Jerrett, M., Spruijt-Metz, D., Chou, C.-P., & Pentz, M. A. (2012). Joint physical activity and sedentary behavior in parent-child pairs. *Medicine and Science in Sports and Exercise*, 44(8), 1473–1480. <https://doi.org/10.1249/MSS.0b013e31825148e9>
- Elder, J. P., Arredondo, E. M., Campbell, N., Baquero, B., Duerksen, S., Ayala, G., Crespo, N. C., Slymen, D., & McKenzie, T. (2010). Individual, family, and community environmental correlates of obesity in Latino elementary school children. *Journal of School Health*, 80(1), 20–30. <https://doi.org/10.1111/j.1746-1561.2009.00462.x>
- Erkelens, N., Kobel, S., Kettner, S., Drenowatz, C., & Steinacker, J. M. (2014). Parental activity as influence on children's BMI percentiles and physical activity. *Journal of Sports Science & Medicine*, 13(3), 645–650. <https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4126304/>
- Eslinger, D. W., Rowlands, A. V., Hurst, T. L., Catt, M., Murray, P., & Eston, R. G. (2011). Validation of the GENEA accelerometer. *Medicine and Science in Sports and Exercise*, 43(6), 1085–1093. <https://doi.org/10.1249/MSS.0b013e31820513be>
- Fairclough, S. J., Noonan, R., Rowlands, A. V., Van Hees, V., Knowles, Z., & Boddy, L. M. (2016). Wear compliance and activity in children wearing wrist- and hip-mounted accelerometers. *Medicine and Science in Sports and Exercise*, 48(2), 245–253. <https://doi.org/10.1249/MSS.0000000000000771>
- Fuemmeler, B. F., Anderson, C. B., & Masse, L. C. (2011). Parent-child relationship of directly measured physical activity. *The International Journal of Behavioral Nutrition and Physical Activity*, 8(1), 17. <https://doi.org/10.1186/1479-5868-8-17>
- Gareth, S. (2016). Canadian 24-hour movement guidelines for children and youth: An integration of physical activity, sedentary behaviour, and sleep1. *Applied Physiology, Nutrition, and Metabolism*, 41(6 (Suppl. 3)), S311. <https://doi.org/10.1139/apnm-2016-0151>
- Gibson, L. Y., Byrne, S. M., Davis, E. A., Blair, E., Jacoby, P., & Zubrick, S. R. (2007). The role of family and maternal factors in childhood obesity. *The Medical Journal of Australia*, 186(11), 591–595. <https://doi.org/10.5694/j.1326-5377.2007.tb01061.x>
- Goisis, A., Sacker, A., & Kelly, Y. (2016). Why are poorer children at higher risk of obesity and overweight? A UK cohort study. *The European Journal of Public Health*, 26(1), 7–13. <https://doi.org/10.1093/eurpub/ckv219>
- Guthold, R., Stevens, G. A., Riley, L. M., & Bull, F. C. (2019). Global trends in insufficient physical activity among adolescents: A pooled analysis of 298 population-based surveys with 1-6 million participants. *The Lancet Child & Adolescent Health*, 4(1), 23–35. [https://doi.org/10.1016/S2352-4642\(19\)30323-2](https://doi.org/10.1016/S2352-4642(19)30323-2)
- Hallal, P. C., Andersen, L. B., Bull, F. C., Guthold, R., Haskell, W., & Ekelund, U. (2012). Global physical activity levels: Surveillance progress, pitfalls, and prospects. *The Lancet*, 380(9838), 247–257. [https://doi.org/10.1016/S0140-6736\(12\)60646-1](https://doi.org/10.1016/S0140-6736(12)60646-1)
- Hayes, A. F. (2012). *PROCESS: A versatile computational tool for observed variable mediation, moderation, and conditional process modeling*. University of Kansas, KS.
- Hernández-Valero, M. A., Wilkinson, A. V., Forman, M. R., Etzel, C. J., Cao, Y., Bárcenas, C. H., Strom, S. S., Spitz, M. R., & Bondy, M. L. (2007). Maternal BMI and country of birth as indicators of childhood obesity in children of Mexican origin. *Obesity*, 15(10), 2512–2519. <https://doi.org/10.1038/oby.2007.298>
- Hildebrand, M., Van Hees, V. T., Hansen, B. H., & Ekelund, U. (2014). Age group comparability of raw accelerometer output from wrist- and hip-worn monitors. *Medicine and Science in Sports and Exercise*, 46(9), 1816–1824. <https://doi.org/10.1249/MSS.0000000000000289>
- Jacobi, D., Caille, A., Borys, J.-M., Lommez, A., Couet, C., Charles, M.-A., & Oppert, J.-M., & FLVS Study Group. (2011). Parent-offspring correlations in pedometer-assessed physical activity. *PLoS ONE*, 6(12), e29195. <https://doi.org/10.1371/journal.pone.0029195>
- Jago, R., Fox, K. R., Page, A. S., Brockman, R., & Thompson, J. L. (2010). Parent and child physical activity and sedentary time: Do active parents foster active children? *BMC Public Health*, 10(1), 194. <https://doi.org/10.1186/1471-2458-10-194>
- Jago, R., Thompson, J. L., Page, A. S., Brockman, R., Cartwright, K., & Fox, K. R. (2009). Licence to be active: Parental concerns and 10–11-year-old children's ability to be independently physically active. *Journal of Public Health*, 31(4), 472–477. <https://doi.org/10.1093/pubmed/fdp053>
- Kitsantas, P., & Gaffney, K. F. (2010). Risk profiles for overweight/obesity among preschoolers. *Early Human Development*, 86(9), 563–568. <https://doi.org/10.1016/j.earlhumdev.2010.07.006>

- Lee, A., Cardel, M., & Donahoo, W. T. (2019). Social and environmental factors influencing obesity. In K. R. Feingold, B. Anawalt, A. Boyce, G. Chrousos, K. Dungan, A. Grossman, J. M. Hershman, G. Kaltsas, C. Koch, P. Kopp, M. Korbonits, R. McLachlan, J. E. Morley, M. New, L. Perreault, J. Purnell, R. Rebar, F. Singer, D. L. Trencle, & D. P. Wilson (Eds.), *Endotext* (pp. 1–52). MDText.com, Inc. <http://www.ncbi.nlm.nih.gov/books/NBK278977/>
- Marmot, M. (2005). Social determinants of health inequalities. *Lancet (London, England)*, 365(9464), 1099–1104. [https://doi.org/10.1016/S0140-6736\(05\)71146-6](https://doi.org/10.1016/S0140-6736(05)71146-6)
- McLellan, G., Arthur, R., & Buchan, D. S. (2018). Wear compliance, sedentary behaviour and activity in free-living children from hip- and wrist-mounted ActiGraph GT3X+ accelerometers. *Journal of Sports Sciences*, 36(21), 2424–2430. <https://doi.org/10.1080/02640414.2018.1461322>
- McMinn, A. M., Griffin, S. J., Jones, A. P., & Van Sluijs, E. M. F. (2013). Family and home influences on children's after-school and weekend physical activity. *European Journal of Public Health*, 23(5), 805–810. <https://doi.org/10.1093/eurpub/cks160>
- McNeill, G., Masson, L. F., Macdiarmid, J. I., Craig, L. C., Wills, W. J., & Bromley, C. (2017). Socio-economic differences in diet, physical activity and leisure-time screen use among Scottish children in 2006 and 2010: Are we closing the gap? *Public Health Nutrition*, 20(6), 951–958. <https://doi.org/10.1017/S1368980016002949>
- Ndahimana, D., & Kim, E.-K. (2017). Measurement methods for physical activity and energy expenditure: A review. *Clinical Nutrition Research*, 6(2), 68–80. <https://doi.org/10.7762/cnr.2017.6.2.68>
- Niermann, C. Y. N., Spengler, S., & Gubbels, J. S. (2018). Physical activity, screen time, and dietary intake in families: A cluster-analysis with mother-father-child triads. *Frontiers in Public Health*, 6, 276. <https://doi.org/10.3389/fpubh.2018.00276>
- Noonan, R. J., Boddy, L. M., Knowles, Z. R., & Fairclough, S. J. (2016). Cross-sectional associations between high-deprivation home and neighbourhood environments, and health-related variables among Liverpool children. *BMJ Open*, 6(1), e008693. <https://doi.org/10.1136/bmjopen-2015-008693>
- O'Donoghue, G., Kennedy, A., Puggina, A., Aleksovska, K., Buck, C., Burns, C., Cardon, G., Carlin, A., Ciarapica, D., Colotto, M., Condello, G., Coppinger, T., Cortis, C., D'Haese, S., De Craemer, M., Di Blasio, A., Hansen, S., Iacoviello, L., Issartel, J., & Boccia, S. (2018). Socio-economic determinants of physical activity across the life course: A 'DEterminants of DIet and Physical ACTivity' (DEDIPAC) umbrella literature review. *PLoS ONE*, 13(1), e0190737. <https://doi.org/10.1371/journal.pone.0190737>
- Pan, H., & Cole, T. J. (2010). *LMSchartmaker, a program to construct growth references using the LMS method*. Retrieved July 2016, from <http://healthforallchildren.com/?product=lmsgrowth>
- Rich, C., Griffiths, L. J., & Dezauteux, C. (2012). Seasonal variation in accelerometer-determined sedentary behaviour and physical activity in children: A review. *International Journal of Behavioral Nutrition and Physical Activity*, 9(1), 49. <https://doi.org/10.1186/1479-5868-9-49>
- Rowlands, A. V., Plekhanova, T., Yates, T., Mirkes, E. M., Davies, M., Khunti, K., & Edwardson, C. L. (2019). Providing a basis for harmonization of accelerometer-assessed physical activity outcomes across epidemiological datasets. *Journal for the Measurement of Physical Behaviour*, 2(3), 131–142. <https://doi.org/10.1123/jmpb.2018-0073>
- Sallis, J. F., Bull, F., Guthold, R., Heath, G. W., Inoue, S., Kelly, P., Oyeyemi, A. L., Perez, L. G., Richards, J., & Hallal, P. C., & Lancet Physical Activity Series 2 Executive Committee. (2016). Progress in physical activity over the olympic quadrennium. *Lancet (London, England)*, 388(10051), 1325–1336. [https://doi.org/10.1016/S0140-6736\(16\)30581-5](https://doi.org/10.1016/S0140-6736(16)30581-5)
- Scaglioni, S., De Cosmi, V., Ciappolino, V., Parazzini, F., Brambilla, P., & Agostoni, C. (2018). Factors influencing children's eating behaviours. *Nutrients*, 10(6), 706. <https://doi.org/10.3390/nu10060706>
- Scottish Government. (2016). *Scottish Index of Multiple Deprivation (SIMD)*. Scottish Index of Multiple Deprivation 2016. <http://simd.scot/2016/>
- Sigmund, E., Sigmundová, D., Baďura, P., & Voráčová, J. (2015). Relationship between Czech parent and child pedometer-assessed weekday and weekend physical activity and screen time. *Central European Journal of Public Health*, 23(Suppl), S83–90. <https://doi.org/10.21101/cejph.a4181>
- Sigmundová, D., Badura, P., Sigmund, E., & Bucksch, J. (2018). Weekday-weekend variations in mother-/father-child physical activity and screen time relationship: A cross-sectional study in a random sample of Czech families with 5- to 12-year-old children. *European Journal of Sport Science*, 18(8), 1158–1167. <https://doi.org/10.1080/17461391.2018.1474951>
- Sigmundová, D., Sigmund, E., Badura, P., & Hollein, T. (2020). Parent-child physical activity association in families with 4- to 16-year-old children. *International Journal of Environmental Research and Public Health*, 17(11), 4015. <https://doi.org/10.3390/ijerph17114015>
- Solomon-Moore, E., Toumpakari, Z., Sebire, S. J., Thompson, J. L., Lawlor, D. A., & Jago, R. (2018). Roles of mothers and fathers in supporting child physical activity: A cross-sectional mixed-methods study. *BMJ Open*, 8(1), e019732. <https://doi.org/10.1136/bmjopen-2017-019732>
- Song, M., Dieckmann, N. F., Stoyles, S., Kim, Y., & Lumeng, J. C. (2017). Associations between mother's and children's moderate-to-vigorous physical activity and sedentary time in the family context. *Preventive Medicine Reports*, 8, 197–203. <https://doi.org/10.1016/j.pmedr.2017.10.012>
- Stalsberg, R., & Pedersen, A. V. (2018). Are differences in physical activity across socioeconomic groups associated with choice of physical activity variables to report? *International Journal of Environmental Research and Public Health*, 15(5), 922. <https://doi.org/10.3390/ijerph15050922>
- Stearns, J. A., Rhodes, R., Ball, G. D. C., Boule, N., Veugelers, P. J., Cutumisu, N., & Spence, J. C. (2016). A cross-sectional study of the relationship between parents' and children's physical activity. *BMC Public Health*, 16(1), 1129. <https://doi.org/10.1186/s12889-016-3793-3>
- Strutz, E., Browning, R., Smith, S., Lohse, B., & Cunningham-Sabo, L. (2018). Accelerometry-derived physical activity correlations between parents and their fourth-grade child are specific to time of day and activity level. *Journal of Physical Activity and Health*, 15(6), 440–447. <https://doi.org/10.1123/jpah.2016-0645>
- Tchicaya, A., & Lorentz, N. (2014). Relationship between children's body mass index and parents' obesity and socioeconomic status: A multilevel analysis applied with Luxembourg data. *Health*, 6(17), 2322. <https://doi.org/10.4236/health.2014.617267>
- Trost, S. G., & Loprinzi, P. D. (2011). Parental influences on physical activity behavior in children and adolescents: A brief review. *American Journal of Lifestyle Medicine*, 5(2), 171–181. <https://doi.org/10.1177/1559827610387236>
- U.S. Centers for Disease Control and Prevention. (2016). *Adult obesity causes & consequences | Overweight & obesity | CDC*. Division of Nutrition, Physical Activity, and Obesity, National Center for Chronic Disease Prevention and Health Promotion. <https://www.cdc.gov/obesity/adult/causes.html>
- U.S. Department of Health and Human Services. (2018). *Physical activity guidelines for Americans. Advisory committee report 2018*. U.S. Public Health Service. Retrieved March 7, 2018, from <https://health.gov/paguidelines/second-edition/report.aspx>
- Van Hees, V. T., Fang, Z., Langford, J., Assah, F., Mohammad, A., Da Silva, I. C. M., Trenell, M. I., White, T., Wareham, N. J., & Brage, S. (2014). Autocalibration of accelerometer data for free-living physical activity assessment using local gravity and temperature: An evaluation on four continents. *Journal of Applied Physiology (Bethesda, MD.: 1985)*, 117(7), 738–744. <https://doi.org/10.1152/jappphysiol.00421.2014>
- Van Hees, V. T., Gorzelniak, L., León, E. C. D., Eder, M., Pias, M., Taherian, S., Ekelund, U., Renström, F., Franks, P. W., Horsch, A., &

- Brage, S. (2013). Separating movement and gravity components in an acceleration signal and implications for the assessment of human daily physical activity. *Plos One*, 8(4), e61691. <https://doi.org/10.1371/journal.pone.0061691>
- Withrow, D., & Alter, D. A. (2011). The economic burden of obesity worldwide: A systematic review of the direct costs of obesity. *Obesity Reviews: An Official Journal of the International Association for the Study of Obesity*, 12(2), 131–141. <https://doi.org/10.1111/j.1467-789X.2009.00712.x>
- World Health Organization. (2018a). *Obesity and overweight*. <https://www.who.int/news-room/fact-sheets/detail/obesity-and-overweight>
- World Health Organization. (2018b, August 21). *Body Mass Index (BMI)*. <http://www.euro.who.int/en/health-topics/disease-prevention/nutrition/a-healthy-lifestyle/body-mass-index-bmi>
- Xu, H., Wen, L. M., & Rissel, C. (2015). Associations of parental influences with physical activity and screen time among young children: A systematic review. *Journal of Obesity*, 2015, 1–23. <https://doi.org/10.1155/2015/546925>