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Complete List of Authors:	Fraysse, Francois; University of South Australia, Sansom Institute, Alliance for Research in Exercise, Nutrition and Activity (ARENA) Grobler, Anneke; Murdoch Children's Research Institute Muller, Josh; Murdoch Children's Research Institute Wake, Melissa; Murdoch Children's Research Institute; The University of Melbourne, Department of Paediatrics Olds, Timothy; University of South Australia, Sansom Institute, Alliance for Research in Exercise, Nutrition and Activity (ARENA)
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Physical activity and sedentary activity: Population epidemiology and concordance in 11-12 year old Australians and their parents

Authors: François Fraysse[1], Anneke Grobler[2], Josh Muller[2], Melissa Wake[2,3,4],Tim Olds[1]

Affiliations: [1]Sansom Institute, Alliance for Research in Exercise, Nutrition and Activity (ARENA), University of South Australia, Adelaide, SA, Australia; [2]Murdoch Children's Research Institute, Parkville, VIC, Australia; [3]Department of Paediatrics, The University of Melbourne, Parkville, Victoria, Australia; [4]Department of Paediatrics & The Liggins Institute, The University of Auckland, Auckland, New Zealand

Correspondence to: Professor Melissa Wake
Murdoch Children's Research Institute
The Royal Children's Hospital
50 Flemington Road, Parkville VIC 3052, AUSTRALIA
T: +61 3 9345 5937
E: melissa.wake@mcri.edu.au

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Abbreviations: α: alpha; ARENA: Alliance for Research in Exercise, Nutrition and Activity; BMI: body mass index; CC: correlation coefficient; CI: confidence interval; CL: confidence level; dur.: duration; frag.; fragmentation; g.min: units of acceleration from GeneActiv devices (g: gravity units, min: minutes); I^2: heterogeneity index; LSAC: Longitudinal Study of Australian Children; MPA: moderate physical activity; MVPA: moderate-to-vigorous physical activity; n: sample size; PA: physical activity; r: Pearson's correlation coefficient; RC: estimated regression coefficient; SB: sedentary behaviours; SD: standard deviation; SVM: signal vector magnitude; TDEE: total daily energy expenditure; VPA: vigorous physical activity.

ABSTRACT

Objectives: To describe the epidemiology and parent-child concordance of objectively measured physical activity in a population-based sample of Australian parent-child dyads at child age 11-12 years.

Design: Cross-sectional study (Child Health CheckPoint) nested within the Longitudinal Study of Australian Children.

Setting: Assessment centres in seven Australian cities and eight regional towns, or home visits; February 2015-March 2016.

Participants: Of all CheckPoint families (n=1,874), 1261 children (50% girls) and 1358 parent (88% mothers) provided objectively measured activity data, comprising 1,077 parent-child dyads.

Outcome measures: Activity behaviour was assessed by GENEActiv accelerometer. Duration of moderate-to-vigorous and vigorous physical activity (MVPA, VPA) and sedentary behaviour (SB) were derived using *Cobra* custom software, along with MVPA/SB fragmentation and mean daily activity. Pearson's correlation coefficients and linear regression estimated parent-child concordance. Survey weights and methods accounted for the complex sample design and clustering.

Results: Although parents had average lower accelerometry counts than children (mean (standard deviation, SD) 209 (46) vs 284 (71) g.min), 93% of parents met MVPA daily duration guidelines on published cutpoints (mean (SD) 125 (63) minutes/day MVPA), compared to only 15% of children (mean 32 (27) minutes). Parents showed less daily SB duration (parents 540 (101), children 681 (69) minutes) and less fragmented accumulation of MVPA (parents α=1.85, children 2.00). Parent-child correlation coefficients were 0.16 (95% CI 0.11 to 0.22) for MVPA duration, 0.10 (95% CI 0.04 to 0.16) for MVPA fragmentation, 0.16 (95% CI 0.11 to 0.22) for SB duration, and 0.18 (95% CI 0.12 to 0.23) for SB fragmentation.

Conclusions: Standardised cutpoints are needed for objective activity measures to inform activity guidelines across the lifecourse. Modest parent-child concordances for objectively-measured activity behaviours at the population level align with previous heritability estimates of around 30%, mainly from self-report studies. This may reflect large amounts of time in non-shared environments (school, work).

Strengths and limitations of the study

- This study used valid, reliable, objective, free-living measures of Australian children and parent activity patterns. The sample is drawn from a nationally-representative cohort.
- We report for the first time parent-child concordance in objective activity duration and fragmentation.
- Although the accelerometry measurements were objective, the multiple choices needed in processing the data could have impacted on the results, requiring caution incomparisons of absolute values with other studies.
- Findings apply to a narrow child age range (11-12 years); parent-child concordance could evolve as children grow up.
- Most adults were mothers, limiting conclusions for fathers and for adults who are not parents.

INTRODUCTION

Physical activity (PA) and sedentary behaviour (SB) have both been independently linked to a wide range of health outcomes in children[1 2] and adults.[3 4] Furthermore, some studies have suggested that, independent of duration, other characteristics of PA and/or SB impact on health. Recent studies have shown that less fragmentation of sedentary time (more long bouts) is associated with obesity and health markers.[5 6] Similarly, higher intensity[7], more continuous[8] bouts of physical activity have been associated with better health outcomes, and most physical activity guidelines contain recommendations regarding the distribution of PA.[9 10] Finally, vigorous PA has added benefits compared to overall moderate-to-vigorous physical activity (MVPA)[1], and some physical activity guidelines[10 11] provide recommendations on the amount of vigorous physical activity (VPA) in addition to MVPA recommendations.

Patterns of activity and sitting result from both genetic and environmental factors,[12] so we would expect a degree of concordance between children's activity patterns and those of their parents, arising from shared genes and shared environments. Shared environments include geographical, climatic and financial contexts, but also social factors such as parental modeling and direct parental involvement. Child-to-parent effects may also play a role. Genetic factors may relate to the heritability of personality traits associated with adherence to PA (conscientiousness, self-motivation, self-discipline), reward-associated hormonal responses to exercise (dopamine, endogenous opioids), or physiological characteristics such as aerobic fitness and strength which encourage participation in sport.

While a high parent-child concordance may be a marker of strong genetic or shared environmental determinants, a lower correlation may indicate greater importance for the non-shared environment — notably the school environment for children and the work environment for parents. School in particular may be a homogenising influence, since at school all children have a very similar daily activity pattern. In terms of interventions, a high concordance would either suggest that interventions may be ineffective (if there is a large non-modifiable genetic component) or that the focus should be on the shared environment. A low concordance may be a marker of relatively high behavioural malleability, with an appropriate focus on the non-shared environment.

Advances in wearable technology have made it possible to objectively measure PA and SB, and a number of studies have quantified free-living activity in children[12-14] and adults.[14-16]

Estimates of the proportion of variability in measured OA which can be scairbed to additive genetic effects range from 20 to 71%.[12 17] The differences may be due to the age of the participants, the powerful effect of the shared school environment, or to the use of less accurate questionnaire data.

To review current literature on parent-child concordance in PA and SB, we used a systematic search to synthesise data from 26 studies[18-41] from 11 mainly European and North American countries. This yielded a total of 119 correlations between parental and child PA (Figure 1). Correlations were classified according to (1) the type of PA measured (sport, exercise, vigorous PA [VPA], moderate PA [MPA], recreational PA, leisure-time PA were all classified as MVPA); estimates of overall energy expenditure were classified as total daily energy expenditure (TDEE); (2) the age of the child; (3) the sex of the parent; (4) the sex of the child; and (5) assessment methodology (questionnaires were classified as subjective; accelerometry, pedometry and direct observation as objective). Using a random effects approach, the overall weighted mean correlation for all PA outcomes was 0.18 (95% confidence level (CL) 0.15-0.21) (Figure 1). Correlations did not differ by outcome (MVPA r=0.18, TDEE r = 0.26), sex of parent (father r=0.23, mother r=0.18), sex of child (daughter r=0.20, son r=0.23), or assessment methodology (subjective r=0.20, objective r=0.17). Heterogeneity was high for all analyses (I^2>55). Only four studies[20 22 23 38] from the UK, Finland and the USA, with a total of 24 correlations, looked at parent-child concordance in some measure of SB (sitting, TV or inactivity). The overall weighted mean correlation was 0.26 (0.17-0.35). Heterogeneity was high (I^2=72).

The sample sizes in most of the PA and SB studies were relatively modest (median n=192), and in only 7 of 26 studies were the activity patterns of both parent and child objectively measured. None of the studies was performed in Australia. Furthermore, these studies only addressed parent-child concordance in the duration of PA or SB, or total daily activity levels, with no data on fragmentation.

The aims of this study were to:

• Report the mean values and distributions of PA and SB, and their fragmentation, in a large, population-based sample of Australian children aged 11-12 years and Australian mid-life adults (their parents); and

• Quantify parent-child concordance in objectively-measured PA and SB duration and fragmentation.

METHODS

Study design and participants: The initial study design and recruitment have been described in detail elsewhere.[42 43] LSAC commenced in 2004, recruiting a nationally representative B cohort of 5107 infants through a two-stage cluster sample design,[44] whereby 10% of all Australian postcodes were randomly selected, stratified by state and urban/rural and in-age children were then randomly selected from the Medicare database.[45 46] 73.7% (n=3764) of participants were retained to LSAC wave 6 in 2014.

At the start of wave 6, all contactable and consenting families were invited to consent to their contact details being shared with the Child Health CheckPoint team (n=3513). In 2015, consenting families were sent an information pack via post and received an information and recruitment phone call. The CheckPoint study was conducted from February 2015 to March 2016, between LSAC waves 6 and 7 (children's age 11-12 years), and 1,874 families participated. A more detailed description of the CheckPoint study design is provided elsewhere.[47 48]

Ethics and Consent: The CheckPoint study protocol was approved by The Royal Children's Hospital (Melbourne, Australia) Human Research Ethics Committee (33225D) and Australian Institute of Family Studies Ethics Committee (14-26). The attending parent provided written informed consent for them and their child to participate in the study.

Patient and Public Involvement: No patient groups were involved in the design or conduct of LSAC, a population-based longitudinal study. To our knowledge, the public was not involved in the study design, recruitment or conduct of LSAC study or its CheckPoint module. Parents received a summary health report for their child and themselves after the assessment visit. They consented to take part knowing that they would not otherwise receive individual results about themselves or their child.

Procedure: All measures were collected at a specialised 3.5 hour (7 capital cities and larger regional towns) or 2.5 hour (8 smaller regional centres) CheckPoint assessment centre visit. 365 families who could not attend a centre received a 1.5 hour home visit. At the end of the visit, a trained research assistant fitted a GENEActiv accelerometer (Activinsights Ltd., UK) on the non-dominant wrist of each child and parent, and provided each with an activity card (see below). Participants were instructed to wear the device at all times for eight continuous days, starting the day of the visit, removing it only for prolonged water immersion

(swimming, bath) or as prescribed by some contact sports rules (eg netball). After eight days, participants returned the device, together with the completed activity card using the pre-paid postal envelope provided.

Physical activity measures:

Activity cards: The activity cards were paper-based logs in a table format with fields for each day of the monitoring period to allow participants to write the following:

1. At what time they went to bed at night ("bed time"),
2. At what time they woke up in the morning ("get up time"),
3. If they took the device off, at what times it was removed and put back on, as well as the reason for removal, and
4. A brief description of their day (eg "school", "travel", "unwell resting"…).

Once returned, activity cards were transcribed in electronic form by research assistants, to be used in the processing of the accelerometer data (see below for details). Reliability testing of card transcription is described in Appendix 1.

Accelerometers were configured through the manufacturer's software (GENEActiv PC Software, Activinsights, UK) to record at 50 Hz for 14 days, starting at midnight following the CheckPoint visit. The 14 days recording duration was chosen to ensure enough valid days were recorded in case the participant could not wear the device for some days and the total monitoring duration had to be extended.

After the device was returned, the research team downloaded the raw acceleration data. The Signal Vector Magnitude (SVM) of the acceleration, minus gravity, was computed and summed over 60 second epochs:

$$SVM = \sum_{60s} \left| \sqrt{a_X^2 + a_Y^2 + a_Z^2} - g \right|$$

where a_x, a_y, a_z are the three components of the acceleration signal and g the acceleration of gravity (9.81 m/s^2). The 60 second epoch data was then imported into custom Matlab software for further processing. This software (*Cobra*, developed at the University of South Australia) provides a user-friendly graphical user interface for processing accelerometer data.

First, sleep was identified using the activity cards completed by the participants. Sleep times were corrected by visual inspection when necessary, that is, in case sleep times were not reported or when obvious discrepancies were observed between reported sleep and

accelerometer trace. Following this, device removals (non-wear) were identified using the activity cards and excluded from analysis. Where the reason given for removal was "sport", the removal period was replaced with a period of MVPA. This was done because (1) most children were not allowed to wear the watch for some sport activities (eg netball, swimming), and (2) these sport activities often made for a large part of daily MVPA, so ignoring them would potentially result in a large underestimation of daily MVPA. Duration of vigorous physical intensity (VPA) was also obtained for each participant.

A day was considered invalid and excluded from analysis if it included ≤10 hours wear during waking hours,[14] or if it included ≥1000 minutes (16 h 40 minutes) of sedentary time (reflecting a day of non-wear not captured by the self-report logs, typically after the end of the recording period). A participant was considered invalid and excluded from analysis if they provided <4 valid days of accelerometry data[14 49] or if they had ≤200 minutes average sleep time.

Each 60 second epoch of waking wear time was then classified into one of four physical activity levels: sedentary, light, moderate or vigorous PA. Cutpoints for PA levels were defined according to Esliger et al.[50] for parents and Phillips et al.[51] for children, and adjusted proportionally to account for the 50 Hz sampling frequency. The resulting cutpoints between sedentary and light, light and moderate, and moderate and vigorous PA were 188, 403 and 1131 gravity units per minute (g.min) for adults, and 244, 788 and 2175 g.min for children, respectively.

Fragmentation of sedentary and MVPA time was characterised using the method described by Chastin et al.[52] The measure of fragmentation (α) was the slope of the regression line of the relative frequency of a bout (of MVPA or SB) plotted against bout length on a log scale. For SB, α was calculated on a per-day basis. However, α for MVPA was calculated using all valid days combined for a given participant, because a good curve fit required more bouts of MVPA than were usually available in a single day. In the present study α was multiplied by -1 so that it is always positive. Higher values of α indicate greater fragmentation, i.e. fewer long bouts - considered desirable for SB - and lower values of α less fragmentation and more prolonged bouts.

Other sample characteristics including potential confounders: Age and sex affect physical activity patterns, which in turn were expected to influence parent-child correlations. Sex and date of birth were exported from Medicare Australia's database at the time of LSAC

enrolment (for the child) or self-reported (parent). Age was rounded to nearest week by calculating the days between the participant's date of birth and date of assessment.

Adjustment was also made for socio-economic status because it is shared by parents and children and is correlated to physical activity and sedentary behaviour patterns. Socio-economic status was determined from the postcode of the participant's primary address using the Socio-Economic Indicators for Areas (SEIFA) 2011 Index of Relative Social Disadvantage (disadvantage index), which factors in household education levels, income, employment status, and disability. The population mean score for Australia is 1000 (standard deviation (SD) 100), with higher scores representing greater advantage.

Statistical analysis: All accelerometry outcome variables were computed for each individual day, then averaged over days for each valid participant using a 5:2 weighting for work/school days versus weekend/holidays.

Objective physical activity variables were described for all children and adults using means and SD. Population summary statistics were estimated by applying survey weights and survey procedures that corrected for sampling, participation and non-response biases, and took into account clustering in the sampling frame. Standard errors were calculated taking into account the complex design and weights. More detail on the calculation of weights is provided elsewhere.[53]

For each of the 1077 biological child-parent pairs, concordance between parents and children was assessed by: 1) Pearson's correlation coefficients with 95% confidence intervals; and 2) linear regression with the child variable as the dependent variable and the parent variable as the independent variable. Linear regression models were adjusted for parent and child age and sex (in models including both sexes), and socioeconomic disadvantage index. As there were only minimal differences between unweighted and weighted results, only the former are presented here.

Data were analysed using Stata version 14.2 (StataA Corp., College Station, TX).

RESULTS

Sample characteristics: Figure 2 shows that valid accelerometry data were obtained for 1261 children (50% female) and 1358 parents, allowing the analysis of 1077 child-parent pairs. Table 1 shows the participant characteristics. Most parents were mothers (88%).

Overall, participants were slightly more advantaged than the average Australian household, with a mean disadvantage index of about 0.1 SD above the Australian average and a narrower spread (SD 64) than the national SD of 100. Body mass index (BMI) for parents and children were comparable with general population values for adults and children of the same age.[54]

Table 1. Participant characteristics (weighted mean and SD).

Characteristic	All			Male			Female		
Child	**n**	**mean***	**SD***	**n**	**mean***	**SD***	**n**	**mean***	**SD***
Age (years)	1261	12.0	0.4	632	12.0	0.4	629	12.0	0.4
BMI (kg/m^2)	1260	19.3	3.5	631	19.2	3.5	629	19.4	3.6
Disadvantage Index	1257	1010	64	629	1010	63	628	1010	65
Parent	**n**	**mean***	**SD***	**n**	**mean***	**SD***	**n**	**mean***	**SD***
Age (years)	1358	43.9	5.6	167	46.3	7.1	1191	43.6	5.3
BMI (kg/m^2)	1350	28.0	6.4	167	28.8	5.1	1183	27.9	6.5

n: sample size; SD: standard deviation; BMI: body mass index.

Physical activity characteristics

Table 2 presents the PA characteristics of all valid participants, including MVPA and SB duration and fragmentation, and VPA duration. Figure 3 shows the distributions of SB and MVPA duration for both parents and children. Parents had on average lower accelerometry counts than children (mean (SD) 209 (46) vs 284 (71) g.min). Overall, children accumulated an average of 32 minutes of MVPA per day, with boys having overall higher MVPA duration (40 minutes/day) than girls (24 minutes/day). Variability (SD of the duration) was large for both boys and girls, relative to the mean (SD 30 and 22 minutes, respectively). Adults' MVPA duration was 142 and 122 minutes/day for mothers and fathers respectively, and the variability (SD 69 and 62 minutes for fathers and mothers respectively) was lower than in children relative to the mean. 15% of children and 93% of parents met MVPA recommendations of 60 and 30 minutes/day respectively. However, it is important to note that children's and parents' MVPA and SB durations are not directly comparable, because different cutpoints are used. Overall, children exhibited a more fragmented pattern of accumulation of MVPA (higher α) than parents, with an overall average α of 2.00 for children and 1.85 for parents.

The sedentary time of boys and girls was , averaging 679 and 684 minutes respectively. This was larger than parents, with 555 and 538 minutes for fathers and mothers, respectively. Parents also exhibited a more fragmented accumulation of SB (α = 2.45) than children (α = 2.13).

Table 2. Distribution of sedentary behaviour and physical activity, weighted for day type.

Activity measure	All				Male				Female			
	n	mean	SD	95% CI	n	mean	SD	95% CI	n	mean	SD	95% CI
Children												
MVPA duration (min)	1261	32.0	27.2	30.3 to 33.7	632	39.5	30.0	36.8 to 42.3	629	24.4	21.9	22.7 to 26.1
MVPA fragmentation, α	1259	2.00	0.18	1.99 to 2.02	631	1.96	0.17	1.94 to 1.98	628	2.05	0.17	2.03 to 2.06
VPA duration (min)	1261	10.0	19.1	8.9 to 11.1	632	11.2	20.7	9.4 to 13.0	629	8.8	17.6	7.5 to 10.2
SB duration (min)	1261	681.3	68.6	676.8 to 685.8	632	679.0	72.5	671.9 to 686.0	629	683.7	65.3	677.9 to 689.5
SB fragmentation, α	1261	2.13	0.17	2.12 to 2.14	632	2.11	0.17	2.10 to 2.13	629	2.14	0.18	2.12 to 2.16
Average daily activity (g.min)	1261	283	69	278 to 287	632	297	76	290 to 304	629	268	60	263 to 273
Parents												
MVPA duration (min)	1358	124.5	62.5	120.0 to 128.9	167	141.6	68.8	127.1 to 156.1	1191	122.1	61.6	117.6 to 126.6
MVPA fragmentation (α)	1358	1.85	0.09	1.85 to 1.86	167	1.83	0.09	1.81 to 1.85	1191	1.86	0.1	1.85 to 1.87
VPA duration (min)	1358	7.0	12.3	6.3 to 7.8	167	9.4	14.5	6.7 to 12.1	1191	6.7	12.0	6.0 to 7.4
SB duration (min)	1358	539.7	101.0	532.4 to 546.9	167	555.4	121.8	531.0 to 579.7	1191	537.5	98.2	530.1 to 545.0
SB Fragmentation (α)	1356	2.45	0.28	2.43 to 2.48	167	2.43	0.31	2.4 to 2.5	1189	2.46	0.28	2.44 to 2.48
Average daily activity (g.min)	1358	210	48	206 to 213	167	217	54	206 to 228	1191	209	47	205 to 212

CI: confidence interval; min: minutes; MVPA: Moderate-to-Vigorous Physical activity; n: sample size; SB: Sedentary Behaviours; VPA: Vigorous Physical Activity; g.min: gravity units per minute

Child-parent concordance

Table 3 presents the correlation (CC) and regression (RC) coefficients estimates between the children and their parents, for each of the five PA metrics. Overall, there were small but significant correlations between children's and parents' PA behaviours. Between mothers and children, all five PA variables were significantly correlated. Correlations were weak for SB, VPA and MVPA duration, and SB fragmentation, and very weak for MVPA fragmentation (0.11). Between fathers and children, only VPA duration and SB fragmentation were significantly associated ($r = 0.29$ and 0.12 respectively, both $p<0.05$), however the sample size was smaller.

Table 3. Parent-child concordance. The upper panel shows unadjusted values, and the lower panel values adjusted for parent and child age and sex, and Disadvantage Index.

	Parent-child			Father-child			Mother-child		
Pearson's Correlation	**n**	**CC**	**95% CI**	**n**	**CC**	**95% CI**	**n**	**CC**	**95% CI**
MVPA duration (min)	1077	0.16	0.11 to 0.22	128	0.13	-0.05 to 0.29	949	0.17	0.11 to 0.23
MVPA fragmentation (α)	1076	0.10	0.04 to 0.16	128	0.04	-0.13 to 0.22	948	0.11	0.05 to 0.18
VPA duration (min)	1077	0.19	0.14 to 0.25	128	0.24	0.07 to 0.40	949	0.19	0.13 to 0.25
SB duration (min)	1077	0.16	0.11 to 0.22	128	0.13	-0.05 to 0.29	949	0.17	0.11 to 0.24
SB fragmentation (α)	1075	0.18	0.12 to 0.23	128	0.22	0.05 to 0.38	947	0.17	0.11 to 0.23
Linear Regression (adjusted for covariates)	**n**	**RC**	**P-value**	**n**	**RC**	**P-value**	**n**	**RC**	**P-value**
MVPA duration (min)	1076	0.32	<0.001	127	0.20	0.24	949	0.29	<0.001
MVPA fragmentation (α)	1075	0.20	0.001	127	0.04	0.84	948	0.15	0.001
VPA duration (min)	1076	0.23	<0.001	127	0.27	0.03	949	0.23	<0.001
SB duration (min)	1076	0.11	<0.001	127	0.10	0.07	949	0.09	<0.001
SB fragmentation (α)	1074	0.11	0.001	127	0.13	0.01	947	0.08	<0.001

Covariates in adjusted linear regression models include parent and child age and sex, and Disadvantage Index. CC: correlation coefficient; CI: confidence interval; MVPA: Moderate-to-Vigorous Physical activity; n: sample size; RC: estimated regression coefficient; SB: Sedentary Behaviours; VPA: Vigorous Physical Activity

DISCUSSION

Principal findings: This study provides normative values for device-measured activity behaviour in a large sample of Australian mid-life adults and 11-12 year old children. Using the specific combination of device and analytical algorithms in this study, children accumulated on average 32 minutes of MVPA each day, of which 10 minutes were VPA. Using different cut-points, adults accumulated 125 minutes/day of MVPA, but only 7 minutes/day of VPA. Children had higher levels of sedentary time (681 minutes/day) than adults (540 minutes/day). Children's MVPA was more fragmented than that of their parents, while sedentary time was less fragmented. Concordance between children and parents for MVPA, VPA and sedentary time duration and fragmentation was weak to moderate, ranging between r=0.04 and r=0.24.

Strengths and limitations: The CheckPoint physical activity study is the largest accelerometry-based cross-generational study of activity in Australia. It is also the first to report concordance of physical activity and sedentary behaviours between parents and 11-12 year old children. This study reports valid, reliable, objective, free-living measures of child and parent physical activity patterns and their concordance from a large national sample. Data were collected simultaneously for parents and children using the same protocol. To our knowledge, this is the first study to report metrics for intensity and fragmentation of PA and SB.

Limitations include the relatively small number of fathers, reducing precision of their estimates. Only one parent was included for each child; this is nonetheless one of very few studies that present separate (but largely similar) mother-child and father-child concordance estimates. Secondly, the sample in this study, while drawn from a cohort which was designed to be nationally representative, was subject both to selective update and attrition. This might have affected both activity and the impacts of BMI on activity, and perhaps concordance values. Furthermore, the age range of the children was narrow (11 to 12 years).

Significance and meaning:

Duration of physical activity and sedentary time: Accelerometry-based assessment of physical activity has well-known limitations. Results depend not only on the accelerometer device itself,[56] but more importantly on the choice of algorithms and processes used, such as sampling frequency, raw data filtering, epoch length, and cutpoint values. At present, there is no consensus on the choice of processes.[57] A recent review has identified wide discrepancies

in processing parameters,[49] with some of these choices having a large impact on results. For example, one study showed that MVPA estimates can vary from 23 to 269 minutes/day for children, depending on the choice of cutpoints. This makes comparison between studies and across the lifecourse difficult.

In spite of this, estimated MVPA and sedentary durations in the CheckPoint study were in line with findings from several previous studies. For instance, Telford et al[58] reported averages of 43 and 31 minutes/day of MVPA for 8-12 year old boys and girls respectively. The ISCOLE study used Actigraph GT3X+ accelerometers, finding that 10 year old boys accumulated 75 minutes/day MVPA, and girls 57 minutes/day.[59] In adults, Rosenberger et al[60] reported MVPA durations of 100 to 220 minutes/day depending on the device used. Recently, Rowlands et al[56] reported average MVPA durations of 92 minutes/day for a small adult sample, using the GeneActiv.

It is unlikely that adults actually do accumulate more MVPA than children. Doubly-labeled water studies show that total daily energy expenditure declines with age,[61] so that the differences in this study between children and adults are probably artefacts of using different cutpoints. The average overall daily activity counts are larger for children than parents (284 vs 209 g.min, respectively), as expected. The lack of consistency in the use of cutpoints both within and across age groups has bedeviled PA epidemiology for two reasons. First, because the cutpoints change from child to adult, there are artefactual discontinuities in PA at the age of 18 making it hard to build a picture of lifecourse PA. Second, it is challenging to use objectively measured MVPA to decide whether children and adults meet PA guidelines (which were themselves originally developed based on self-report, rather than accelerometry). While most physical activity guidelines[10 11 62 63] recommend 60 and 30 minutes per day for children adults respectively, assessing guideline adherence using accelerometry is inherently limited. Using our combination of device and algorithms, only 15% of children meet these recommendations. A recent Australian survey showed that only 19% of children aged 5-17 years meet the physical activity guidelines.[64] Our study indicates that Australian adults easily met the recommendations, which is at odds with self-report data.[65]

Fragmentation of physical activity and sedentary time: Both parents and children presented fragmentation of sedentary time in line with levels of healthy populations.[52] Children's sedentary fragmentation was overall lower than adults', perhaps reflecting both long periods of sitting during school and sessions of unbroken screen time. In contrast, children exhibited

a more fragmented accumulation of MVPA than adults, in line with observations that children's physical activity tends to be sporadic.[66 67]

Concordance between children and parents: The correlation for MVPA duration (r=0.16) was consistent with our review of studies (r=0.15-0.21), most of which used self-report. The weakest correlation was for MVPA fragmentation (r=0.10), and the strongest for VPA duration (r=0.19). This suggests that genetic effects on objective MVPA and SB are relatively modest, and that non-shared environments (principally work and school) may be the major determinant.

Implications for clinicians and policymakers: Children's MVPA levels in this study were low (32 minutes/day), and sedentary time was high (681 minutes/day) and showed evidence or prolonged, unbroken sedentary periods. Australian children are not sufficiently active, and efforts should be made to increase participation. Regarding sedentary time, we found that children accumulate more than 11 hours/day of sedentary time. However, the guidelines generally provide recommendations regarding screen time only[10 11 62] whereas accelerometers do not distinguish screen time from the rest of sedentary time. A previous study of Australian children[68] found that this high level of sedentary time represents mainly screen time (40%), sitting at school (25%), sedentary social occasions (12%), eating (10%) and passive transport (10%). While interventions can address each of these domains, there is mounting evidence that not all types of sedentary time are equally harmful, with television in particular being inculpated in unfavourable health outcomes. The composition of sedentary time may therefore be as important as the overall duration.

For adults, the vast majority meet the recommended MVPA. Regarding sedentary time, guidelines tend to only recommend that sedentary time should be broken up into bouts of 30 minutes or less when possible. In their study, Chastin et al.[52] showed that a fragmentation index of 2.27 means that half the total sedentary time is accumulated in bouts of 17 minutes or shorter. Our results for adults (α=2.45) mean that the sedentary time for our adult sample is even more fragmented that this, indicating sufficient fragmentation of sedentary time. That said, the extent to which sedentary time *must* be broken down in order to avoid negative health effects is unknown.

Unanswered questions and future research: This study highlights the need to standardise methods for objective measures of use of time, to enable pooling and comparison of results from different countries and study centres and across ages. Moreover, there is a need to

enable better comparisons between objectively measured physical activity and guidelines based on subjective reports. One initiative might be to establish a repository of raw accelerometry data, along with harmonised key covariates, which can be re-analysed using common metrics. The International Children's Accelerometry Database is moving towards this objective.[69]

While the cross-sectional nature of the study does not allow us to infer causation, the relatively weak concordance values suggest that genetic factors relating to PA and sedentary time are not strong, and that parents only moderately influence their children's PA and sedentary behaviours (and/or vice versa). The latter is to be expected given that children spend a large part of their waking day at school. The relative contribution of genetic and environmental factors could be addressed by genetic studies using, for example, Mendelian randomisation.

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CONTRIBUTIONS: FF, JM, MW and TO conceptualised the manuscript. FF led the writing, AG, JM, MW and TO provided expert advice and critical review of this manuscript,

AG analysed the data. MW is the Principal Investigator of the Child Health CheckPoint, planned the analyses and provided critical review of this manuscript.

DATA SHARING STATEMENT: Dataset and technical documents available from Growing Up in Australia: The Longitudinal Study of Australian Children via low-cost license for bone fide researchers. More information is available at www.growingupinaustralia.gov.au

FIGURE CAPTIONS AND FOOTNOTES:

Figure 1. Funnel plot of correlations between parent and child physical activity from 26 studies. Data derived from objective measures are shown with filled symbols; data derived form subjective measures with empty symbols. Circles indicate studies where the outcome was MVPA, and squares studies where the outcome was TDEE.

MVPA = moderate-to-vigorous physical activity

TDEE = total daily energy expenditure

Figure 2: Recruitment and retention of participants for Child Health CheckPoint, including sample size for PA and SB.

n=number of families, c=number of children, p=number of attending adults.

MAC=main assessment centre, mAC=mini assessment centre, HV=home visit assessment, LSAC=Longitudinal Study of Australian Children.

*Unable to assess due to equipment failure, poor quality data or time constraints.

~Participants excluded if valid days available did not meet the minimum criteria of at least 4 days of any type, ≤200 minutes sleep and <=1000minutes sedentary time.

^Data from 12 non-biological child-parent pairs excluded from concordance analysis.

Figure 3. Density plots for average sedentary and MVPA time per day.

Males/boys (blue), females/girls (red) and both sexes combined (dotted).

SUPPLEMENTARY DOCUMENTS:

Appendix 1: Transcription of accelerometry activity cards reliability (agreement)

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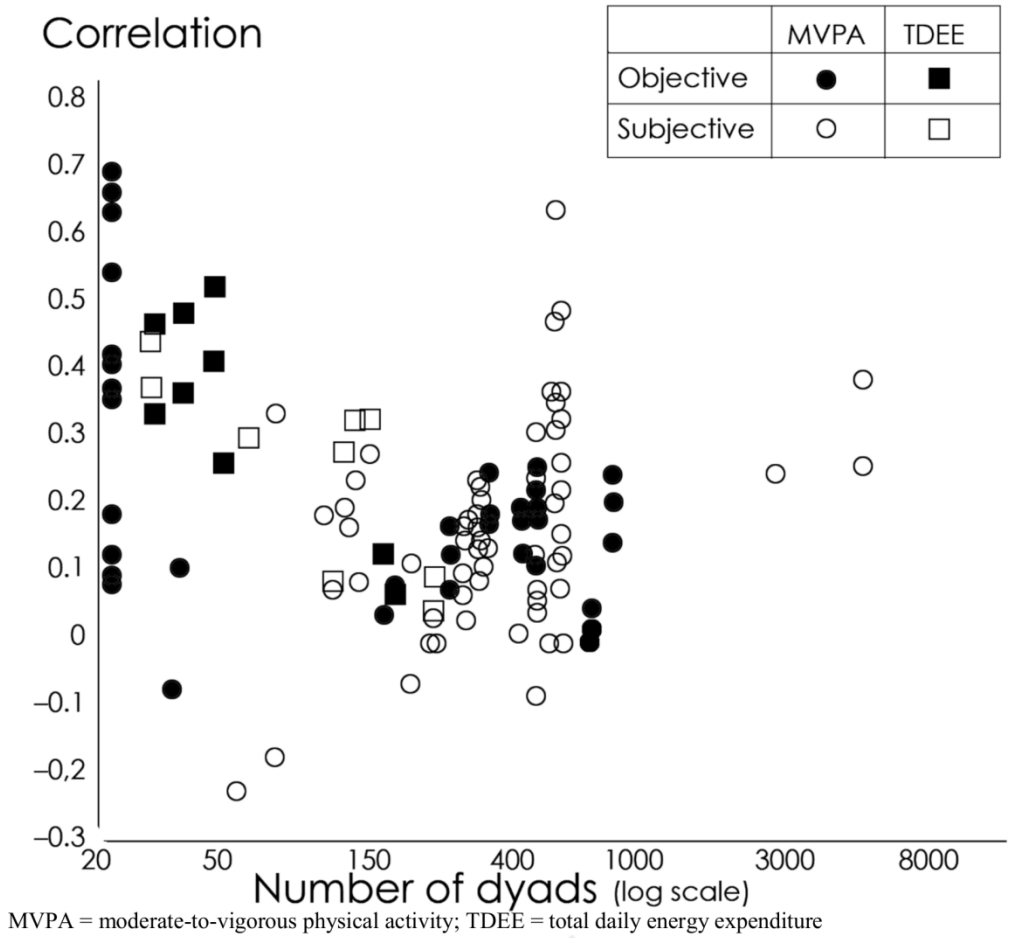

Figure 1. Funnel plot of correlations between parent and child physical activity from 26 studies. Data derived from objective measures are shown with filled symbols; data derived form subjective measures with empty symbols. Circles indicate studies where the outcome was MVPA, and squares studies where the outcome was TDEE.
MVPA = moderate-to-vigorous physical activity
TDEE = total daily energy expenditure

153x144mm (300 x 300 DPI)

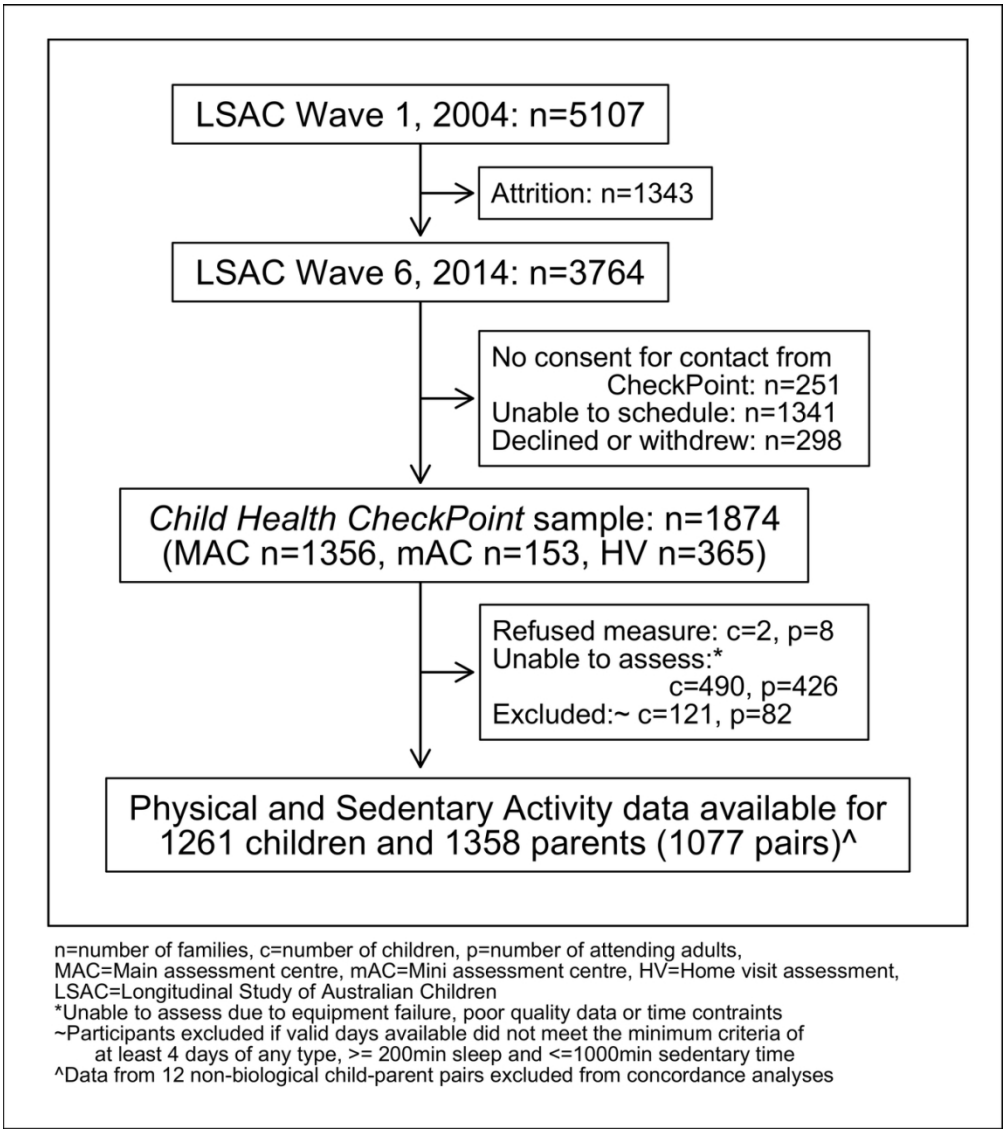

Figure 2: Recruitment and retention of participants for Child Health CheckPoint, including sample size for PA and SB.
n=number of families, c=number of children, p=number of attending adults.
MAC=main assessment centre, mAC=mini assessment centre, HV=home visit assessment, LSAC=Longitudinal Study of Australian Children.
*Unable to assess due to equipment failure, poor quality data or time constraints.
~Participants excluded if valid days available did not meet the minimum criteria of at least 4 days of any type, ≤200 minutes sleep and <=1000minutes sedentary time.
^Data from 12 non-biological child-parent pairs excluded from concordance analysis.

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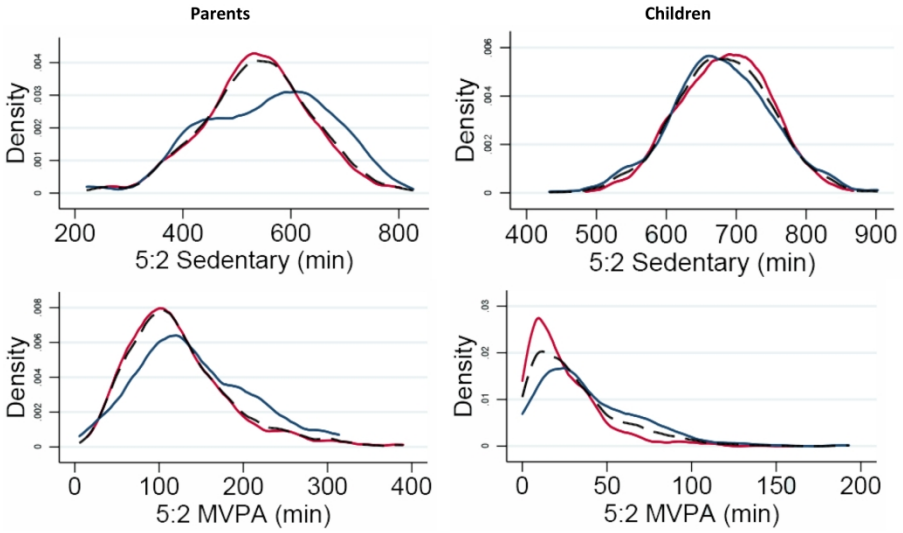

Figure 3. Density plots for average sedentary and MVPA time per day. Males/boys (blue), females/girls (red) and both sexes combined (dotted).

297x209mm (300 x 300 DPI)

APPENDIX 1: TRANSCRIPTION OF ACCELEROMETRY ACTIVITY CARDS RELIABILITY (AGREEMENT)

Ten subjects (including children and parents) were randomly selected from subjects previously coded by each of four raters. Therefore, a random sample of 40 subjects (24 children and 16 parents) each coded by four raters was used. Agreement on the classification of log text data in to one of twelve categories was assessed (coding of what the subject was doing when the bracelet was off based upon the log book). There were potentially 12 days of log text for each coding and coders looked at the field that indicated whether the watch had ever been removed. We investigated the 23 subjects who provided reasons to remove the device on day 1. Rater disagreement only occurred when interpretation of text included an interpretation of 'other' by at least one rater. In four of these cases three raters agreed and coded entries as 'other' whilst one rater chose an alternative code. In the other two cases, two raters coded as 'other' and the other two raters agreed on the alternative code. For day 2, activity log text detailed that the watch was not worn in 16/40 (40%) of subjects. Disagreement between raters occurred in 4/16 (25%) cases. In all 4 cases, three of the raters agreed and one differed, again all contained at least one coding of 'other'.

STROBE Statement—checklist of items that should be included in reports of observational studies

Paper title: Physical activity and sedentary activity: Population epidemiology and concordance in 11-12 year old Australians and their parents

	Item No	Recommendation	Page number
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract	2
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found	2
Introduction			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	4
Objectives	3	State specific objectives, including any prespecified hypotheses	5-6
Methods			
Study design	4	Present key elements of study design early in the paper	6
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	7
Participants	6	(*a*) *Cohort study*—Give the eligibility criteria, and the sources and methods of selection of participants. Describe methods of follow-up ~~*Case-control study*—Give the eligibility criteria, and the sources and methods of case ascertainment and control selection. Give the rationale~~ for the choice of cases and controls *Cross-sectional study*—Give the eligibility criteria, and the sources and methods of selection of participants	6-7
		~~(*b*) *Cohort study*—For matched studies, give matching criteria and number of exposed and unexposed~~ ~~*Case-control study*—For matched studies, give matching criteria and the number of controls per case~~	
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	7,8,9
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	*7,8,9*
Bias	9	Describe any efforts to address potential sources of bias	9,10
Study size	10	Explain how the study size was arrived at	6,10
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	7,8,9
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding	9
		(*b*) Describe any methods used to examine subgroups and interactions	9
		(*c*) Explain how missing data were addressed	6,8
		(*d*) *Cohort study*—If applicable, explain how loss to follow-up was addressed	
		(*e*) Describe any sensitivity analyses	

Results			
Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed	6,10
		(b) Give reasons for non-participation at each stage	6
		(c) Consider use of a flow diagram	Fig 2
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	10
		(b) Indicate number of participants with missing data for each variable of interest	11,13,15
		(c) *Cohort study*—Summarise follow-up time (eg, average and total amount)	
Outcome data	15*	*Cohort study*—Report numbers of outcome events or summary measures over time	
		Case-control study—Report numbers in each exposure category, or summary measures of exposure	
		Cross-sectional study—Report numbers of outcome events or summary measures	*13,15*
Main results	16	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	13,15
		(*b*) Report category boundaries when continuous variables were categorized	13,15
		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	
Discussion			
Key results	18	Summarise key results with reference to study objectives	16
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias	16
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	16,17,18
Generalisability	21	Discuss the generalisability (external validity) of the study results	17,18,19
Other information			
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	20

*Give information separately for cases and controls in case-control studies and, if applicable, for exposed and unexposed groups in cohort and cross-sectional studies.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at www.strobe-statement.org.

BMJ Open

Physical activity and sedentary activity: Population epidemiology and concordance in 11-12 year old Australians and their parents

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Primary Subject Heading:	Epidemiology
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Keywords:	Actigraphy, Physical activity, Reference values, Children, Inheritance patterns, Epidemiologic studies

Physical activity and sedentary activity: Population epidemiology and concordance in 11-12 year old Australians and their parents

Authors: François Fraysse[1], Anneke Grobler[2], Josh Muller[2], Melissa Wake[2,3,4], Timothy Olds[1]

Affiliations: [1]Sansom Institute, Alliance for Research in Exercise, Nutrition and Activity (ARENA), University of South Australia, Adelaide, SA, Australia; [2]Murdoch Children's Research Institute, Parkville, VIC, Australia; [3]Department of Paediatrics, The University of Melbourne, Parkville, Victoria, Australia; [4]Department of Paediatrics & The Liggins Institute, The University of Auckland, Auckland, New Zealand

Correspondence to: Professor Melissa Wake
Murdoch Children's Research Institute
The Royal Children's Hospital
50 Flemington Road, Parkville VIC 3052, AUSTRALIA
T: +61 3 9345 5937
E: melissa.wake@mcri.edu.au

Keywords: Actigraphy, physical activity, reference values, parents, children, inheritance patterns, correlation studies, epidemiologic studies, cross-sectional studies.

Word count: 4595

Abbreviations: α: alpha; ARENA: Alliance for Research in Exercise, Nutrition and Activity; BMI: body mass index; CC: correlation coefficient; CI: confidence interval; CL: confidence level; dur.: duration; frag.; fragmentation; g.min: units of acceleration from GeneActiv devices (g: gravity units, min: minutes); I^2: heterogeneity index; LSAC: Longitudinal Study of Australian Children; MPA: moderate physical activity; MVPA: moderate-to-vigorous physical activity; n: sample size; PA: physical activity; r: Pearson's correlation coefficient; RC: estimated regression coefficient; SB: sedentary behaviours; SD: standard deviation; SVM: signal vector magnitude; TDEE: total daily energy expenditure; VPA: vigorous physical activity.

ABSTRACT

Objectives: To describe the epidemiology and parent-child concordance of objectively measured physical activity in a population-based sample of Australian parent-child dyads.

Design: Cross-sectional study (Child Health CheckPoint) nested within the Longitudinal Study of Australian Children.

Setting: Assessment centres in seven Australian cities and eight regional towns, or home visits; February 2015-March 2016.

Participants: Of all CheckPoint families (n=1,874), 1261 children (50% girls) and 1358 parent (88% mothers) provided objectively measured activity data, comprising 1,077 parent-child dyads.

Outcome measures: Activity behaviour was assessed by GENEActiv accelerometer. Duration of moderate-to-vigorous and vigorous physical activity (MVPA, VPA) and sedentary behaviour (SB) were derived using *Cobra* custom software, along with MVPA/SB fragmentation and mean daily activity. Pearson's correlation coefficients and linear regression estimated parent-child concordance. Survey weights and methods accounted for the complex sample design and clustering.

Results: Although parents had average lower accelerometry counts than children (mean (standard deviation, SD) 209 (46) vs 284 (71) g.min), 93% of parents met MVPA daily duration guidelines on published cutpoints (mean (SD) 125 (63) minutes/day MVPA), compared to only 15% of children (mean 32 (27) minutes). Parents showed less daily SB duration (parents 540 (101), children 681 (69) minutes) and less fragmented accumulation of MVPA (parents α=1.85, children 2.00). Parent-child correlation coefficients were 0.16 (95% CI 0.11 to 0.22) for MVPA duration, 0.10 (95% CI 0.04 to 0.16) for MVPA fragmentation, 0.16 (95% CI 0.11 to 0.22) for SB duration, and 0.18 (95% CI 0.12 to 0.23) for SB fragmentation.

Conclusions: Standardised cutpoints are needed for objective activity measures to inform activity guidelines across the lifecourse. This may reflect large amounts of time in non-shared environments (school, work).

Strengths and limitations of the study

- This study used valid, reliable, objective, free-living measures of Australian children and parent activity patterns. The sample is drawn from a nationally-representative cohort.

- We report for the first time parent-child concordance in objective activity duration and fragmentation.
- Although the accelerometry measurements were objective, the multiple choices needed in processing the data could have impacted on the results, requiring caution in comparisons of absolute values with other studies.
- Findings apply to a narrow child age range (11-12 years); parent-child concordance could evolve as children grow up.
- Most adults were mothers, limiting conclusions for fathers and for adults who are not parents.

INTRODUCTION

Physical activity (PA) and sedentary behaviour (SB) have both been independently linked to a wide range of health outcomes in children[1 2] and adults.[3 4] Furthermore, some studies have suggested that, independent of duration, other characteristics of PA and/or SB impact on health. For this reason, there has recently been a growing interest in examining the patterns of accumulation of sedentary and physical activity times; the term "pattern" encompassing notions such as sequencing, timing, consistency, and fragmentation. Recent studies have shown that less fragmentation of sedentary time (more long bouts) is associated with obesity and health markers in adults, although analyses involving children have been less conclusive.[5 6] Similarly, higher intensity[7], more continuous[8] bouts of physical activity have been associated with better health outcomes, and most physical activity guidelines contain recommendations regarding the distribution of PA.[9 10] Finally, vigorous PA has added benefits compared to overall moderate-to-vigorous physical activity (MVPA)[1], and some physical activity guidelines[10 11] provide recommendations on the amount of vigorous physical activity (VPA) in addition to MVPA recommendations.

Patterns of activity and sitting result from both genetic and environmental factors,[12] so we would expect a degree of concordance between children's activity patterns and those of their parents, arising from shared genes and shared environments. Shared environments include geographical, climatic and financial contexts, but also social factors such as parental modeling and direct parental involvement. Child-to-parent effects may also play a role. Genetic factors may relate to the heritability of personality traits associated with adherence to PA (conscientiousness, self-motivation, self-discipline), reward-associated hormonal responses to exercise (dopamine, endogenous opioids), or physiological characteristics such as aerobic fitness and strength which encourage participation in sport.

While a high parent-child concordance may be a marker of strong genetic or shared environmental determinants, a lower correlation may indicate greater importance for the non-shared environment — notably the school environment for children and the work environment for parents. School in particular may be a homogenising influence, since at school all children have very similar timings of daily activities. In terms of interventions, a high concordance would either suggest that interventions may be ineffective (if there is a large non-modifiable genetic component) or that the focus should be on the shared environment. A low concordance may be a marker of relatively high behavioural malleability, with an appropriate focus on the non-shared environment.

Advances in wearable technology have made it possible to objectively measure PA and SB, and a number of studies have quantified free-living activity in children[12-14] and adults.[14-16] Estimates of the proportion of variability in measured PA which can be ascribed to additive genetic effects range from 20 to 71%.[12 17] The differences may be due to the age of the participants, the powerful effect of the shared school environment, or to the use of questionnaire data.

To review current literature on parent-child concordance in PA and SB, we used a systematic search to synthesise data from 26 studies[17-40] from 11 mainly European and North American countries. This yielded a total of 119 correlations between parental and child PA (Figure 1). Correlations were classified according to (1) the type of PA measured (sport, exercise, vigorous PA [VPA], moderate PA [MPA], recreational PA, leisure-time PA were all classified as MVPA); estimates of overall energy expenditure were classified as total daily energy expenditure (TDEE); (2) the age of the child; (3) the sex of the parent; (4) the sex of the child; and (5) assessment methodology (questionnaires were classified as subjective; accelerometry, pedometry and direct observation as objective). Using a random effects approach, the overall weighted mean correlation for all PA outcomes was 0.18 (95% confidence level (CL) 0.15-0.21) (Figure 1). Correlations did not differ by outcome (MVPA r=0.18, TDEE r = 0.26), sex of parent (father r=0.23, mother r=0.18), sex of child (daughter r=0.20, son r=0.23), or assessment methodology (subjective r=0.20, objective r=0.17). Heterogeneity was high for all analyses (I^2>55). Only four studies[19 21 22 37] from the UK, Finland and the USA, with a total of 24 correlations, looked at parent-child concordance in some measure of SB (sitting, TV or inactivity). The overall weighted mean correlation was 0.26 (0.17-0.35). Heterogeneity was high (I^2=72).

The sample sizes in most of the PA and SB studies were relatively modest (median n=192), and in only 7 of 26 studies were the activity patterns of both parent and child objectively measured. None of the studies was performed in Australia. Furthermore, these studies only addressed parent-child concordance in the duration of PA or SB, or total daily activity levels, with no data on fragmentation.

The aims of this study were to:

• Report the mean values and distributions of PA and SB, and their fragmentation, in a large, population-based sample of Australian children aged 11-12 years and Australian mid-life adults (their parents); and

• Quantify parent-child concordance in objectively-measured PA and SB duration and fragmentation. In addition, report mother-child and father-child concordances separately in order to allow comparison with previous concordance studies.

METHODS

Study design and participants: The initial study design and recruitment have been described in detail elsewhere.[41 42] LSAC commenced in 2004, recruiting a nationally representative cohort of 5107 infants through a two-stage cluster sample design,[43] whereby 10% of all Australian postcodes were randomly selected, stratified by state and capital city/rest of state and children born between March 2003 and February 2004 were then randomly selected from the Medicare database.[44 45] 73.7% (n=3764) of participants were retained to LSAC wave 6 in 2014.

At the start of wave 6, all contactable and consenting families were invited to consent to their contact details being shared with the Child Health CheckPoint team (n=3513). In 2015, consenting families were sent an information pack via post and received an information and recruitment phone call. The CheckPoint study was conducted from February 2015 to March 2016, between LSAC waves 6 and 7 (children's age 11-12 years), and 1,874 families participated. The overall aim of the Checkpoint study was to examine relationships between multiple environmental factors and multiple health outcomes; a more detailed description of the study design is provided elsewhere.[46 47]

Ethics and Consent: The CheckPoint study protocol was approved by The Royal Children's Hospital (Melbourne, Australia) Human Research Ethics Committee (33225D) and Australian Institute of Family Studies Ethics Committee (protocol number 14-26). The attending parent provided written informed consent for them and their child to participate in the study.

Patient and Public Involvement: No patient groups were involved in the design or conduct of LSAC, a population-based longitudinal study. To our knowledge, the public was not involved in the study design, recruitment or conduct of LSAC study or its CheckPoint module. Parents received a summary health report for their child and themselves after the assessment visit. They consented to take part knowing that they would not otherwise receive individual results about themselves or their child.

Procedure: All measures were collected at a specialised 3.5 hour (7 capital cities and larger regional towns) or 2.5 hour (8 smaller regional centres) CheckPoint assessment centre visit. 365 families who could not attend a centre received a 1.5 hour home visit. At the end of the visit, a trained research assistant fitted a GENEActiv accelerometer (Activinsights Ltd., UK) on the non-dominant wrist of each child and parent, and provided each with an activity card (see below). Participants were instructed to wear the device at all times for eight continuous days, starting the day of the visit, removing it only for prolonged water immersion (swimming, bath) or as prescribed by some contact sports rules (eg netball). After eight days, participants returned the device, together with the completed activity card using the pre-paid postal envelope provided. For more information on data collection, refer to the Physical activity section of the Data Issues Paper of the LSAC Checkpoint study.[48]

Physical activity measures:

Activity cards: The activity cards were paper-based logs in a table format with fields for each day of the monitoring period to allow participants to write the following:

1. At what time they went to bed at night ("bed time"),
2. At what time they woke up in the morning ("get up time"),
3. If they took the device off, at what times it was removed and put back on, as well as the reason for removal, and
4. A brief description of their day (eg "school", "travel", "unwell resting"…).

Once returned, activity cards were transcribed in electronic form by research assistants, to be used in the processing of the accelerometer data (see below for details). Reliability testing of card transcription is described in Appendix 1.

Accelerometers were configured through the manufacturer's software (GENEActiv PC Software, Activinsights, UK) to record at 50 Hz for 14 days, starting at midnight following the CheckPoint visit. The 14 days recording duration was chosen to ensure enough valid days were recorded in case the participant could not wear the device for some days and the total monitoring duration had to be extended.

After the device was returned, the research team downloaded the raw acceleration data. The Signal Vector Magnitude (SVM) of the acceleration, minus gravity, was computed and summed over 60 second epochs:

$$SVM = \sum_{60s} \left| \sqrt{a_X^2 + a_Y^2 + a_Z^2} - g \right|$$ where a_x, a_y, a_z are the three components of the acceleration signal and g the acceleration of gravity (9.81 m/s^2). The 60 second epoch data was then imported into custom Matlab software for further processing. This software (*Cobra*, developed at the University of South Australia) provides a user-friendly graphical user interface for processing accelerometer data.

First, sleep was identified using the activity cards completed by the participants. Sleep times were corrected by visual inspection when necessary, that is, in case sleep times were not reported or when obvious discrepancies were observed between reported sleep and accelerometer trace. Following this, device removals (non-wear) were identified using the activity cards and excluded from analysis. Where the reason given for removal was "sport", the removal period was replaced with a period of MVPA. This was done because (1) most children were not allowed to wear the watch for some sport activities (eg netball, swimming), and (2) these sport activities often made for a large part of daily MVPA, so ignoring them would potentially result in a large underestimation of daily MVPA. MVPA imputed in this way was not considered for the calculation of MVPA fragmentation (see below). Duration of vigorous physical intensity (VPA) was also obtained for each participant.

A day was considered invalid and excluded from analysis if it included ≤10 hours wear during waking hours,[14] or if it included ≥1000 minutes (16 h 40 minutes) of sedentary time (reflecting a day of non-wear not captured by the self-report logs, typically after the end of the recording period). A participant was considered invalid and excluded from analysis if they provided <4 valid days of accelerometry data[14 49] or if they had ≤200 minutes average sleep time.

Each 60 second epoch of waking wear time was then classified into one of four physical activity levels: sedentary, light, moderate or vigorous PA. Cutpoints for PA levels were defined according to Esliger et al.[50] for parents and Phillips et al.[51] for children, and adjusted proportionally to account for the 50 Hz sampling frequency. The resulting cutpoints between sedentary and light, light and moderate, and moderate and vigorous PA were 188, 403 and 1131 gravity units per minute (g.min) for adults, and 244, 788 and 2175 g.min for children, respectively.

Fragmentation of sedentary and MVPA time was characterised using the method described by Chastin et al.[52] The measure of fragmentation (α) was the slope of the regression line of the relative frequency of a bout (of MVPA or SB) plotted against bout length on a log scale. For

SB, α was calculated on a per-day basis. However, α for MVPA was calculated using all valid days combined for a given participant, because a good curve fit required more bouts of MVPA than were usually available in a single day. In the present study α was multiplied by -1 so that it is always positive. Higher values of α indicate greater fragmentation, i.e. fewer long bouts - considered desirable for SB - and lower values of α less fragmentation and more prolonged bouts.

Other sample characteristics including potential confounders: Age and sex affect physical activity patterns, which in turn were expected to influence parent-child correlations. Sex and date of birth were exported from Medicare Australia's database at the time of LSAC enrolment (for the child) or self-reported (parent). Age was rounded to nearest week by calculating the days between the participant's date of birth and date of assessment.

Adjustment was also made for socio-economic status because it is shared by parents and children and is correlated to physical activity and sedentary behaviour patterns. Socio-economic status was determined from the postcode of the participant's primary address using the Socio-Economic Indicators for Areas (SEIFA) 2011 Index of Relative Social Disadvantage (disadvantage index), which factors in household education levels, income, employment status, and disability. The population mean score for Australia is 1000 (standard deviation (SD) 100), with higher scores representing greater advantage.

Statistical analysis: All accelerometry outcome variables were computed for each individual day, then averaged over days for each valid participant using a 5:2 weighting for work/school days versus weekend days. School holidays were counted as weekend days for children.

Objective physical activity variables were described for all children and adults using means and SD. Population summary statistics were estimated by applying survey weights and survey procedures that corrected for sampling, participation and non-response biases, and took into account clustering in the sampling frame. Standard errors were calculated taking into account the complex design and weights. More detail on the calculation of weights is provided elsewhere.[53]

For each of the 1077 biological child-parent pairs, concordance between parents and children was assessed by: 1) Pearson's correlation coefficients with 95% confidence intervals; and 2) linear regression with the child variable as the dependent variable and the parent variable as the independent variable. Linear regression models were adjusted for parent and child age and sex (in models including both sexes), and socioeconomic disadvantage index. As there were

only minimal differences between unweighted and weighted results, only the former are presented here.

Data were analysed using Stata version 14.2 (StataA Corp., College Station, TX).

RESULTS

Sample characteristics: Figure 2 shows that valid accelerometry data were obtained for 1261 children (50% female) and 1358 parents, allowing the analysis of 1077 child-parent pairs. Only biological child-parent pairs were included in the concordance analysis, resulting in the exclusion of 12 non-biological pairs. Table 1 shows the participant characteristics. Most parents were mothers (88%). Overall, participants were slightly more advantaged than the average Australian household, with a mean disadvantage index of about 0.1 SD above the Australian average and a narrower spread (SD 64) than the national SD of 100. Body mass index (BMI) for parents and children were comparable with general population values for adults and children of the same age.[54]

Table 1. Participant characteristics (weighted mean and SD).

Characteristic	All			Male			Female		
Child	**n**	**mean**	**SD**	**n**	**mean**	**SD**	**n**	**mean**	**SD**
Age (years)	1261	12.0	0.4	632	12.0	0.4	629	12.0	0.4
BMI (kg/m^2)	1260	19.3	3.5	631	19.2	3.5	629	19.4	3.6
Disadvantage Index	1257	1010	64	629	1010	63	628	1010	65
Parent	**n**	**mean**	**SD**	**n**	**mean**	**SD**	**n**	**mean**	**SD**
Age (years)	1358	43.9	5.6	167	46.3	7.1	1191	43.6	5.3
BMI (kg/m^2)	1350	28.0	6.4	167	28.8	5.1	1183	27.9	6.5

n: sample size; SD: standard deviation; BMI: body mass index. Sample sizes vary according to availability of data.

Physical activity characteristics

Table 2 presents the PA characteristics of all valid participants, including MVPA and SB duration and fragmentation, and VPA duration. Figure 3 shows the distributions of SB and MVPA duration for both parents and children. Parents had on average lower accelerometry counts than children (mean (SD) 209 (46) vs 284 (71) g.min). Overall, children accumulated an average of 32 minutes of MVPA per day, with boys having overall higher MVPA duration (40 minutes/day) than girls (24 minutes/day). Variability (SD of the duration) was large for both boys and girls, relative to the mean (SD 30 and 22 minutes, respectively). Adults' MVPA duration was 142 and 122 minutes/day for mothers and fathers respectively, and the variability (SD 69 and 62 minutes for fathers and mothers respectively) was lower than in children relative to the mean. 15% of children and 93% of parents met MVPA recommendations of 60 and 30 minutes/day respectively. However, it is important to note that children's and parents' MVPA and SB durations are not directly comparable, because different cutpoints are used. Overall, children exhibited a more fragmented pattern of accumulation of MVPA (higher α) than parents, with an overall average α of 2.00 for children and 1.85 for parents.

The sedentary time of boys and girls was averaging 679 and 684 minutes respectively. This was larger than parents, with 555 and 538 minutes for fathers and mothers, respectively. Parents also exhibited a more fragmented accumulation of SB ($\alpha = 2.46$) than children ($\alpha = 2.13$).

Table 2. Distribution of sedentary behaviour and physical activity, weighted for day type.

Activity measure	All				Male				Female			
	n	mean	SD	95% CI	n	mean	SD	95% CI	n	mean	SD	95% CI
Children												
MVPA duration (min)	1261	32.0	27.2	30.3 to 33.7	632	39.5	30.0	36.8 to 42.3	629	24.4	21.9	22.7 to 26.1
MVPA fragmentation, α	1259	2.00	0.18	1.99 to 2.02	631	1.96	0.17	1.94 to 1.98	628	2.05	0.17	2.03 to 2.06
VPA duration (min)	1261	10.0	19.1	8.9 to 11.1	632	11.2	20.7	9.4 to 13.0	629	8.8	17.6	7.5 to 10.2
SB duration (min)	1261	681.3	68.6	676.8 to 685.8	632	679.0	72.5	671.9 to 686.0	629	683.7	65.3	677.9 to 689.5
SB fragmentation, α	1261	2.13	0.17	2.12 to 2.14	632	2.11	0.17	2.10 to 2.13	629	2.14	0.18	2.12 to 2.16
Average daily activity (g.min)	1261	283	69	278 to 287	632	297	76	290 to 304	629	268	60	263 to 273
Parents												
MVPA duration (min)	1358	124.5	62.5	120.0 to 128.9	167	141.6	68.8	127.1 to 156.1	1191	122.1	61.6	117.6 to 126.6
MVPA fragmentation (α)	1358	1.85	0.09	1.85 to 1.86	167	1.83	0.09	1.81 to 1.85	1191	1.86	0.1	1.85 to 1.87
VPA duration (min)	1358	7.0	12.3	6.3 to 7.8	167	9.4	14.5	6.7 to 12.1	1191	6.7	12.0	6.0 to 7.4
SB duration (min)	1358	539.7	101.0	532.4 to 546.9	167	555.4	121.8	531.0 to 579.7	1191	537.5	98.2	530.1 to 545.0
SB Fragmentation (α)	1358	2.46	0.32	2.44 to 2.49	167	2.43	0.31	2.4 to 2.5	1191	2.47	0.32	2.44 to 2.49
Average daily activity (g.min)	1358	210	48	206 to 213	167	217	54	206 to 228	1191	209	47	205 to 212

CI: confidence interval; min: minutes; MVPA: Moderate-to-Vigorous Physical activity; n: sample size; SB: Sedentary Behaviours; VPA: Vigorous Physical Activity; g.min: gravity units per minute. MVPA fragmentation could not be calculated for participants with no MVPA.

Child-parent concordance

Table 3 presents the correlation (CC) and regression (RC) coefficients estimates between the children and their parents, for each of the five PA metrics. Overall, there were small but significant correlations between children's and parents' PA behaviours. Between mothers and children, all five PA variables were significantly correlated. Correlations were weak for SB, VPA and MVPA duration, and SB fragmentation, and very weak for MVPA fragmentation (0.11). Between fathers and children, only VPA duration and SB fragmentation were significantly associated ($r = 0.24$ and 0.22 respectively, both $p<0.05$), however the sample size was smaller.

Influence of MVPA imputation method

34% of children and 10% of parents had any amount of reported sport-related nonwear. Replacing these nonwear periods with MVPA may have had an influence on the results. To investigate this, we also replaced these sport-related nonwear periods with a composition of 50% MVPA, 30% LPA and 20% sedentary time, as reported by Ridley et al. in an observational study of children.[55]. Pearson's correlation between children's daily MVPA while using 100% MVPA replacement, and using the 50/30/20% MVPA/LPA/sedentary composition, was 0.96. Parent-child correlation for daily MVPA duration increased slightly from 0.16 (Table 3) to 0.166.

Table 3. Parent-child concordance. The upper panel shows unadjusted values, and the lower panel values adjusted for parent and child age and sex, and Disadvantage Index.

	Parent-child			Father-child			Mother-child		
Pearson's Correlation	**n**	**CC**	**95% CI**	**n**	**CC**	**95% CI**	**n**	**CC**	**95% CI**
MVPA duration (min)	1077	0.16	0.11 to 0.22	128	0.13	-0.05 to 0.29	949	0.17	0.11 to 0.23
MVPA fragmentation (α)	1076	0.10	0.04 to 0.16	128	0.04	-0.13 to 0.22	948	0.11	0.05 to 0.18
VPA duration (min)	1077	0.19	0.14 to 0.25	128	0.24	0.07 to 0.40	949	0.19	0.13 to 0.25
SB duration (min)	1077	0.16	0.11 to 0.22	128	0.13	-0.05 to 0.29	949	0.17	0.11 to 0.24
SB fragmentation (α)	1077	0.16	0.10 to 0.22	128	0.22	0.05 to 0.38	949	0.15	0.09 to 0.21
Linear Regression (adjusted for covariates)	**n**	**RC**	**P-value**	**n**	**RC**	**P-value**	**n**	**RC**	**P-value**
MVPA duration (min)	1076	0.32	<0.001	127	0.20	0.24	949	0.34	<0.001
MVPA fragmentation (α)	1075	0.20	0.001	127	0.04	0.84	948	0.22	0.001
VPA duration (min)	1076	0.23	<0.001	127	0.27	0.03	949	0.23	<0.001
SB duration (min)	1076	0.11	<0.001	127	0.10	0.07	949	0.12	0.001
SB fragmentation (α)	1076	0.08	<0.001	127	0.13	0.01	949	0.08	<0.001

Covariates in adjusted linear regression models include parent and child age and sex, and Disadvantage Index. CC: correlation coefficient; CI: confidence interval; MVPA: Moderate-to-Vigorous Physical activity; n: sample size; RC: estimated regression coefficient; SB: Sedentary Behaviours; VPA: Vigorous Physical Activity. MVPA fragmentation could not be calculated for participants with no MVPA.

DISCUSSION

Principal findings: This study provides normative values for device-measured activity behaviour in a large sample of Australian mid-life adults and 11-12 year old children. Using the specific combination of device and analytical algorithms in this study, children accumulated on average 32 minutes of MVPA each day, of which 10 minutes were VPA. Using different cut-points, adults accumulated 125 minutes/day of MVPA, but only 7 minutes/day of VPA. Children had higher levels of sedentary time (681 minutes/day) than adults (540 minutes/day). Children's MVPA was more fragmented than that of their parents, while sedentary time was less fragmented. Concordance between children and parents for MVPA, VPA and sedentary time duration and fragmentation was weak to moderate, ranging between r=0.08 and r=0.32.

Strengths and limitations: The CheckPoint physical activity study is the largest accelerometry-based cross-generational study of activity in Australia. It is also the first to report concordance of physical activity and sedentary behaviours between parents and 11-12 year old children. This study reports valid, reliable, objective, free-living measures of child and parent physical activity patterns and their concordance from a large national sample. Data were collected simultaneously for parents and children using the same protocol. To our knowledge, this is the first study to report metrics for intensity and fragmentation of PA and SB.

Limitations include the relatively small number of fathers, reducing precision of their estimates. Only one parent was included for each child; this is nonetheless one of very few studies that present separate (but largely similar) mother-child and father-child concordance estimates. Secondly, the sample in this study, while drawn from a cohort which was designed to be nationally representative, was subject both to selective update and attrition. This might have affected both activity and the impacts of BMI on activity, and perhaps concordance values. Furthermore, the age range of the children was narrow (11 to 12 years).

Significance and meaning:

Duration of physical activity and sedentary time: It is surprising that our results indicate parents accumulated more daily MVPA than children (Table 2). Most studies find that children are more active than adults, both by self-report and using accelerometers.[14] Moreover, doubly-labeled water studies show that total daily energy expenditure declines with age.[56] In that regard, the differences in this study between children and adults almost certainly come from the fact that two separate sets of cutpoints were used. Although the cutpoints we used were

developed specifically for children and adults, the MPA cutpoint for children (788 g.min) is almost double that of adults (403 g.min), resulting in a much lower MVPA estimate for children. The fact that daily average accelerations were 35% higher for children than parents (283 and 210 g.min, respectively) confirms the fact that children in fact moved more than their parents, and children exhibiting lower daily MVPA is an artifact of the different cutpoints used. In other words, using children's cutpoints to analyse parents' MVPA would result in parents exhibiting less daily MVPA than children.

In spite of this, estimated MVPA and sedentary durations in the CheckPoint study were in line with findings from several previous studies. For instance, in adults, Rosenberger et al[57] reported MVPA durations of 100 to 220 minutes/day depending on the device used. Recently, Rowlands et al[58] reported average MVPA durations of 92 minutes/day for a small adult sample, using the GeneActiv. A recent study using the large (n=22,978) Biobank dataset reported 106 min/day MVPA in healthy adults.[59] In children, Telford et al[60] reported averages of 43 and 31 minutes/day of MVPA for 8-12 year old boys and girls respectively. The ISCOLE study used Actigraph GT3X+ accelerometers, finding that 10 year old boys accumulated 75 minutes/day MVPA, and girls 57 minutes/day.[61]

Of note, accelerometer-based estimates of children's PA tend to show more variability between studies than adults'. This may be due, in part, to the more sporadic nature of children's PA. A study of 47 children aged 6-11 by Schaefer et al. showed that daily MVPA was 308 min/day when including all episodes of 1 second or more, but decreased twentyfold, to 14 min/day, when only including MVPA episodes of at least 60 seconds.[62] Secondly, a study by Reilly et al. showed that estimates of children's MVPA varied from 28 to 266 min/day depending on the set of cutpoints used.[63]

Overall, our results once again highlight the fact that accelerometry-based assessment of physical activity is highly dependent on a number of factors, including the accelerometer device itself,[58] but more importantly the choice of algorithms and processes used, such as sampling frequency, raw data filtering, epoch length, and cutpoint values. At present, there is no consensus on the choice of processes.[64] A recent review has identified wide discrepancies in processing parameters,[49] with some of these choices having a large impact on results. This makes comparison between studies difficult. In this regard, accelerometry could be seen as better suited to assess *relative* change in PA, be it across populations, in longitudinal studies, or in interventions, provided that protocols and data processing methods are consistent. Assessment of absolute values of PA appear more difficult since they are highly dependent on

a number of factors. This also means it is challenging to use objectively measured PA to decide whether children and adults meet PA guidelines, which were themselves originally developed based on self-report, rather than accelerometry. While most physical activity guidelines[10 11 65 63] recommend 60 and 30 minutes per day for children adults respectively, assessing guideline adherence using accelerometry is inherently limited. Using our combination of device and algorithms, only 15% of children meet these recommendations. A recent Australian survey showed that only 19% of children aged 5-17 years meet the physical activity guidelines.[66] Our study indicates that Australian adults easily met the recommendations, which is at odds with self-report data.[67]

Fragmentation of physical activity and sedentary time: Parents presented fragmentation of sedentary time (2.46) in line with levels of healthy populations (2.27).[52] Children's sedentary fragmentation was overall lower than adults', perhaps reflecting both long periods of sitting during school and sessions of unbroken screen time. Children spent 50% of their sedentary time in bouts of 43min or more, and parents in bouts of 26min or more. In contrast, children exhibited a more fragmented accumulation of MVPA than adults, in line with observations that children's physical activity tends to be sporadic.[68 69] Our study is the first to use the alpha coefficient to quantify fragmentation of MVPA in adults, and the first to use it for both sedentary time and MVPA in children, so there is no available comparison point.

Concordance between children and parents: The correlation for MVPA duration (r=0.16) was consistent with our review of studies (r=0.15-0.21), most of which used self-report. The method chosen for imputing MVPA time during sport-related nonwear events only had little effect. The weakest correlation was for MVPA fragmentation (r=0.10), and the strongest for VPA duration (r=0.19). This suggests that genetic effects on objective MVPA and SB are relatively modest, and that non-shared environments (principally work and school) may be the major determinant.

Implications for clinicians and policymakers: Children's MVPA levels in this study were low (32 minutes/day), and sedentary time was high (681 minutes/day) and showed evidence or prolonged, unbroken sedentary periods. Australian children are not sufficiently active, and efforts should be made to increase participation. Regarding sedentary time, we found that children accumulate more than 11 hours/day of sedentary time. However, the guidelines generally provide recommendations regarding screen time only[10 11 65] whereas accelerometers do not distinguish screen time from the rest of sedentary time. A previous study of Australian children[70] found that this high level of sedentary time represents mainly screen time (40%),

sitting at school (25%), sedentary social occasions (12%), eating (10%) and passive transport (10%). While interventions can address each of these domains, there is mounting evidence that not all types of sedentary time are equally harmful, with television in particular being inculpated in unfavorable health outcomes. The composition of sedentary time may therefore be as important as the overall duration.

For adults, the vast majority meet the recommended MVPA. Regarding sedentary time, guidelines tend to only recommend that sedentary time should be broken up into bouts of 30 minutes or less when possible. In their study, Chastin et al.[52] showed that a fragmentation index of 2.27 means that half the total sedentary time is accumulated in bouts of 17 minutes or shorter. Our results for adults (α=2.46) mean that the sedentary time for our adult sample is even more fragmented that this, indicating sufficient fragmentation of sedentary time. That said, the extent to which sedentary time *must* be broken down in order to avoid negative health effects is unknown.

Unanswered questions and future research: This study highlights the need to standardise methods for objective measures of use of time, to enable pooling and comparison of results from different countries and study centres and across ages. Moreover, there is a need to enable better comparisons between objectively measured physical activity and guidelines based on subjective reports. One initiative might be to establish a repository of raw accelerometry data, along with harmonised key covariates, which can be re-analysed using common metrics. The International Children's Accelerometry Database is moving towards this objective.[71]

While the cross-sectional nature of the study does not allow us to infer causation, the relatively weak concordance values suggest that genetic factors relating to PA and sedentary time are not strong, and that parents only moderately influence their children's PA and sedentary behaviours (and/or vice versa). The latter is to be expected given that children spend a large part of their waking day at school. The relative contribution of genetic and environmental factors could be addressed by genetic studies using, for example, Mendelian randomisation.

ACKNOWLEDGEMENTS:

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CONTRIBUTIONS: FF, JM, MW and TO conceptualised the manuscript. FF led the writing, AG, JM, MW and TO provided expert advice and critical review of this manuscript, AG

analysed the data. MW is the Principal Investigator of the Child Health CheckPoint, planned the analyses and provided critical review of this manuscript.

DATA SHARING STATEMENT: Dataset and technical documents available from Growing Up in Australia: The Longitudinal Study of Australian Children via low-cost license for bone fide researchers. More information is available at www.growingupinaustralia.gov.au

FIGURE CAPTIONS AND FOOTNOTES:

Figure 1. Funnel plot of correlations between parent and child physical activity from 26 studies. Data derived from objective measures are shown with filled symbols; data derived form subjective measures with empty symbols. Circles indicate studies where the outcome was MVPA, and squares studies where the outcome was TDEE.

MVPA = moderate-to-vigorous physical activity

TDEE = total daily energy expenditure

Figure 2: Recruitment and retention of participants for Child Health CheckPoint, including sample size for PA and SB.

n=number of families, c=number of children, p=number of attending adults.

MAC=main assessment centre, mAC=mini assessment centre, HV=home visit assessment, LSAC=Longitudinal Study of Australian Children.

*Unable to assess due to equipment failure, poor quality data or time constraints.

~Participants excluded if valid days available did not meet the minimum criteria of at least 4 days of any type, ≤200 minutes sleep and <=1000minutes sedentary time.

^Data from 12 non-biological child-parent pairs excluded from concordance analysis.

Figure 3. Density plots for average sedentary and MVPA time per day.

Males/boys (dash-dotted line), females/girls (solid line) and both sexes combined (dotted line).

SUPPLEMENTARY DOCUMENTS:

Supplementary File 1. Transcription of accelerometry activity cards reliability (agreement)

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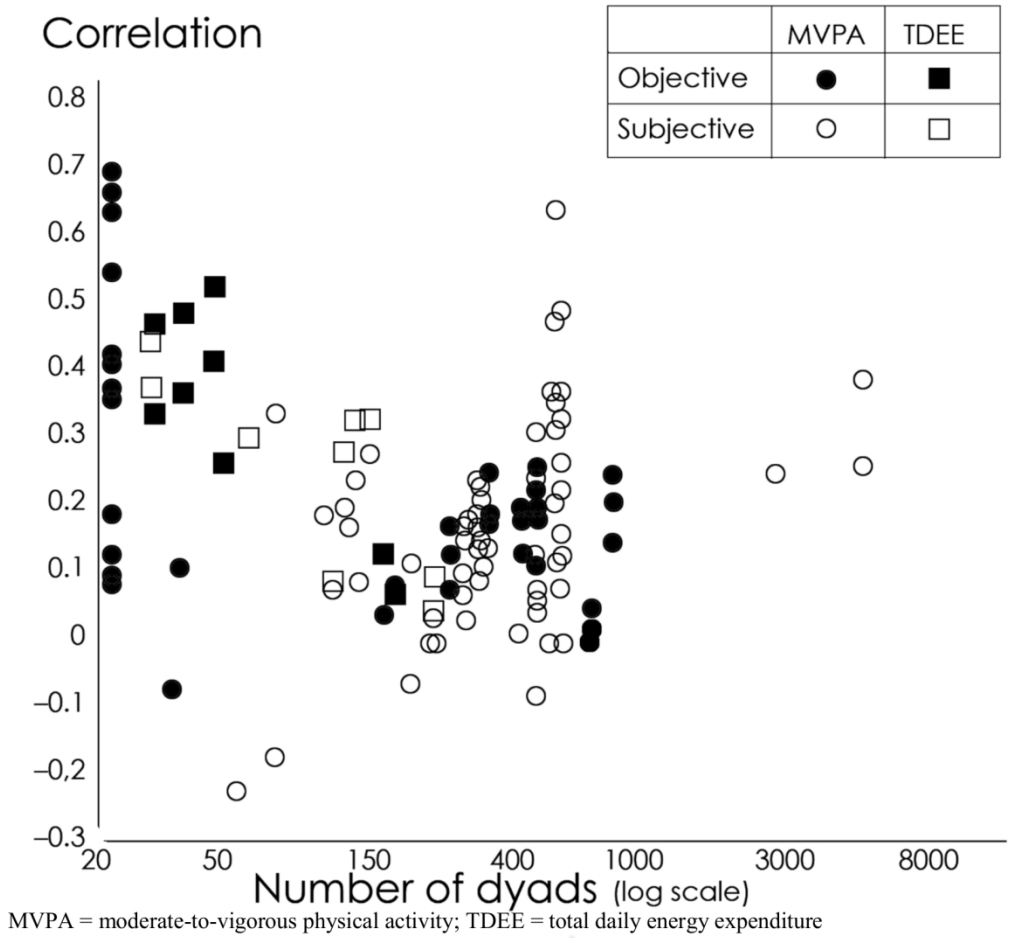

Figure 1. Funnel plot of correlations between parent and child physical activity from 26 studies. Data derived from objective measures are shown with filled symbols; data derived form subjective measures with empty symbols. Circles indicate studies where the outcome was MVPA, and squares studies where the outcome was TDEE.
MVPA = moderate-to-vigorous physical activity
TDEE = total daily energy expenditure

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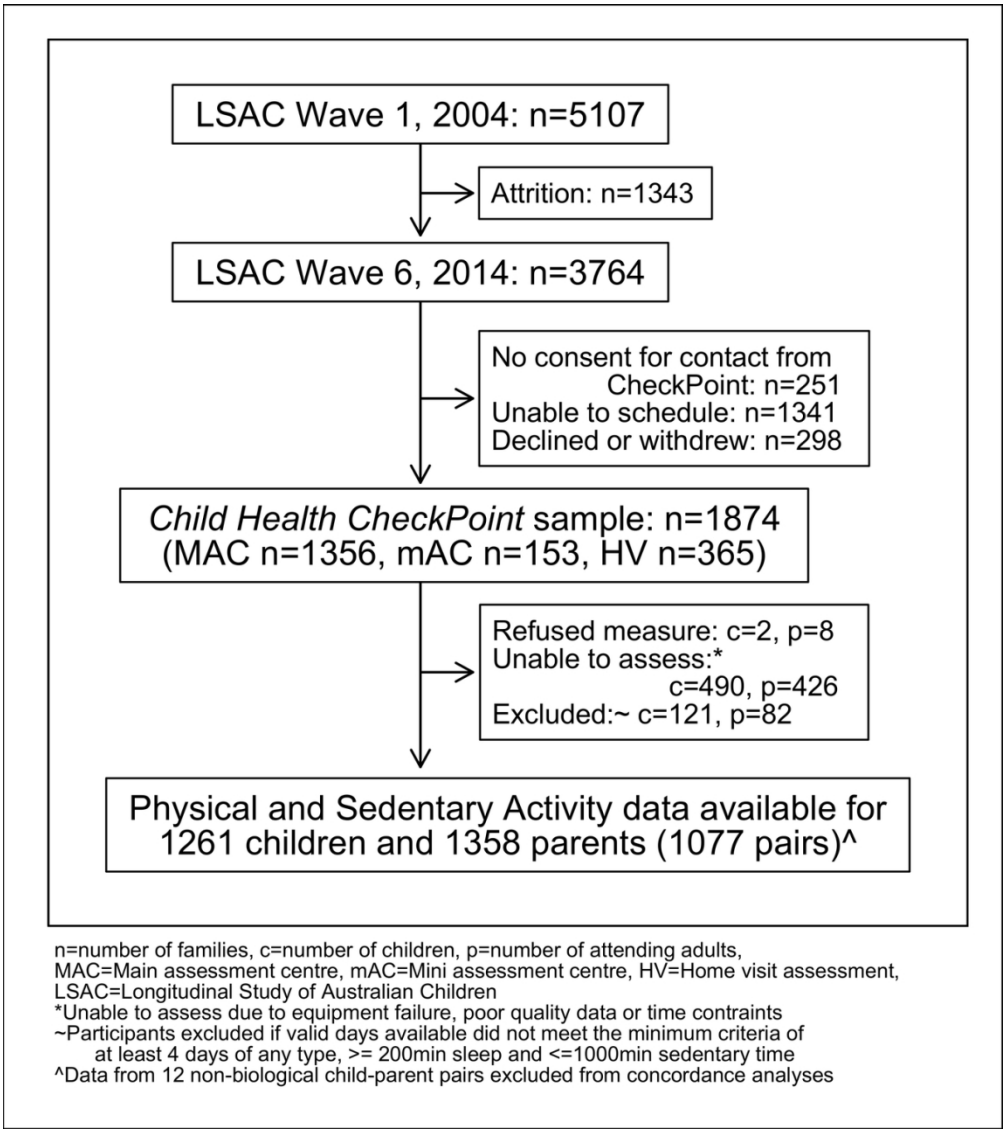

Figure 2: Recruitment and retention of participants for Child Health CheckPoint, including sample size for PA and SB.
n=number of families, c=number of children, p=number of attending adults.
MAC=main assessment centre, mAC=mini assessment centre, HV=home visit assessment,
LSAC=Longitudinal Study of Australian Children.
*Unable to assess due to equipment failure, poor quality data or time constraints.
~Participants excluded if valid days available did not meet the minimum criteria of at least 4 days of any type, ≤200 minutes sleep and <=1000minutes sedentary time.
^Data from 12 non-biological child-parent pairs excluded from concordance analysis.

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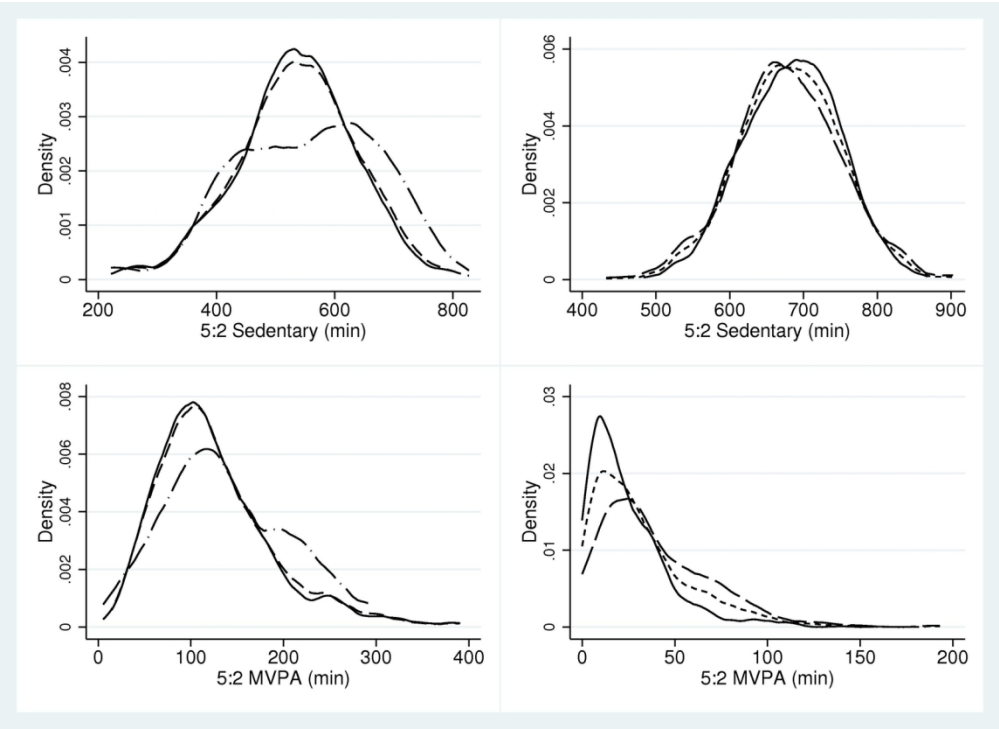

Density plots for average sedentary and MVPA time per day. Males/boys (dash-dotted line), females/girls (solid line) and both sexes combined (dotted line).

139x101mm (300 x 300 DPI)

APPENDIX 1: TRANSCRIPTION OF ACCELEROMETRY ACTIVITY CARDS RELIABILITY (AGREEMENT)

Ten subjects (including children and parents) were randomly selected from subjects previously coded by each of four raters. Therefore, a random sample of 40 subjects (24 children and 16 parents) each coded by four raters was used. Agreement on the classification of log text data in to one of twelve categories was assessed (coding of what the subject was doing when the bracelet was off based upon the log book). There were potentially 12 days of log text for each coding and coders looked at the field that indicated whether the watch had ever been removed. We investigated the 23 subjects who provided reasons to remove the device on day 1. Rater disagreement only occurred when interpretation of text included an interpretation of 'other' by at least one rater. In four of these cases three raters agreed and coded entries as 'other' whilst one rater chose an alternative code. In the other two cases, two raters coded as 'other' and the other two raters agreed on the alternative code. For day 2, activity log text detailed that the watch was not worn in 16/40 (40%) of subjects. Disagreement between raters occurred in 4/16 (25%) cases. In all 4 cases, three of the raters agreed and one differed, again all contained at least one coding of 'other'.

STROBE Statement—checklist of items that should be included in reports of observational studies

Paper title: Physical activity and sedentary activity: Population epidemiology and concordance in 11-12 year old Australians and their parents

	Item No	Recommendation	Page number
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract	2
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found	2
Introduction			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	4
Objectives	3	State specific objectives, including any prespecified hypotheses	5-6
Methods			
Study design	4	Present key elements of study design early in the paper	6
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	7
Participants	6	(*a*) *Cohort study*—Give the eligibility criteria, and the sources and methods of selection of participants. Describe methods of follow-up ~~*Case-control study*—Give the eligibility criteria, and the sources and methods of case ascertainment and control selection. Give the rationale~~ for the choice of cases and controls *Cross-sectional study*—Give the eligibility criteria, and the sources and methods of selection of participants	6-7
		~~(*b*) *Cohort study*—For matched studies, give matching criteria and number of exposed and unexposed~~ ~~*Case-control study*—For matched studies, give matching criteria and the number of controls per case~~	
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	7,8,9
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	*7,8,9*
Bias	9	Describe any efforts to address potential sources of bias	9,10
Study size	10	Explain how the study size was arrived at	6,10
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	7,8,9
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding	9
		(*b*) Describe any methods used to examine subgroups and interactions	9
		(*c*) Explain how missing data were addressed	6,8
		(*d*) *Cohort study*—If applicable, explain how loss to follow-up was addressed	
		(*e*) Describe any sensitivity analyses	

Results			
Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed	6,10
		(b) Give reasons for non-participation at each stage	6
		(c) Consider use of a flow diagram	Fig 2
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	10
		(b) Indicate number of participants with missing data for each variable of interest	11,13,15
		(c) *Cohort study*—Summarise follow-up time (eg, average and total amount)	
Outcome data	15*	*Cohort study*—Report numbers of outcome events or summary measures over time	
		Case-control study—Report numbers in each exposure category, or summary measures of exposure	
		Cross-sectional study—Report numbers of outcome events or summary measures	*13,15*
Main results	16	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	13,15
		(*b*) Report category boundaries when continuous variables were categorized	13,15
		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	
Discussion			
Key results	18	Summarise key results with reference to study objectives	16
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias	16
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	16,17,18
Generalisability	21	Discuss the generalisability (external validity) of the study results	17,18,19
Other information			
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	20

*Give information separately for cases and controls in case-control studies and, if applicable, for exposed and unexposed groups in cohort and cross-sectional studies.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at www.strobe-statement.org.