Potential moderators of day-to-day variability in children's physical activity patterns

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Abstract

Little is known about whether physical activity compensation occurs and, if so, what are potential moderators of such responses. This study examined whether children's physical activity, sedentary time and energy expenditure on one day was associated with these behaviours the following day, and what factors may moderate observed associations. One hundred and twenty-seven children (8-11 years) wore a GT3X+ ActiGraph accelerometer for eight consecutive days and were included in the analyses. Time spent in sedentary time and physical activity was obtained. A sub-sample of 98 children also wore a SenseWear Armband to assess daily energy expenditure and were included in the analyses. Moderators examined were sex, age, BMI, fitness, and fundamental movement skills (FMS). Multilevel analyses were conducted using generalized mixed models. On any given day, every additional 10 minutes spent in moderate-to-vigorous physical activity (MVPA) was associated with 9.3 minutes less MVPA the following day. Every additional 10kcal expended on one day was associated with 2.9 fewer kcal expended the following day. Moderator analyses showed that additional time spent sedentary on any given day was associated with less light physical activity the following day in children with lower FMS. The results are largely consistent with the compensation hypothesis, with children appearing to compensate their activity between days. Strategies to minimise potential compensatory changes may be needed for children overall rather than for specific population sub-groups.

Introduction

Regular engagement in physical activity is associated with a number of physical and psychological health benefits during childhood, including lower body mass index (BMI), higher fitness, lower depression, reduced prevalence of cardiovascular disease risk factors (Janssen & Le Blanc, 2012; Okely et al., 2012). Although equivocal (Chinapaw, Proper, Brug, van Mechelen, & Singh, 2011), there is also evidence that sedentary behaviour (time spent sitting and expending <1.5METs) is an independent risk factor for children's health (Tremblay et al., 2011). Global population estimates suggest that many primary school-aged children do not engage in the recommended 60 minutes of moderate- to vigorous-intensity physical activity (MVPA; Tremblay et al., 2016). In contrast, children spend approximately 60% of their day sitting (Ridgers, Timperio, Cerin, & Salmon, 2015). There is a clear need for efficacious interventions to increase children's physical activity and reduce and break up their sitting time. However, a meta-analysis of intervention studies that used objective measures found very modest positive effects of interventions on children's physical activity levels, with intervention children engaging in ~4 min/day more MVPA compared to control children (Metcalf, Henley, & Wilkin, 2012). A recent review also found unconvincing evidence for interventions solely targeting sedentary behaviour (Altenberg, Kist-van Holthe, & Chinapaw, 2016).

While it is likely that there are a wide range of reasons for these underwhelming results (Metcalf et al., 2012), one explanation worth exploring is that children possess an innate set-point that controls their physical activity (an 'activitystat') or energy expenditure ('energystat') over time (Gomersall, Rowlands, English, Maher, & Olds, 2013; Rowland, 1998). The activitystat and energystat are hypothesised to regulate physical activity and energy expenditure via homeostatic feedback processes (Wilkin, 2011). As such, increases in physical activity, sedentary time or energy expenditure in one part of the day are hypothesised to result in decreases in physical activity, sedentary time or energy expenditure in another part of the day in order to maintain a child's set-point (Rowland, 1998; Rowlands, 2009). This 'compensation' mechanism has important implications for interventions designed to increase physical activity (or physical activity-related energy expenditure) and/or decrease sedentary time, as the effectiveness of interventions targeting one part of a day may be negated by decreases in activity in another part of the day, thus having little effect on overall daily activity levels (Metcalf et al., 2012; Rowland, 1998; Rowlands, 2008).

Whether or not compensation occurs has attracted debate, yet surprisingly little empirical research (Reilly, 2011; Wilkin, 2011). Few studies have examined how the amount of physical activity or sedentary time a child engages in on one day impacts their activity levels the following day. Positive associations between physical activity levels from one day to the next would be indicative of activity synergy, whereby participation in active behaviours on one day increases physical activity the following day (Goodman, Mackett, & Paskins, 2011). Activity compensation would be indicated by negative associations between activity on one day and the next; whereby increases in physical activity on one day are associated with a decrease in activity the next day (Rowland, 1998). Some studies have reported finding no evidence of physical activity compensation within- or between-days (Baggett et al., 2010; Goodman et al., 2011; Long et al., 2013), whilst others have reported within-day activity synergy (Goodman et al., 2011). However, most of these studies only focused on MVPA (Goodman et al., 2011; Long et al., 2013), despite compensatory responses being hypothesised to occur across the activity spectrum (i.e. from sitting through to vigorous-intensity physical activity). Several recent studies have found evidence of compensation both within- and between-days across intensities (i.e. sedentary, light and MVPA (Ridgers, Timperio, Cerin, & Salmon, 2014; Ridgers et al., 2015). For example, increased time spent in MVPA on one day was associated with less time spent in light-intensity physical activity and MVPA the following day (Ridgers et al., 2014), supporting the hypothesis that all intensities contribute to a daily set-point (Rowland, 1998).

To date, little research has examined whether some children compensate their activity to a greater extent than others. As the activitystat is considered to be a homeostatic mechanism, it is possible that the set-point differs between different population subgroups. Factors such as cardio-respiratory and musculoskeletal fitness, fundamental movement skill (FMS) competency, weight status, sex and age may be moderators of physical activity compensation. For example, the activitystat may be highly responsive to fitness levels (which relates to children’s ability to perform physical activity over an extended period) where a child who has higher fitness may compensate less than a child with a lower fitness level. Similarly, children with better FMS competency (e.g. catching, kicking, throwing) may compensate less than children with poorer FMS as they may be more efficient in their movements when performing the skills. Identifying whether compensatory responses are greater in some children compared to others is critical for identifying whether and how future intervention studies can overcome this phenomenon (if indeed it exists), and whether specific strategies are needed in different population sub-groups to minimise potential compensation.

Therefore, the primary aim of this study was to examine whether children’s physical activity, sedentary time and energy expenditure on one day was associated with these behaviours the following day. The secondary aim was to explore whether these associations were moderated by children's age, sex, fitness, FMS, and BMI.

Methods

Participants

Primary schools located within a 30km radius of the university campus in the eastern suburbs of Melbourne, Australia were identified. Sixty-eight schools located in low, medium and high socioeconomic status (SES) areas were randomly selected and invited to participate in the Fitness, Activity and Skills Testing (FAST) Study. Six schools (9% response rate) located in high SES areas (based on the Socio-Economic Index for Areas, 2011) agreed to participate. Once informed written consent was obtained from the school Principal, all children in Years 4 and 5 (age 8-11 years) were invited to participate (n=458). One hundred and thirty-eight children (68 boys, 70 girls; response rate=30%) returned informed written parental consent for the primary outcome assessments (accelerometer, survey, fitness, and fundamental movement skills). A subsample of children (51 boys, 51 girls) also provided written informed consent to simultaneously wear a SenseWear Armband (BodyMedia, Inc, Pittsburgh, Pa., USA). Approval for the study was provided by the University's Human Ethics Advisory Group (HEAG-H 19_2014) and the Catholic Education Office Archdiocese of Melbourne (Project #1998).

Sample size calculation

Mantel's Test, conducted in R, was used to determine the sample size for this study. In brief, autoregressive processes were simulated to examine the power to detect a difference between the estimated within-child correlation matrices for two groups (i.e. children classed as above or below the average value for each moderator). Based on previous research (Baggett et al., 2010) the autocorrelation parameter for compensatory behaviour could range from 0.2 to -0.5. These permutation tests indicated that 60 children per group were needed to detect a difference in association with 70% power while adopting a two-tailed probability level of 0.05.

Procedure

Each school was visited on two occasions. During visit 1, all children (n=138) were provided with an ActiGraph accelerometer (Pensacola, FL, USA) and asked to wear it for eight consecutive days. The subsample of children (51 boys, 51 girls) also received the SenseWear Armband (BodyMedia Inc., Pittsburgh, USA). Children were instructed to wear the monitor(s) according to manufacturer guidelines and to remove them only for water-based activities (e.g. showering, swimming) or during contact activities (e.g. Australian Rules Football). Information concerning the correct wear and care of the monitor(s) was provided. Children also had their anthropometric data collected and their FMS assessed in the school gym during visit 1. During visit 2, the monitor(s) were collected and children completed the fitness assessments in the school gym. Data were collected July to November 2014 (mid-winter to late spring).

Measures

Anthropometry: Stature was measured to the nearest 0.1cm using SECA portable stadiometers (model 217; SECA, Germany). Body mass was measured to the nearest 0.1kg using a calibrated electronic scale (Tanita BC-351; Tanita, Japan). Two measures were taken and, in the event of a discrepancy of ≥0.1cm for stature or ≥0.1kg for body mass, a third measure was taken and the average of the two closest measurement recorded. BMI ($kg.m^{-2}$) was also calculated. All measures were taken by trained research staff using standardised protocols (Stewart & Marfell-Jones, 2006).

Physical activity and sedentary time: Each child wore a GT3X+ ActiGraph accelerometer on their right hip using an adjustable nylon belt. This monitor samples acceleration data using a 12 bit analogue converter at a user-specified rate (30-100 Hz) and is stored in the non-volatile flash memory (ActiGraph, 2014). Raw tri-axial acceleration data were sampled at 30 Hz. The ActiGraph has acceptable reliability and validity in paediatric populations (Trost et al., 1998).

Data were downloaded in 5 second epochs using ActiLife software (v.6.11.2; ActiGraph, Pensacola, FL) and processed using a customised Excel macro. A short epoch length was used to capture the sporadic nature of children's activity engagement (Bailey et al., 1995). Age-specific cut-points were generated using the Freedson and colleagues (2005) prediction equation and used to determine time spent in moderate (MPA; ≥4 to 5.99 METs) and vigorous- (VPA; ≥6 METs) intensity physical activity; Freedson, Pober, & Janz, 2005). A threshold of 4 METs was used to classify MPA, as brisk walking has been associated with an energy cost of 4 METs in calibration studies with children (Trost, Loprinzi, Moore, & Pfeiffer, 2011). Time spent in sedentary (≤100 counts per minute; Ridgers et al., 2012) and light-intensity physical activity (>100 counts per minute to the age-specific MPA cut-point) were also determined. As all cut-points applied are based on counts per minute, the cut-points were divided by 12 to provide thresholds for the 5 second epoch data. Once each epoch was classified as either sedentary, light, moderate or vigorous, the epochs were summed to provide the total time spent in each activity intensity for each day (Ridgers & Fairclough, 2011).

Non-wear time was defined as intervals with at least 20 minutes of consecutive zeros. This is the most commonly used definition in children (Cain, Sallis, Conway, Van Dyck, & Calhoon, 2013) and has been found to provide almost identical wear time estimates compared to the activPAL, which is a direct measure of sitting time (Gabel et al., 2016). A valid day was defined as ≥8 hours on weekdays and ≥7 hours on weekend days (Cain et al., 2013). The lower weekend wear time requirement is due to children typically waking later on weekends (Gabel et al., 2016; Rowlands, Pilgrim, & Eston, 2008). To be included in the analyses, children were required to have a minimum of 3 days of valid data.

Measured energy expenditure: One hundred and two children simultaneously wore a SenseWear Armband on the left upper arm over the triceps muscle to measure free-living energy expenditure. The SenseWear is a multi-sensor monitor (tri-axial accelerometer, heat flux, galvanic skin response, skin temperature, and near-body ambient temperature sensors), which has been validated in children against doubly-labelled water and indirect calorimetry in free-living and laboratory conditions for energy expenditure (Calabro, Stewart, & Welk, 2013; Lee, Kim, Bai, Gaesser, & Welk, 2016). Each monitor was configured with the child's date of birth, sex, handedness, stature and body mass using proprietary software (SenseWear Professional v7, BodyMedia Inc). Energy expenditure data were downloaded in 1 minute epochs using algorithms within the proprietary software. Non-wear criteria were not required as the SenseWear Armband can directly identify periods of non-wear through the skin sensors (Johannsen et al., 2010). A valid day was defined as ≥12 hours of wear and children were required to have a minimum of 2 days of data to be included in the analyses (Ridgers et al., 2016).

FMS: The Test of Gross Motor Development-2 (TGMD-2) was used to assess children's object control (kick, catch, underhand roll, overhand throw, stationary dribble, two-handed strike) and locomotor (run, leap, gallop, hop, slide, jump) FMS (Ulrich, 1985). Each skill has three to five performance component indicators, with children receiving a '1' if they correctly execute a component and a '0' if not. The sum of each skill score was summed to obtain an overall object control score (out of 48) and a locomotor skill score (out of 48). A total FMS score (out of 96) was obtained by summing the object control and locomotor skill scores. Each skill was performed twice and assessed live in the field by trained observers who have previously demonstrated excellent inter-rater reliability (intraclass correlation coefficient (ICC) = 0.93; Barnett, Minto, Lander, & Hardy, 2014). Furthermore, interrater reliability was conducted with 14 children (11% of sample) in the field. Each observer paired with one other observer for each live observation (i.e. Observer 1 and Observer 2 for six observations, Observer 1 and Observer 3 for four observations, and Observer 2 and Observer 3 for four observations). The ICC on the 14 paired observations using a two-way mixed effects model where people were defined as random effects and the multiple measures as fixed effects was excellent for all 12 skills (ICC = 0.88, 95% CI 0.68 - 0.96), the six object control skills (ICC = 0.89, 95% CI 0.70 - 0.96) and the six locomotor skills (ICC = 0.92, 95% CI 0.76 - 0.97).

Fitness: Cardiorespiratory fitness was measured using the 20m shuttle test using standardised testing protocols (Institute of Medicine, 2012). Children paced themselves in time to recorded beeps, which increase in speed as the test progresses. The total number of shuttles that each child successfully completed before being unable to keep pace with the audio beeps was recorded and used in the analyses. Musculoskeletal fitness was assessed using the standing long jump. Whilst this test is a performance of a skill in a similar fashion to the FMS tests, it is assessed using a product of the skill execution (i.e. distance jumped), rather than a process (skill form) measure (i.e., technique used), and therefore can be interpreted as providing a fitness measure. Children stood with both feet parallel behind a marked line and were asked to jump with both feet simultaneously as far as possible (Eather, Morgan, & Lubans, 2011). Children performed the standing long jump twice and the furthest distance jumped (m) was used in the analyses (Castro-Piñero et al., 2010).

Statistical Analyses

All statistical analyses were conducted using Stata v12. Descriptive analyses were initially calculated for all measured variables. Independent *t* tests were conducted to examine differences between children who were provided with both an ActiGraph and a SenseWear and those who were not.

Due to the hierarchical nature of the collected data, multilevel analyses were performed using the generalised linear latent and mixed models (GLLAMM) procedure. GLLAMMs account for the correlation of data points and are the most appropriate technique for analysing data that are not independent of each other (e.g., multiple PA measurements on the same participants; Twisk, 2006). The main analysis consisted of GLLAMMs that estimated associations between temporally adjacent values (i.e. pairs of days) of the outcome variables (e.g. MVPA on day *d* with MVPA on day *d-1*) whilst adjusting for person-level (overall mean daily) physical activity, sedentary time or energy expenditure (as appropriate). The analyses examined whether the activity level a child engaged in on a subsequent day (day *d* in the model) was associated with their activity on the previous day (day *d-1* in the model). As data were collected for eight consecutive days, each child provided a maximum of seven data points for analysis (e.g. day 3 (*d*) compared with day 2 (*d-1*), day 2 (*d*) compared with day 1 (*d-1)*). In all models, the random structure considered random intercepts at the school and child levels, and random slopes at the person level for physical activity, sedentary time and energy expenditure at *d-1*. All main effects models examining the association between values of the outcomes on adjacent days were adjusted for sex, age, day of measurement, and monitor wear time on a given day. The potential moderating effects of sex, age, BMI, object control skills, locomotor skills, total FMS, and cardiorespiratory and musculoskeletal fitness on the associations between values of the outcomes on adjacent days were estimated by adding the moderator and an interaction term of the moderator by the outcome on day *d-1*. Separate models were estimated for each moderator. All continuous variables were centred around their mean. Significant interaction effects were probed by estimating the associations of outcome values on adjacent days at average ('moderate'), one SD above ('high'), and one SD below ('low') average values of the moderator, as recommended by Aitken and West (1991). This approach enables analyses to be performed on continuous data. The alpha level was set ≤0.05 for main effects and ≤0.1 for interaction terms (Twisk, 2006) due to the exploratory nature of the analyses.

Results

One hundred and twenty-seven children (64 boys, 63 girls; 92%) met the ActiGraph inclusion criteria. Ninety-eight (48 boys, 50 girls; 96.1%) met the SenseWear inclusion criteria. Children who wore both an ActiGraph and a SenseWear were significantly taller (3.4cm; $P<0.05$), had a higher body weight (4.4kg; $P<0.01$) and BMI (1.4 $kg.m^{-2}$; $P<0.01$), and engaged in more daily LPA (14.2 min/day; $P<0.05$). No differences were observed for decimal age, object control skills, locomotor skills, total FMS, and cardiorespiratory and musculoskeletal fitness. Descriptive data for the ActiGraph and SenseWear sample are shown in Table 1.

[Insert Table 1 about here]

Temporal associations between days

Associations between temporally adjacent values on physical activity, sedentary time and energy expenditure variables are presented in Table 2. Overall, six statistically significant associations were observed. On any given day, every additional 10 minutes spent in MVPA was associated with 9.3 minutes less MVPA (95% CI: -13.1 to -5.4 minutes) and 16.8 minutes less LPA (95% CI: -20.9 to -12.6 min) the following day. Similarly, on any given day, every additional 10 minutes spent in LPA was associated with 4.7 minutes less LPA (95% CI: -5.8 to -3.5 min) and 2.6 minutes less MVPA (95% CI: -3.7 to -1.5 min) the following day. Lastly, every additional 10kcal expended on one day was associated with 2.9 fewer kcal expended the following day (95% CI: -3.9 to -1.9 kcal).

[Insert Table 2 about here]

Moderator analyses

Significant interactions were observed for sedentary time on any given day and sedentary time the following day for locomotor skills, total FMS, and age. Significant interactions were also found for sedentary time on any given day and LPA the following day for total FMS, and for LPA on any given day and sedentary time the following day for musculoskeletal fitness and age.

Follow-up analyses showed that every additional 10 minutes of sedentary time on any given day was associated with 0.4 minutes less LPA the following day in children with lower FMS (95% CI: -0.6 to -0.1; Table 3). No significant associations were observed for children with higher FMS. The remaining follow-up analyses found no significant moderator effects (Table 3).

There were no moderating effects of sex, BMI, cardiorespiratory fitness or object control skills with any activity intensity based on the ActiGraph (all P>0.1; data not shown). None of the potential moderators interacted with energy expenditure (P>0.1; data not shown).

[Insert Table 3 about here]

Discussion

This study examined associations between accumulated physical activity and/or sedentary time and energy expenditure between temporally adjacent pairs of days, and whether these associations were moderated by sex, age, BMI, FMS and fitness. A number of significant associations were observed between days that were largely consistent with the direction predicted by the activitystat hypothesis (Rowland, 1998). However, only six significant moderator effects were observed. Follow-up analyses showed one significant association for children with lower FMS that was not consistent with the activitystat hypothesis in that a negative association was observed between time spent sedentary on a given day and LPA accumulated the following day.

The negative associations observed between physical activity and/or sedentary time on any given day and the following day are consistent with two recent studies that found significant findings within- and between-days in the direction predicted by the activitystat hypothesis (Ridgers et al., 2014; Ridgers et al., 2015). Interestingly, the magnitude and direction of the observed associations are similar to previous studies based on accelerometry conducted in children aged 8-11 years (Ridgers et al., 2014), despite the demographic differences (e.g. age, socioeconomic status) between the samples. However, these findings contrast other studies that found no evidence of activity compensation; that is, an increase in physical activity during one period or day was not associated with a decrease in physical activity in a subsequent time period or day (Baggett et al., 2010; Goodman et al., 2011; Long et al., 2013). Indeed, several studies have reported that active travel to school, non-school active travel, and school-day physical activity may promote active behaviours across the day (i.e. activity synergy; Cooper, Page, Foster, & Qahwaji, 2003; Goodman et al., 2011; Long et al., 2014). It should be noted that it is possible that factors such as participation in physical education (PE), sport club attendance, or the school day schedule may result in active days being followed by less active days (Pereira et al., 2015), thus potentially influencing the results. However, the analyses used in this study account for such circumstances where (for example) a PE day may be followed by a non-PE day or vice versa. Given that significant associations between days that are consistent with the activitystat hypothesis were still observed, arguably it is unlikely that such activity opportunities completely account for these findings.

It was interesting to note that the associations observed in this study were greater when children engaged in additional minutes of MVPA compared to when they spent more time in LPA. These findings are also consistent with the activitystat hypothesis, where engagement in higher activity intensities, which require greater energy expenditure, should result in lower activity the following day to compensate for the additional energy cost (Rowland, 1998). This is also reflected in the findings of the current study where an increase in energy expenditure on one day was significantly negatively associated with energy expenditure the following day, highlighting that all intensities would be expected to contribute to an activity set-point (Rowland, 1998).

Overall, these findings suggest that specific strategies may be needed to negate any potential compensatory changes that may occur. This could be particularly important when MVPA, the mainstay of children's physical activity interventions and the focus of physical activity guidelines (van Sluijs, McMinn, & Griffin, 2007; Dobbins, Husson, DeCorby, & LaRocca, 2013), is the physical activity intensity being promoted. For example, Rowlands (2008) suggested that targeting frequent short bouts of different activity intensities every day rather than increasing the duration of activity bouts may be one such strategy to minimise compensatory changes, as this is more reflective of the way children accumulate their daily activity (Bailey et al., 1995). Comprehensive school physical activity programs that combine approaches such as daily active classroom breaks (Barr-Anderson, AuYoung, Whitt-Glover, Glenn, & Yancey, 2011), regular short free-play (recess) periods throughout the day (Ridgers, Toth, & Uvacsek, 2009), and supportive and active lessons (Cohen, Morgan, Plotnikoff, Callister & Lubans, 2015) may be needed. Research is needed to establish whether such strategies may be effective in negating potential compensatory changes in activity levels in primary school-aged children.

To our knowledge, this is the first study to investigate whether a range of factors known to influence children's physical activity patterns (Dorsey, Herrin, & Krumholz, 2011; Lubans, Morgan, Cliff, Barnett, & Okely, 2010; Ridgers, Graves, Foweather, & Stratton, 2010) moderate associations between physical activity, sedentary time and energy expenditure from one day to the next. It is important to identify whether some children may be at greater risk of compensatory responses than others, as this will provide insights into strategies for minimising the variation in activity between days in different population subgroups to benefit overall activity levels. However no interactions were observed for sex, which is consistent with previous findings (Long et al., 2013; Ridgers et al., 2014), nor for cardiorespiratory fitness, BMI or object control skills. Several significant interactions were observed for participant age, locomotor skills, total FMS and musculoskeletal fitness. However, follow-up analyses identified only one significant negative association between sedentary time on one day and LPA the following day for children with lower FMS. This finding is not consistent with the activitystat hypothesis. It is possible that this finding could be explained by children with lower FMS proficiency not being provided with the opportunities to be active, lacking the skills to increase their activity levels, not choosing to be active following increased engagement in sedentary time, or experiencing a negative spiral of disengagement in activity due to their poor skill level (Cohen, Morgan, Plotnikoff, Callister, & Lubans, 2014; Robinson et al., 2015; Stodden et al., 2008). However, it may also be a spurious finding, and further research is needed to examine whether FMS competency moderates associations between physical activity and sedentary time between days. Overall, the results suggest that strategies are not needed for specific population sub-groups but could target child populations more broadly.

There are several limitations in this study that should be noted. Firstly, all schools that agreed to participate were from high SES areas, and as such these findings may only be generalizable to children living in high SES areas; further research should examine whether the observed associations and effects of potential moderators are also found in mid- and low-SES children. Secondly, this study was observational in nature. Purpose-designed experimental studies that increase or decrease physical activity engagement during periods of activity or inactivity, respectively, are required to identify whether compensatory changes occur (Rowlands, 2008). Such designs would also provide insights into the potential time scales in which compensatory changes may occur. Thirdly, the study may have been underpowered to detect significant moderating effects for energy expenditure as the outcome variable and larger samples may be required in future studies. Lastly, the majority of the significant interaction terms were small, and it is possible that the results may be sample specific. Future research is needed to further explore moderators of potential compensatory responses in diverse samples to cross-validate the results observed in this study.

Conclusion

Negative associations were observed between time spent in LPA and MVPA on any given day and physical activity accumulated the following day. Similar findings were observed for energy expenditure, which is consistent with the direction of results predicted by the activitystat hypothesis. The moderator analyses suggested that children with lower FMS may not increase their activity levels to 'compensate' for increased sedentary time, but other FMS parameters, fitness, BMI and sex of the child were not significant moderators. Such information is critical for the design and delivery of future interventions that aim to increase children's physical activity levels.

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Table 1: Descriptive data from included participants (mean ± SD)

	ActiGraph Sample (n=127; 50.4% boys)	SenseWear Sample (n=98; 49% boys)
Age (years)	10.4 (0.6)	10.5 (0.6)
Stature (cm)	142.4 (7.3)	143.1 (7.2)
Body mass (kg)	36.4 (7.4)	37.2 (7.1)
BMI ($kg.m^{-2}$)	17.8 (2.5)	18.0 (2.4)
20m shuttle run (shuttles)	57.4 (24.7)	55.0 (25.1)
Standing long jump (cm)	135.9 (21.3)	135.9 (21.5)
Object control skills (raw score)	38.1 (6.2)	38.4 (6.5)
Locomotor skills (raw score)	37.5 (5.9)	38.0 (6.5)
Total FMS (raw score)	75.7 (9.6)	76.5 (9.5)
Sedentary time (min/day)	549.3 (109.2)	-
LPA (min/day)	163.6 (29.2)	-
MVPA (min/day)	79.7 (22.9)	-
Wear time (min/day)	792.6 (109.3)	1285.2 (129.4)
Energy expenditure (kcal/day)	-	1541.5 (302.4)

Key: - = Not measured

Abbreviations: BMI = Body mass index; FMS = Fundamental movement skills; LPA = Light-intensity physical activity; MVPA = Moderate- to vigorous-intensity physical activity

Table 2: Associations of time (min) or energy expenditure (kcal) variables between adjacent pairs of days

	b (95% CI)	*p* value
‡SED_{D1} → SED_{D2}	0.01 (-0.03 to 0.05)	0.70
‡LPA_{D1} → LPA_{D2}	-0.47 (-0.58 to -0.35)	<0.001
‡$MVPA_{D1}$ → $MVPA_{D2}$	-0.93 (-1.31 to -0.54)	<0.001
‡SED_{D1} → LPA_{D2}	-0.03 (-0.05 to -0.01)	<0.01
‡SED_{D1} → $MVPA_{D2}$	-0.01 (-0.03 to 0.01)	0.34
‡LPA_{D1} → SED_{D2}	0.10 (-0.12 to 0.33)	0.36
‡LPA_{D1} → $MVPA_{D2}$	-0.26 (-0.37 to -0.15)	<0.001
‡$MVPA_{D1}$ → SED_{D2}	0.04 (-0.88 to 0.80)	0.93
‡$MVPA_{D1}$ → LPA_{D2}	-1.68 (-2.09 to -1.26)	<0.001
***EE_{D1} → EE_{D2}**	-0.29 (-0.39 to -0.19)	<0.001

Key: ‡ Assessed using ActiGraph; * Assessed using SenseWear Armband

Analyses adjusted for: sex, decimal age, measurement day, wear time, person-level physical activity and/or sedentary time or EE (as appropriate)

Abbreviations: SED = sedentary time; LPA = Light-intensity physical activity; MVPA = Moderate-to vigorous-intensity physical activity

Table 3: Moderating effects on associations of time (min) between temporally adjacent pairs of days

Moderator Association	**1 SD below average value of moderator b (95% CI)**	**p-value**	**Average value of moderator b (95% CI)**	**p-value**	**1 SD above average of moderator b (95% CI)**	**p-value**
Locomotor skills	31.6		37.5		43.4	
‡$SED_{D1} \rightarrow SED_{D2}$	0.04 (-0.01 to 0.09)	0.141	0.01 (-0.03 to 0.05)	0.691	-0.02 (-0.07 to 0.03)	0.455
Total FMS	66.1		75.7		85.3	
‡$SED_{D1} \rightarrow SED_{D2}$	0.03 (-0.01 to 0.08)	0.157	0.01 (-0.03 to 0.05)	0.744	-0.02 (-0.01 to 0.03)	0.456
‡$SED_{D1} \rightarrow LPA_{D2}$	**-0.04 (-0.06 to -0.01)**	**0.002**	-0.03 (-0.05 to -0.01)	0.019	-0.01 (-0.04 to 0.01)	0.296
Decimal age	9.8		10.4		11	
‡$SED_{D1} \rightarrow SED_{D2}$	0.05 (-0.01 to 0.11)	0.054	0.02 (-0.03 to 0.06)	0.445	-0.02 (-0.07 to 0.03)	0.403
‡$LPA_{D1} \rightarrow SED_{D2}$	0.20 (-0.04 to 0.44)	0.107	0.12 (-0.11 to 0.34)	0.308	0.03 (-0.20 to 0.27)	0.772
Musculoskeletal fitness	114.6		135.9		157.2	

[‡]LPA_{D1} → SED_{D2}	0.22 (-0.02 to 0.46)	0.078	0.15 (-0.08 to 0.37)	0.198	0.08 (-0.16 to 0.31)	0.515

Key: [‡] Assessed using ActiGraph

Analyses adjusted for: sex, decimal age, measurement day, wear time, person-level physical activity and/or sedentary time (as appropriate)

Abbreviations: FMS = Fundamental movement skills; SED = sedentary time; LPA = Light-intensity physical activity