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Section: Original Research

Article Title: Intensity- and Domain-specific Levels of Physical Activity and Sedentary Behavior in 10-14 Year-old Children

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Running Head: Levels of physical activity behavior in children

Journal: *Journal of Physical Activity & Health*

Acceptance Date: February 17, 2015

DOI: http://dx.doi.org/10.1123/jpah.2014-0416

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Running head: Levels of physical activity in children

Manuscript type: Original research

Abstract word count: 196

Manuscript word count: 5270

Abstract

Background: to investigate levels of physical activity (PA) and sedentary behavior (SB) in 10-14 year-olds and to determine PA differences between week-weekend days, genders and school stages. **Methods:** 241 children were recruited from 15 primary and 15 secondary schools. PA was assessed for 7 days using the SenseWear Mini Armband and an electronic diary. Week-weekend and gender differences were determined using 2-way repeated-measures ANOVA. Combined intensity- and domain-specific PA differences between genders and school stages were examined using 2-way ANOVA. **Results:** Weekdays were more active compared to weekend days. Physical activity level (PAL) of boys was higher compared with girls. Boys showed more moderate (+15 min/day) and vigorous PA (+9 min/day), no differences were found for SB and light PA. Secondary school children showed more SB (+111 min/day), moderate (+8 min/day) and vigorous (+9 min/day) PA and less light PA (-66 min/day) compared with primary school children. No difference was found for PAL. The results of the combined intensity- and domain-specific parameters revealed more nuanced differences between genders and school stages. **Conclusions:** Our results demonstrate the complexity of PA and SB behavior of children, indicating the need for a multidimensional and differentiated approach in PA promotion.

Keywords: SenseWear Mini Armband, electronic activity diary, gender differences, school transition

Introduction

The promotion of an active lifestyle during childhood is an important topic in current public health policy. It is well known that children who are regularly physically active benefit from positive health effects with regard to body composition, cardiovascular risk factors, bone health and mental well-being [1,2,3,4]. Moreover, children and adolescents who are regularly physically active are more likely to adopt this active lifestyle into adulthood, which underlines the need for physical activity (PA) promotion at a young age [5,6].

Over time, epidemiological evidence has consequently designated the same priority target groups for PA promotion during childhood. For example girls are an important priority target, as lower levels of PA have been reported consistently in girls compared with boys across all ages [7,8,9]. An accelerometry-based study on 2185 European children from various countries has shown that the overall PA level of boys was 20% higher at the age of 9 and 26% higher at the age of 15 compared with girls [10]. Besides the well-known gender difference, longitudinal evidence has shown that activity levels decline as children progress from childhood into adolescence [11,12]. In addition, certain key periods in life coincide with important changes in PA behavior. In children, the life event that is known to have a considerable negative impact on activity behaviors is the transition from primary to secondary school [9,13,14]. In the review by Dumith et al. [12] the average annual decrease in PA starting from early adolescence was estimated at 7%. Maintaining the activity levels of children in the first grades of secondary school has therefore been a priority target for PA promotion.

Despite the knowledge on the priority groups and despite the investment that has been put in PA promotion, little progress has been made in recent years. Developing effective public-health campaigns to counter physical inactivity requires a comprehensive and precise understanding of the current activity patterns of children. For that reason, the assessment method applied in epidemiological research plays an essential role. Many of the studies that have investigated PA patterns during childhood have relied on self-report measures of PA [12]. Due to cognitive immaturity and typically intermittent activity patterns, children often experience difficulties remembering their past PA behavior. As a result, retrospective self-report measures are not appropriate for accurate assessment of PA in a preadolescent population [15,16].

During the past two decades, the assessment of PA in children has become more accurate, as PA research has emerged towards objective monitoring of PA through accelerometry. The introduction of accelerometers has enabled the objective quantification of PA behavior in 3 dimensions: the frequency, duration and intensity of the activities [17]. However, if we intend to evaluate PA in all its 4 dimensions, assessment through accelerometry on its own is insufficient, since it does not provide information on the type of the activities. Only by assessing the 4 dimensions of PA simultaneously, a comprehensive image on the PA behaviors of children can be obtained [18]. To our knowledge, few studies have tried to investigate PA patterns of children combining accelerometry with simultaneous assessment of the behavioral domain in which activities occur (i.e. school, sports, transport, screen-based activities, etc.). In addition, activity behaviors are too often evaluated based on one single outcome measure, whereas PA is a complex multi-dimensional construct. As a consequence, crucial information on the activity behavior of children is ignored. If we aim for an accurate and nuanced understanding of PA patterns, the complexity of the PA construct should be taken into account. By doing so, specific priority behaviors and target groups can be detected in order to develop more effective strategies for PA promotion.

Therefore, this study aims to profoundly investigate levels of PA and sedentary behavior (SB) in 10 to 14 year-old Flemish children by combining the SenseWear Mini Armband (SWM) with an electronic activity diary. This combination enables us to establish intensity- and domain-specific PA levels of boys and girls round the ages of the school transition. Since children's pastimes during weekend days can differ substantially from weekdays, week and weekend activity levels will be compared and evaluated separately. Furthermore, differences in PA behavior between genders and school stages (i.e. primary versus secondary school) will be investigated. Based on the literature, it is hypothesized that overall PA levels will be higher in boys compared with girls and higher in primary compared with secondary school children. Nevertheless, our aim is to reveal more detailed insights in the gender and school-stage differences by investigating PA levels of children from a combined intensity- and domain-specific perspective and thus offering better guidance for PA promotion during childhood.

Methods

Participants

In total 241 children (122 boys and 119 girls) between 10-14 years took part in the study. Participants were recruited from 15 primary and 15 secondary schools in Flanders, Belgium. All participants followed class in the last two years of primary or the first two years of secondary school. Schools were selected in both rural and urban areas, within the 3 different school networks in Flanders. Sixty-one percent of the approached schools consented to participate in the study. Within each school an equal amount of boys and girls were randomly selected. Both parents and children were informed about the study purposes, study-related activities, benefits and risks. The study was approved by the Medical Ethics Committee of the KU Leuven and written informed consent was received from both children and their parents prior to the start of the measurements.

Anthropometrics

Anthropometric measures were obtained in light clothing and without shoes one day before the start of the PA monitoring period. Body weight was determined to the nearest 0.1kg using a Seca Robusta 813 digital scale (Seca, Hamburg, Germany). Stature was assessed to the nearest 0.1cm using a portable anthropometer (GPM anthropological instruments, Zurich, Switzerland). BMI was calculated as weight/stature^2 (kg/m^2). Weight status (i.e. normal weight versus overweight) was established based on age and gender specific BMI cut-offs of Flemish children [19].

PA assessment

Participants were instructed to wear the SWM (Bodymedia, Inc, Pittsburg, PA, USA) over the triceps muscle of the left upper arm. The SWM is a PA monitor that combines tri-axial accelerometry with physiological measures (i.e. skin temperature, heat-flux and galvanic skin response) for the estimation of energy expenditure. Data from the different sensors combined with gender, age, stature, weight and handedness are used to estimate energy expenditure, PA intensity and number of steps through proprietary algorithms that are incorporated in the SenseWear software (SenseWear Professional software v7.0). The validity of the SenseWear Mini has been examined in a study by Calabro et al. [20]. According to the authors, the SWM provided reasonably accurate estimates of total energy expenditure under free-living conditions in 10-16 year-old children. The armband was worn for 7 consecutive days, 24h per day, except during water-based activities. A 7-day accelerometry protocol has shown to provide reliable estimates of habitual PA behavior in youth [21].

Besides the continuous monitoring through the SWM, participants were asked to register their activities by means of an electronic activity diary that was developed at the Department of Kinesiology of the KU Leuven. The electronic activity diary is a real-time self-report assessment strategy that provides information on the type or context of the activities. The diary consists of a software program, integrated in a Palm Z22 handheld computer (Palm, Inc., Sunnyvale, CA, USA) and was originally developed for a study on an adult population [22]. Through several pilot studies the software program for adults was modified and simplified for a child population. The diary for children consists of 7 main categories: school, eating and drinking, personal care, household chores, sleep, transportation and leisure time. The last two main categories were divided into subcategories. Transportation consists of walking, cycling and motorized travel. Leisure time was subdivided into a series of active and inactive behaviors (e.g. television viewing, reading, active play, sport participation etc.). Participants were instructed to register their actions in the electronic diary at the start of every activity for the entire 7-day period, except during school hours. Information on the schedule of the different recess breaks was provided by the school administration. Real-time assessment strategies (e.g. ecological momentary assessment, electronic activity diaries) are known to provide more accurate behavioral information compared with traditional retrospective assessment strategies, because detailed activity information is registered at the time of occurrence [23]. Real-time assessment is especially beneficial in children, given the incidental nature of their activity behavior and cognitive immaturity [15,16]. Data from the SWM were merged with the electronic activity diary output. As a result, 24-h information on all 4 PA dimensions (i.e. frequency, intensity, time and type) was available on a minute-by-minute basis. Type-specific information of the electronic diary was used to impute missing values from the SWM. Missing data for sleep were substituted with the average energy cost observed for sleep during all other nights. Missing data for personal care and swimming were replaced with the MET-value and corresponding energy expenditure according to the compendium of PA for youth [24].

Several variables were created based on the SWM and electronic diary data. Physical activity level (PAL) is an expression of daily energy expenditure and was calculated as the average MET-value provided by the SWM (MET_{SWM}). Time spent in the 4 intensity levels was calculated based on device-specific intensity thresholds of the SWM: sedentary ($\leq$1.8 MET_{SWM}), light (>1.8 – $\leq$5.1 MET_{SWM}), moderate (>5.1 – $\leq$7.2 MET_{SWM}) and vigorous (>7.2 MET_{SWM}) activities. These SWM thresholds were established using a structured indirect calorimetry protocol and were verified against the MET-values of the compendium of PA for youth by Ridley et al. [24]. The different activities from the diary output were translated into 9 domains in which behaviors of children mostly occur during the day. The behavioral domain of school activities consists of all activities that took place during school time, including classes, recess, lunch and physical education. Homework entails all the inactive school-related activities performed after school hours. Screentime consists of computer/tablet use and watching television, but does not include screentime for homework. The domain of motorized travel encompasses all transfers children make by car, bus, train or any other motorized vehicle. Transfers on foot or by bike are part of the active travel domain. Sport participation consists of all the organized and non-organized sport activities children engage in during leisure time. The active leisure domain entails active behaviors during leisure time (e.g. playing outdoors, active hobbies, shopping) except for the previously mentioned sport activities. The inactive leisure domain encompasses all the inactive behaviors during leisure time, screentime excluded (e.g. reading, inactive hobbies, social interactions with peers). Finally, eating and drinking, personal care and household chores are part of the domain of common activities of daily life (CADL).

By combining the information from the 4 intensity categories with the information from the 9 behavioral domains, a series of intensity- and domain-specific PA variables were created. Time spent sedentary was calculated for the domains of school, homework, screentime, motorized travel, inactive leisure time and CADL. Time spent at light, moderate and vigorous intensity was calculated for the domains of school, sports, active travel, active leisure and CADL. Within the behavioral domain of school, total recess time was calculated together with the proportions of sedentary, light, moderate and vigorous activity during recess.

Participants were included for further analysis if data of at least 6 valid monitoring days were available, including both weekend days and a minimum of 4 week days. A valid monitoring day was defined as a day with at least 1296 min (i.e. 90% compliance) of combined SWM and activity diary output, after imputation of missing data. In total, 201 of the initial 241 participants met the compliance criteria. Consequently, 40 participants (23 boys and 17 girls) were excluded from further analysis. The group that did not meet the compliance criteria did not differ significantly from the final sample with regard to age and weight-status.

Statistical analysis

Personal characteristics and overall PA parameters of the participants were computed as means and standard deviations. In order to determine whether multilevel analyses were required, the effect of nesting on the school-level was examined by computing design effects. A design-effect of 2.00 or more implies that the school-level has a meaningful effect on the PA levels of the participants and consequently multilevel analysis would be appropriate [25,26]. For the current data, the design effects for the variables PAL and moderate-to-vigorous PA (MVPA) did not exceed the criterion of 2.00 (1.63 and 1.97 respectively). Consequently, 2-way repeated-measures analysis of variance models were used to examine differences between week and weekend days and between genders. PA differences between genders and school stages were determined using 2-way analysis of variance models. Since the activity behavior of children displayed almost no structured pattern or general tendency during weekend days, analysis on the combined intensity-and domain-specific PA variables focused on weekdays only. Statistical significance was set at an alpha level of 0.05. All statistical analyses were carried out using SAS statistical software version 9.2 (SAS Institute, Cary, NC, USA).

Results

Personal characteristics and general PA parameters (i.e. PAL and steps/day) of the participants are presented in Table 1, together with the results of the 2-way ANOVA for gender and school stage. Results in Table 1 are presented as pooled means since no significant gender by school-stage interaction effects were found. Based on the age and gender specific BMI cut-off, 12% of the total study population was categorized as overweight. Both PAL (+0.14 MET_{SWM}; P<0.001) and steps (+1951 n/day; P<0.001) were significantly higher in boys compared with girls. Children from primary school took significantly more steps (+1326 n/day; P<0.001) than secondary school children. No significant difference between school stages was found for PAL.

The results of the 2-way repeated measures ANOVA for the comparison between weekdays versus weekend days and gender is shown in Table 2. Both PAL (P<0.001) and steps (P<0.001) were significantly higher during weekdays compared with weekend days. Also higher levels of light (P<0.001), moderate (P<0.001) and vigorous (P<0.001) intensity PA were observed on weekdays. The results showed no difference for sedentary time, however a longer sleeping time was shown on weekend days (P<0.001).

The combined intensity- and domain-specific PA variables on weekdays and the differences between genders and school stages are shown in Table 3. These results were pooled by gender and school stage because only one significant interaction effect was observed. With regard to the overall intensity categories a significant gender difference for moderate and vigorous PA was found, boys spent more time doing moderate (+15 min/day; P<0.001) and vigorous intensity activities (+9 min/day; P<0.001) compared with girls. Overall sport participation (i.e. sum of light, moderate and vigorous sport activities) did not differ significantly between genders (boys: 31 min/day; girls: 30 min/day) (not shown in table). Within the moderate and vigorous category, the behavioral domains of school (P<0.001 and P<0.001 respectively) and sport participation (P=0.003 and P<0.001 respectively) differed significantly between boys and girls, again in favor of the boys. No significant gender difference was observed for overall time spent at sedentary and light intensity activities. However, within the sedentary category boys collected significantly more screentime (+29 min/day; P<0.001), but less other inactive leisure time (-19 min/day; P<0.001) and sedentary time during school hours (-25 min/day; P<0.001) compared with girls. The category of light intensity activities only displayed a significant difference for the domain of school activities, with boys being more involved in light PA (+16 min/day; P=0.001) compared with girls.

Differences between school stages were apparent for all overall intensity categories (i.e. sedentary, light, moderate and vigorous). Secondary school children collected significantly more time in sedentary activities (+111 min/day; $P<0.001$). The behavioral domains of school (+63 min/day; $P<0.001$), homework (+17 min/day; $P<0.001$), screentime (+29 min/day; $P=0.002$) and motor travel (+10 min/day; $P=0.02$) added significantly to this higher level of SB. In contrast, primary school children showed more inactive leisure time (+12 min/day; $P=0.01$) compared with secondary school children. Higher levels of light PA were apparent in primary school children (+66 min/day; $P<0.001$). This was also shown in the light intensity domains of school (+36 min/day; $P<0.001$) and sport participation (+8 min/day; $P=0.007$). Overall sport participation was significantly higher in primary than in secondary school children (primary: 34 min/day, secondary: 27 min/day; $P=0.04$) (not shown in table). Moderate (+8 min/day; $P=0.01$) and vigorous (+9 min/day; $P<0.001$) activity levels were higher in secondary school children compared with primary school children. For moderate PA, only time spent on active transportation (+6 min/day; $P<0.001$) differed significantly between school stages, in favor of secondary school children. The higher level of vigorous PA of secondary school children was reflected through the domains of sport participation (+3 min/day; $P=0.009$) and active travel (+5 min/day; $P<0.001$).

During the school recess breaks, girls spent a greater proportion of total recess time doing sedentary activities compared with boys (boys: 14.3%, girls: 21.3%) and boys spent more time at moderate (boys: 15.8%, girls: 7.5%) and vigorous intensity (boys: 4.6%, girls: 1.7%). No significant gender difference was found for light intensity activity during recess (boys: 65.4%, girls: 69.5%).

Despite longer school days for secondary school children, total recess time was higher in primary schools compared with secondary schools (93 min/day and 69 min/day respectively; $P<0.001$). Children from secondary school spent a greater proportion at sedentary intensity during recess (primary: 15.9%, secondary: 20.7%) and a smaller proportion at light intensity (primary: 69.9%, secondary: 63.9%). No significant difference between the school stages was found for the proportion moderate (primary: 11.4%, secondary: 11.9%) and vigorous activities (primary: 2.9%, secondary: 3.4%).

Discussion

This study investigated levels of PA and SB of 10-14 year-old school children using a combination of the SWM with an electronic activity diary. The protocol enabled us to profoundly analyze PA levels from a combined intensity- and domain-specific perspective, thus creating a more detailed image on children's PA behavior. Moreover, week and weekend levels of PA behavior were compared and differences between genders and school stages were established.

Our results showed that children were more active on weekdays compared with weekend days. These lower activity levels on weekend days have been reported earlier [9]. But still, this finding is somewhat remarkable. Weekend days are less structured with more opportunities for children to spend their pastimes in function of their own preferences, whereas weekdays entail a considerable amount of institutionalized sitting during school hours. It appears that when children can autonomously decide what to do during the unstructured weekend days, they will rather choose inactive over active pursuits. Contradictory results have been reported in adults, their activity levels on weekend days exceeded activity levels on weekdays [22].

Epidemiological studies on the activity behavior of children have consistently reported higher activity levels in boys compared with girls [7,8]. Our results for PAL and daily steps endorse this general finding. However, the results of the combined intensity- and domain-specific PA parameters revealed extra nuances that add to the understanding of gender differences in activity behavior during childhood. For total sedentary time, no significant difference between genders was observed. However, gender differences were apparent with respect to the sedentary domains. Boys were more engaged in screen-based activities, whereas girls collected a greater proportion of their sedentary time during school hours and doing non-screen leisure activities. The finding that boys and girls demonstrate differences in leisure-time sedentary behavior has been documented before [27]. Another study stated that the higher levels of screentime observed in boys could be explained by the fact that boys played more electronic video games, whereas no gender difference for TV-viewing was found [28]. Furthermore, it has been shown that girls generally take part in more various sedentary activities during leisure time (e.g. extracurricular reading, social interaction with peers and writing) [29,30].

Most research has primarily focused on MVPA to describe PA gender differences. These studies consistently found higher levels of MVPA in boys [31,32]. As expected, boys from our sample collected significantly more moderate and vigorous PA. Within both these intensity categories the behavioral domains that indicated a significant difference in favor of boys were school and sport participation. It has to be noted, however, that the significant gender difference for vigorous PA during sports participation and school hours in terms of time represents only a small difference of 3-4 min/day. Although the relevance of these differences for vigorous PA seems negligible, the sum of all these small daily differences could imply important consequences regarding health outcomes in children.

With regard to school PA, boys collected higher levels of light, moderate and vigorous PA and lower levels of sedentary time. Comparable findings have been reported in a study by Van Stralen et al. [33] on the activity level of 10-12 year-old children from various European countries during school hours. Their results showed that girls spent significantly more time during school hours on sedentary activities and less time in MVPA than boys. Recess breaks are known to have a considerable impact on school PA levels, as these are the only relatively unstructured moments during school time. During recess breaks children are free to choose what type of activities they engage in. Our results show that during recess, girls were less physically active compared with boys. Bailey et al. [34] established similar results in their study on school-related PA. They concluded that PA behavior during recess was more beneficial for health in boys, since they collected lower levels of sedentary time and higher levels of MVPA. Moreover, a study on a sample of 9-10 year-old children used direct observation to examine PA during recess. Gender was a significant influencing factor of recess PA, with girls engaging in 13.8% more sedentary and 8.2% less vigorous activities compared with boys [35].

Total time spent on sport participation (i.e. combined light, moderate and vigorous sports) did not differ significantly between genders. This is somewhat surprising, since several studies have reported higher levels of sport participation in boys [36]. However, boys from our sample showed significantly more moderate and vigorous minutes during sports. Apparently, girls were less engaged in sport activities at the higher end of the intensity span. In line with our results, a study on youth practices of several team-sports in 7-14 year-old children reported that boys spent on average 7.8% more time at moderate to vigorous intensity during sport participation [37].

The multifaceted differences between the PA levels of boys and girls provide endorsement for gender-based PA promotion strategies. In order to ameliorate activity levels of both genders, PA interventions should more appropriately consider the different needs and interests of boys and girls separately. Moreover, improving PA levels of girls should be high on the priority list for PA promotion.

Another aim of our study was to investigate to what extent PA levels differ between children from primary (last 2 years) and secondary school (first 2 years). Interestingly, our results revealed that the overall PA parameter, PAL, did not differ significantly between school stages. However, children from primary school collected significantly more steps. By evaluating the combined intensity- and domain-specific information, a more detailed and comprehensive image of primary and secondary school children’s PA levels was revealed.

In general, our results showed that secondary school children spent a greater proportion of the day sedentary compared with primary school children, which is especially apparent during school activities, homework, screen-based behaviors and motorized travel. Only the amount of non-screen sedentary activities during leisure time was higher in primary school. Several longitudinal studies have found significant increases in SB during the transition from primary to secondary school [28,13]. Rutten et al. [13] observed both an increase in screentime (girls: +3.13 h/week; boys: +2.81 h/week) and time spent on homework (girls: +3.57 h/week; boys +1.47 h/week) assessed by self-report in Flemish children. According to the authors, the observed increase in screentime was mainly attributable to an increase in computer use rather than television viewing. Our data also showed higher levels of motorized travel in secondary school children. Presumably, this finding is attributable to longer commuting distances to school, since secondary schools in Flanders are more often centralized in urban areas.

Despite lower levels of SB, children from primary school also showed less MVPA compared with secondary school children. It appears that lower levels of SB do not necessarily imply higher levels of MVPA and vice versa. Instead, primary school children were more involved in light intensity activities compared with secondary school children. The higher levels of MVPA in secondary school were somewhat remarkable as several longitudinal studies have reported a decline of PA during the transition from childhood to adolescence [9,12]. Two other studies have also found an increase in moderate and vigorous PA after the school transition. Cooper et al. [38] found a small yet significant increase in MVPA (+2.6 min/day; P=0.017) after the transition to secondary school. A self-report study of Telama et al. [39] in a sample of Finnish children and adolescents found comparable results with regard to vigorous PA. Although overall levels of PA declined, levels of vigorous PA increased from childhood to preadolescence. Similarly, our results indicated that despite a shorter waking time and despite lower levels of MVPA, the level of total activity behavior (i.e. sum of time spent at light, moderate and vigorous intensity activities) was higher in primary school children.

Overall time spent on sport participation was higher in primary school children compared with secondary school. Yet, slightly higher levels of vigorous PA and lower levels of light PA during sport participation were observed in secondary school. This finding deserves proper attention, as vigorous PA is known to display positive associations with health parameters irrespective of PA at lower intensity levels [40]. Again, it has to be noted that the significant school-stage difference for vigorous PA during sports participation and school hours represents only a small difference of 3 min/day.

Consistent to what is generally reported, our data indicated higher levels of active travel after the transition to secondary school [13,14,41]. The increased independence of secondary school children might partially explain this difference. As children get older, parents more often allow their kids to commute by themselves, usually by bike or on foot. Also the longer commuting distances to school provide an explanation for this difference. A study of Carver et al. [42] concluded that active travel is an important source of daily PA, particularly in secondary school. Higher levels of active travel in secondary school might partially compensate for lower PA levels in other life domains.

This study exposed the complexity of PA behaviors in children. The development of effective PA promotion strategies requires a clear understanding of children's pattern of PA and SB. Consequently, the different dimensions and behavioral domains of PA should be properly assessed and evaluated. By summarizing PA in terms of one single outcome measure (e.g. time spent in MVPA), crucial information on the activity behavior of children is ignored.

Based on the PA levels of the current study-sample some recommendations for PA promotion policy can be made. Our results justify a differentiated PA promotion strategy for different subgroups of children, as differences in activity behaviors between genders and school stages were apparent across the different activity intensities and behavioral domains. Also the high degree of variability in PA outcomes supports the need for differentiation, since it indicates that PA levels differ substantially between individuals within the various subgroups. Moreover, PA promotion policy would profit from a holistic approach on PA behavior by using the complexity of the PA construct as an opportunity to ameliorate overall PA levels in children. In order to imply this holistic approach the following aspects should be considered.

First, not only PA but also SB should be a target for PA promotion. Since SB is the dominant activity category of children during the day (on average 6.5 h/day for primary and 8.4 h/day for secondary school children), a large opportunity for improvement of total activity levels lies in the reduction of SB. In the past decade, the overall focus of PA research has expanded from MVPA to the combination of both MVPA and SB. The current evidence on the detrimental consequences of excessive sitting on a variety of heath indicators (i.e. body composition, cardiovascular risk factors and metabolic profiles) is still ambiguous and weak [43,44]. However, reducing SB might automatically increase opportunities to engage in MVPA, for which the positive relationship with health indicators is well established [45]. Secondly, policy makers have often ignored light intensity PA as an essential part of PA promotion. According to Lee et al. [46], the lack of attention with regard to light PA was caused by the incapability of accurately measuring light-intensity PA through self-report measures. As a consequence, current PA guidelines rarely prescribe light PA as a part of a healthy lifestyle. However, PA promotion strategies might increase their effectiveness by focusing on enhancing levels of light PA alongside MVPA. Thirdly, the holistic approach could entail broadening the scope of PA promotion to multiple behavioral domains. The majority of PA promotion strategies in children have focused primarily on sport participation or PA during school hours, whereas other domains (e.g. active transport and several sedentary domains) have remained relatively unexplored. By simultaneously targeting several activity domains, the well-known pitfall that increasing PA levels in one domain of daily life are compensated by declining PA levels in another domain can be avoided [47]. Finally, the majority of PA promotion strategies and interventions have primarily targeted school settings, whereas community- and family-based promotion strategies remain rather scarce [48,49]. Our results showed that weekend days of children were less active compared with typical school days. Targeting families and offering them tools to stimulate children to be more active might alter PA levels during the relatively unstructured weekend days.

Some limitations should be taken into account when interpreting the results of this study. First, the comparison of PA levels between primary and secondary school children was based on cross-sectional data instead of longitudinal data. As a consequence, our results did not aim to reflect actual changes in PA behavior over time. Nevertheless, our data demonstrated that PA levels differ between children in the last two years of primary and children in the first two years of secondary school. Therefore, we can conclude that both subgroups should be addressed separately based on their specific needs for PA promotion. Secondly, it should be noted that some sort of selection-bias could not be ruled out completely. The children in our sample were randomly selected within the different schools. However, parents had to grant permission to enroll their child in the study. Since physically active families are generally more interested in this type of research, a relatively active sample might have been recruited. The major strength of this study was the assessment method of PA and SB. The combination of the SWM and the electronic activity diary enabled us to register all 4 PA dimensions simultaneously on a 24h basis. In addition, the electronic activity diary eliminated bias associated with recall, since detailed activity-type information was registered in real-time. Furthermore, we applied a high compliance standard of 90% for both SWM and diary information. This high standard is essential if one wants to capture the complexity and nuances of PA behaviors.

To conclude, our results showed that overall 1) boys were more active than girls 2) primary school children were more active compared with secondary school children and 3) activity levels on week days were higher than on weekend days. However, these findings were not straightforward when considering the different intensity- and domain-specific aspects of PA and SB in children. Cleary, PA is a complex behavior that takes place in multiple domains of daily life. Therefore, policy makers should consider this complexity as an opportunity to promote PA from different perspectives.

Acknowledgements

The authors would like to thank all the children and their parents for their collaboration in the study.

Funding source

Stijn De Baere was funded by the Flemish Policy Research Center of Sports

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Table 1. Person characteristics and physical activity parameters by gender and school stage: 2-way ANOVA.

	Boys (n=99)	**Girls (n=102)**	**Primary (n=106)**	**Secondary (n=95)**
Age (yr)	12.0 (1.2)	12.1 (1.2)	11.1 (0.6)	13.1 (0.7) [b]
Overweight (%)*	10.1	13.7	14.2	9.5
PAL (MET_{SWM})	1.95 (0.21)	1.81 (0.21) [a]	1.90 (0.21)	1.86 (0.23)
Steps (n/day)	11654 (3594)	9703 (2324) [a]	11291 (3192)	9965 (2997) [b]

Results are presented as means and standard deviations. * Analyzed using a Chi-squared test. [a] Significant main effect for gender.

[b] Significant main effect for school stage. No interaction effects were found. All tests $P < 0.05$.

Table 2. Week versus weekend and gender differences for the overall and intensity-specific PA parameters: 2-way repeated-measures ANOVA

	Boys (n=99)		**Girls (n=102)**		**Sign.**
	Week	**Weekend**	**Week**	**Weekend**	**P < 0.05**
PAL (MET_{SWM})	1.99 (0.20)	1.88 (0.28)	1.84 (0.22)	1.74 (0.26)	a, b
Steps (n/day)	12251 (3650)	10177 (4759)	10214 (2511)	8488 (3325)	a, b
Sedentary (min/day)	438 (100)	447 (117)	452 (101)	450 (110)	
Light (min/day)	355 (75)	289 (90)	359 (75)	298 (93)	a
Moderate (min/day)	51 (22)	44 (33)	36 (19)	27 (20)	a, b
Vigorous (min/day)	24 (18)	18 (20)	15 (14)	12 (18)	a, b
Sleep (min/day)	571 (55)	642 (65)	579 (49)	653 (49)	a

Results are presented as means and standard deviations. [a] Significant main effect for week versus weekend.
[b] Significant main effect for gender. No interaction effects were found.

Table 3 Combined intensity- and domain-specific PA patterns on weekdays: differences between genders and school stage.

	Boys (n=99)		Girls (n=102)		Primary (n=106)		Secondary (n=95)	
	Min·day^{-1}	**%**	**Min·day^{-1}**	**%**	**Min·day^{-1}**	**%**	**Min·day^{-1}**	**%**
Sedentary	**438 (100)**	**30.4**	**452 (101)**	**31.4**	**393 (83)**	**27.2**	**504 (85)** [b]	**35.0**
School	162 (49)		187 (52) [a]		145 (40)		208 (42) [b]	
Homework	34 (24)		40 (26)		29 (18)		46 (29) [b]	
Screen	126 (65)		97 (57) [a]		98 (60)		127 (63) [b]	
Motor travel	37 (32)		34 (27)		31 (21)		41 (36) [b]	
Inactive leisure	27 (21)		46 (39) [a]		42 (35)		30 (29) [b]	
CADL*	42 (21)		41 (19)		40 (17)		44 (23)	
Other	9 (20)		8 (25)		8 (19)		9 (25)	
Light	**355 (75)**	**24.7**	**359 (75)**	**24.9**	**388 (68)**	**26.9**	**322 (66)** [b]	**22.4**
School	196 (43)		180 (41) [a]		205 (40)		169 (37) [b]	
Sport	18 (21)		23 (19)		24 (22)		16 (17) [b]	
Active travel	15 (13)		16 (13)		14 (11)		17 (15)	
Active leisure	17 (20)		18 (23)		20 (25)		15 (17)	
CADL	64 (22)		64 (20)		65 (21)		63 (21)	
Other	46 (42)		58 (34)		60 (44)		43 (20)	
Moderate	**51 (22)**	**3.5**	**36 (19)** [a]	**2.5**	**40 (23)**	**2.8**	**48 (20)** [b]	**3.3**
School	25 (11)		16 (10) [a]		19 (12)		21 (10) [c]	
Sport	8 (10)		4 (5) [a]		7 (10)		5 (6)	
Active travel	6 (7)		6 (7)		3 (3)		9 (8) [b]	
Active leisure	4 (6)		2 (4)		3 (6)		4 (5)	
CADL	3 (3)		3 (3)		3 (3)		3 (3)	
Other	6 (8)		5 (5)		5 (6)		6 (7)	
Vigorous	**24 (18)**	**1.7**	**15 (14)** [a]	**1.0**	**15 (12)**	**1.0**	**24 (19)** [b]	**1.7**
School	9 (8)		5 (7) [a]		7 (8)		8 (8)	
Sport	6 (8)		3 (4) [a]		3 (5)		6 (8) [b]	
Active travel	5 (8)		5 (9)		3 (4)		8 (11) [b]	
Active leisure	3 (5)		1 (2) [a]		1 (3)		2 (5) [b]	
Other	2 (4)		1 (2)		1 (2)		1 (4)	
Sleep	**571 (55)**	**39.7**	**579 (49)**	**40.2**	**605 (44)**	**42.0**	**542 (40)** [b]	**37.6**

Results are presented as means and standard deviations. [a] Significant main effect for gender. [b] Significant main effect for school stage.

[c] Significant interaction effect. All tests $P < 0.05$. * CADL: common activities of daily life.