Between- and within-day variability in physical activity and inactivity in 9- and 15-yr-old European children

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To examine differences in level of physical activity (PA), time spent at moderate-to-vigorous intensity PA (MVPA) and time spent sedentary between and within days in children from four European countries, 1954 nine- and 15-year-olds were included. PA was measured during two weekdays and two weekend days using the MTI accelerometer. Average count per minute, time spent sedentary, time spent at MVPA and proportions of children accumulating ≥ 60 minutes of MVPA were calculated. Data were compared between weekdays and weekend days and between school time and leisure time. Although not entirely consistent across countries, overall PA, time spent sedentary and the proportion of children accumulating ≥ 60 minutes of MVPA were higher during weekdays compared with weekend days. Differences in overall PA between school time and leisure time were highly inconsistent between countries. Few children (4-31%) accumulated ≥ 60 minutes of MVPA during either school time or leisure time. Differences in activity patterns between weekdays and weekend days are explained by less accumulated time in MVPA during weekend days. Weekend days and leisure time during weekdays seem appropriate targets when promoting physical activity in order to increase the proportion of children achieving current recommendations on health enhancing physical activity.

The relationship between physical activity (PA) and health outcomes is less conclusive in children compared to adults (Riddoch, 1998). However, recent studies using objective monitoring of physical activity have shown beneficial associations between physical activity and an array of health-related outcomes, such as obesity (Ekelund et al., 2004), insulin resistance (Brage et al., 2004), and clustered metabolic risk (Andersen et al.,2006; Ekelund et al., 2006). To establish healthy lifestyles already in young ages, actions aiming at increasing levels of PA and subsequently decrease sedentary behaviours should be considered a public health priority. For maintaining a good health through growth it has been stated that all school-age youth should accumulate at least 60 minutes of moderate-to-vigorous physical activity (MVPA) preferably every day (Biddle et al., 1998). Accurate prevalence estimates of habitual PA levels in youth, including proportions who meet stated recommendations about PA, will provide important baseline information and increase knowledge about variations in PA levels with regard to gender, age and geographical location.

Currently, population based data on objectively assessed PA in youth are limited which prohibits comparisons of data on PA behaviours and related determinants. The choice of assessment method (e.g. objective methods vs. self-report), diverse approaches in data reduction and analysis, and unadjusted seasonal variability in PA patterns are all identified as limiting factors when interpreting prevalence data of PA from different studies (Livingstone et al., 2003). Although self-report methods may still be the most frequent choice in larger population studies the use of activity monitors has become a preferred method when assessing PA in children (Riddoch et al., 2004; Trost et al., 2002; Dale et al., 2000). The uni-axial MTI Actigraph accelerometer is one of the more frequently used activity monitors, is valid for assessing the total amount of PA (Ekelund et al., 2000), and is also able to provide detailed information of PA at different levels of intensity (Nilsson et al., 2002).

In youth, weekdays and weekend days are likely to provide different opportunities for being active, as well as school time compared to leisure time within a weekday. Assessing time in PA and sedentary both between days and within days is of interest to increase our understanding about variation in PA behaviour. For example, type of days or periods within a day typically related to lower levels of PA and increased time in sedentary can be identified and such information may facilitate the planning of interventions aiming to promote increased levels of PA. Several studies (Treuth et al., 2007; Trost et al., 2000; Gavarry et al., 2003; Sallo & Silla, 1997) have presented data on between day variability (e.g. weekdays vs. weekend days) and others have presented differences between different time blocks within days in selected (i.e. non-population based) groups of children (Dale et al., Janz et al., 2005; Jago et al., 2005). However, differences in assessment methods and data reduction procedures between studies combined with relatively small sample sizes have made conclusions about variability in PA patterns between and within days elusive.

Furthermore, it is unclear to what extent potential between- and within-day variations in PA and sedentary activities may differ between children from diverse geographical locations. Opportunities to participate in PA at school and during leisure time may vary depending on several factors (e.g. climate, economic, cultural) related to a specific study location.

The aim of the present study was to examine differences in level of PA including proportions meeting recommended PA levels, time in MVPA and time in sedentary between- and within-days with regard to age, gender and geographical location in 9- and 15-year olds from four European countries.

Materials and methods

Subjects

This cross-sectional study includes data on 9- and 15-year-olds who participated in the European Youth Heart Study (EYHS). The aims, design and sampling procedures of EYHS have previously been described (Riddoch et al., 2005). In short, the study population was randomly selected using a 2-stage cluster sample procedure, with schools as primary sampling units, in geographically defined areas in four European countries (Denmark, Portugal, Estonia and Norway). Written informed consent was obtained from parent or legal guardian to each participant and the study was approved locally in each country.

Measurements

Height was measured to the nearest 0.5 cm with a portable Harpenden stadiometer and weight was measured to the nearest 0.1 kg with a beam balance scale. PA was measured using the MTI accelerometer, model 7164 (Manufacturing Technology Inc., Fort Walton Beach, FL). The children wore the accelerometer using an elastic belt attached on the hip during all waking hours for four consecutive days, including two weekdays and two weekend days. All children were verbally instructed on how to use the accelerometer the day before the start of the measurement. The accelerometer was set to record PA data every minute (60s epoch). The administration of accelerometers was conducted in collaboration with the schools and therefore the measurement period followed the school year, with the majority of measurements performed between September and May. Since the measurements were carried out during a full school year in all countries any possible seasonal effect on habitual PA is likely to have been accounted for.

Data reduction and analysis

After downloaded to a computer, a special written programme (MAHUFFE available on request) was used to analyse the raw outcome data. Sequences of 10 or more consecutive zero counts was defined as missing data (Riddoch et al., 2004). Total number of counts over registered time (cnts·min^{-1}) was calculated and expressed as average level of PA. All minutes above 2000 counts during a day was summarized and expressed as time spent in moderate-to-vigorous PA (MVPA). This threshold roughly estimates a walking pace of 4 km/h (Eston et al. 1998; Brage et al., 2003; Puyau et al., 2002), and has been used in previous studies for defining time in MVPA (Ekelund et al., 2004; Andersen et al., 2006). Time in sedentary was defined as < 100 counts per minute. This threshold approximates to sitting and playing video games in children (Puyau et al., 2002) and has been used to define time spent sedentary in previous studies (Treuth et al., 2007). All data was calculated separately for weekdays and weekend days. In addition, all data from weekdays were divided into two time blocks. In 9-year-olds, the two time blocks were set from 8 AM to 2 PM and 2 PM to midnight. Corresponding values for the 15-year-olds were 8 AM to 3 PM and 3 PM to midnight, respectively. These two time blocks were selected representing an average school day based on personal knowledge about schooling times obtained during the data collection in the participating schools (Andersen, Sardinha, Wedderkopp, personal communication). Finally, the proportions accumulating at least 60 minutes in MVPA was calculated and separated for weekdays and weekend days, and school time and leisure time.

A total of 2739 children participated in the study. Inclusion criteria were a minimum of three days of registration, including at least one weekend day, and at least 600 registered minutes per day. A total of 1184 nine-year-olds (Denmark: 301 [141 boys]; Portugal: 292 [151 boys]; Estonia: 299 [151 boys]; Norway: 292 [152 boys]) and 770 fifteen-year-olds (Denmark: 198 [86 boys]; Portugal: 162 [79 boys]; Estonia: 272 [100 boys]; Norway; 138 [58 boys]) fulfilled the inclusion criteria. When analysing results between school time and leisure time within a weekday, all children who had completed measurements on weekdays with at least 600 registered minutes per day were included, which added 59 nine-year-olds and 46 fifteen-year-olds for this specific analysis. All other results are based on data including both weekdays and weekend days.

Statistics

Mean ± SD are used to describe physical characteristics and all PA variables. Analysis of variance (ANOVA) was used to examine age and gender differences in anthropometric variables. ANOVA for repeated measures was used to investigate differences in average PA level, time spent at MVPA and time spent sedentary between weekdays and weekends, and between school time and leisure time within a weekday. We first examined a possible interaction between age and country with the dependent variables, day (weekday vs. weekend day) and time period (school time vs. leisure time). In the second step, we repeated our analysis stratified by age and country including gender as between-subject factor. The results from these stratified analyses are subsequently presented. We finally reanalysed between-day differences by adjusting for registered time. However, this adjustment did not change the results and are not included in the final model. Square-root transformations were performed on all dependent variables due to positive skewness. Differences in proportions who reached recommended levels of PA (60 min) between days was analysed by sign tests based on two related samples. All assumptions to perform the statistical analysis were fulfilled. All data were analysed by SPSS (Statistical Package for the Social Sciences for Windows, 14.0, 2005, SPSS Inc., Chicago. IL) and alpha was set at 0.05.

Results

Mean age was 9.7 ± 0.4 years and 15.5 ± 0.5 years in the two age groups. In 9-year-olds mean height was 138 ± 7 cm (boys: 138 ± 6 girls: 138 ± 7; $p = 0.10$) and mean weight was 33 ± 6 kg (boys: 33 ± 6, girls: 33 ± 7; $p = 0.21$). Corresponding values for 15-year-olds were 168 ± 8 cm (boys: 174 ± 8, girls: 164 ± 6; $p < 0.001$) and 59 ± 10 kg (boys: 63 ± 10, girls: 56 ± 8; $p < 0.001$), respectively.

ANOVA for repeated measures on average level of PA, time in MVPA and time spent sedentary both between days (weekday vs. weekend day) and within days (school time vs. leisure time) showed significant interactions with age ($p < 0.01$) and country ($p < 0.01$). Further analyses were subsequently stratified by age and country.

Table 1. Level of PA, time spent sedentary and time in MVPA between an average weekday and weekend day among 9-year-olds stratified by gender and country.

	Weekday		Weekend day		P(ANOVA)
	boys (n=595)	girls (n=589)	boys (n=595)	girls (n=589)	
Level of PA ($cnts \cdot min^{-1}$)					
Denmark	742 ± 263	606 ± 228	652 ± 289	607 ± 290	[a,b] $p < 0.01$
Portugal	726 ± 236	585 ± 165	758 ± 271	642 ± 224	[a] $p < 0.01$
Estonia	789 ± 280	655 ± 200	801 ± 327	670 ± 253	
Norway	901 ± 303	746 ± 213	803 ± 418	695 ± 269	[a] $p < 0.01$
Sedentary (min)					
Denmark	311 ± 78	309 ± 75	299 ± 87	280 ± 87	[a] $p < 0.01$
Portugal	318 ± 81	344 ± 75	269 ± 89	279 ± 96	[a] $p < 0.01$
Estonia	277 ± 77	307 ± 75	239 ± 94	257 ± 80	[a] $p < 0.01$
Norway	298 ± 70	314 ± 62	289 ± 81	280 ± 75	[a,b] $p < 0.01$
MVPA (min)					
Denmark	90 ± 45	59 ± 36	66 ± 45	52 ± 41	[a,b] $p < 0.01$
Portugal	94 ± 43	66 ± 31	89 ± 47	65 ± 40	[a] $p < 0.05$
Estonia	104 ± 55	77 ± 36	94 ± 61	67 ± 41	[a] $p < 0.01$
Norway	121 ± 41	91 ± 30	87 ± 51	70 ± 35	[a] $p < 0.01$ [b] $p < 0.05$

[a] difference between days
[b] difference between days by gender interaction

Weekdays vs. weekend days

In 9-year-olds the average registered time was 810 ± 59 min on weekdays and 760 ± 75 min on weekend days ($p < 0.01$). Corresponding results for 15-year-olds was 852 ± 81 min and 770 ± 83 min ($p < 0.01$) for weekdays and weekend days, respectively. In 9-year-olds, a difference between weekdays versus weekend days for average level of PA was observed in all countries except in Estonia. However, a significant day by gender interaction in Denmark revealed that this difference was only evident in boys ($p < 0.01$). Notably, the direction of between-day difference was inconsistent between country groups (Table 1).

All country groups showed consistent between-day differences for time spent at MVPA, indicating higher levels of MVPA during weekdays. A significant day by gender interaction in Norway was observed and further stratification by gender indicated significant between-day differences in both genders. Similarly to time spent at MVPA, more time spent sedentary was observed during weekdays compared to weekend days in all country groups. After stratification by gender, differences between days were only evident in Norwegian girls ($p < 0.01$) (Table 1).

In 15-year-olds, higher average levels of PA during weekdays compared to weekend days was observed in all country groups except Portugal. Regardless of country and gender group, significantly more time was spent at MVPA and sedentary on weekdays compared to weekend days (Table 2).

Proportions of 9- and 15-year-old children who accumulated at least 60 min of MVPA during either weekdays or weekend days are shown in Figure 1.

Table 2. Level of PA, time spent sedentary and time in MVPA between an average weekday and weekend day among 15-year-olds stratified by gender and country.

	Weekday		Weekend day		P(ANOVA)
	boys (n=323)	girls (n=447)	boys (n=323)	girls (n=447)	
Level of PA ($cnts \cdot min^{-1}$)					
Denmark	441 ± 166	425 ± 172	411 ± 198	385 ± 159	[a] p < 0.01
Portugal	611 ± 223	463 ± 136	625 ± 230	468 ± 152	
Estonia	676 ± 235	505 ± 192	625 ± 281	476 ± 219	[a] p < 0.01
Norway	707 ± 257	572 ± 165	583 ± 285	492 ± 212	[a] p < 0.01
Sedentary (min)					
Denmark	454 ± 90	457 ± 83	412 ± 93	412 ± 94	[a] p < 0.01
Portugal	411 ± 91	435 ± 82	344 ± 84	351 ± 89	[a] p < 0.01
Estonia	388 ± 95	444 ± 89	331 ± 103	367 ± 86	[a] p < 0.01
Norway	445 ± 76	466 ± 94	385 ± 81	402 ± 86	[a] p < 0.01
MVPA (min)					
Denmark	47 ± 28	44 ± 29	40 ± 37	34 ± 26	[a] p < 0.01
Portugal	82 ± 41	55 ± 26	72 ± 42	41 ± 27	[a] p < 0.01
Estonia	93 ± 44	67 ± 37	70 ± 47	48 ± 36	[a] p < 0.01
Norway	96 ± 41	74 ± 24	62 ± 40	49 ± 32	[a] p < 0.01

[a] difference between days

In both age groups, a significantly higher proportion ($p < 0.01$) reached the 60-min recommendation on weekdays compared to weekends in all countries, except for 15-year-old Danes.

School time vs. leisure time

In 9-year-olds the average registered time set as school time was 352 ± 20 min and registered leisure time was 385 ± 59 min. Corresponding results for 15-year-olds was 401 ± 32 min during school time and 380 ± 64 min during leisure time, respectively.

In 9-year-olds, average level of PA was significantly higher during school time compared with leisure time in Denmark, which was evident in both gender groups. In contrast, a higher level of PA during leisure time was observed in Portugal, while no difference between time periods was seen in Estonia and Norway (Table 3).

Time spent sedentary was significantly higher during leisure time in all country groups except in Norwegian children, who spent an equal amount of time sedentary during school time compared with leisure time. In the Danish group, the time period difference remained significant in both gender groups.

In 15-year-olds, higher average levels of PA during leisure time compared to school time was observed in Estonia (Table 4). In the Danish group, a significant gender by time period interaction was observed. Gender stratified analysis revealed that Danish boys had higher average levels of PA during school time compared to leisure time ($p < 0.05$), while the opposite was true for Danish girls ($p < 0.05$). No difference between time blocks for average PA level was observed for Portugal and Estonia. A significant difference between time periods for time spent at MVPA with more minutes accumulated during school time was observed in Portugal, and after gender stratification also in Danish boys ($p < 0.01$). Norway and Estonia showed similar amounts of time spent at MVPA during the two time periods regardless of gender. Portuguese adolescents spent significantly more time sedentary during school time compared to leisure time.

Table 3. Level of PA, time spent sedentary and time in MVPA between school time and leisure time among 9-year-olds stratified by gender and country.

	School time		Leisure time		P(ANOVA)
	boys (n=620)	girls (n=623)	boys (n=620)	girls (n=623)	
Level of PA ($cnts \cdot min^{-1}$)					
Denmark	884 ± 334	644 ± 276	656 ± 282	587 ± 263	[a,b] $p < 0.01$
Portugal	682 ± 268	552 ± 185	779 ± 282	622 ± 208	[a] $p < 0.01$
Estonia	787 ± 276	655 ± 227	814 ± 401	671 ± 264	
Norway	954 ± 452	756 ± 228	873 ± 414	771 ± 352	
Sedentary (min)					
Denmark	115 ± 38	128 ± 38	152 ± 43	136 ± 42	[a,b] $p < 0.01$
Portugal	146 ± 42	153 ± 40	153 ± 48	169 ± 48	[a] $p < 0.01$
Estonia	122 ± 40	138 ± 36	132 ± 48	146 ± 50	[a] $p < 0.05$
Norway	128 ± 33	140 ± 31	137 ± 47	138 ± 42	
MVPA (min)					
Denmark	49 ± 25	29 ± 18	34 ± 22	24 ± 19	[a,b] $p < 0.01$
Portugal	38 ± 22	26 ± 14	52 ± 26	36 ± 20	[a] $p < 0.01$
Estonia	46 ± 23	35 ± 17	52 ± 38	37 ± 24	
Norway	58 ± 27	44 ± 19	52 ± 28	39 ± 22	[a] $p < 0.01$

[a] difference between time periods
[b] difference between time periods by gender interaction

Gender by time period interactions were observed in Denmark, Estonia and Norway (Table 4). After gender stratification, both genders in Estonia and Norway accumulated significantly more time sedentary during school hours, whereas in Denmark this difference was observed in girls only ($p < 0.01$).

Depending on age and geographical location, between 4% and 31% accumulated at least 60 minutes of MVPA during either school time or leisure time within a weekday.

Finally, we reanalyzed all data including data collection period (divided into autumn, winter and spring) in the model to adjust for potential influence of seasonal variation on PA variability, and the main results were unchanged.

Discussion

We show here objectively assessed data on average levels of PA, time in MVPA and time spent sedentary in a large sample of 9- and 15-year-olds from four European countries. No previous study has investigated between-day and within-day differences in objectively assessed PA patterns incorporating diverse geographical locations in Europe.

A recent study hypothesised that the variation in physical activity lies within the child and not his environment (Wilkin et al., 2006). If this is true, it would imply a consistent activity level between days and geographical location (i.e. country). In contrast, our results indicate that the overall trend in both age groups is that average level of PA ($cnts \cdot min^{-1}$), time spent at MVPA and sedentary is higher on weekdays compared to weekend days. Furthermore, results on between-day differences in average level of PA ($cnts \cdot min^{-1}$) were inconsistent between countries, especially in the younger age group. For example, Portuguese children showed higher average level of PA on weekend days compared to weekdays, Danish and Norwegian children demonstrated higher levels of PA on weekdays, while no between-day difference was observed in Estonian children (Table 1).

Table 4. Level of PA, time spent sedentary and time in MVPA between school time and leisure time among 15-year-olds stratified by gender and country.

	School time		Leisure time		P(ANOVA)
	boys (n=345)	girls (n=471)	boys (n=345)	girls (n=471)	
Level of PA ($cnts \cdot min^{-1}$)					
Denmark	477 ± 208	408 ± 184	431 ± 231	454 ± 233	[b] $p < 0.01$
Portugal	596 ± 249	460 ± 153	622 ± 291	464 ± 168	
Estonia	652 ± 244	467 ± 184	715 ± 378	535 ± 290	[a] $p < 0.05$
Norway	653 ± 257	510 ± 153	733 ± 440	611 ± 343	
Sedentary (min)					
Denmark	205 ± 51	218 ± 45	208 ± 55	191 ± 52	[a,b] $p < 0.01$
Portugal	206 ± 47	217 ± 45	183 ± 56	191 ± 50	[a] $p < 0.01$
Estonia	186 ± 53	227 ± 48	168 ± 57	187 ± 54	[a,b] $p < 0.01$
Norway	206 ± 38	228 ± 43	189 ± 52	190 ± 60	[a] $p < 0.01$, [b] $p < 0.05$
MVPA (min)					
Denmark	26 ± 17	21 ± 14	18 ± 16	20 ± 16	[a,b] $p < 0.01$
Portugal	40 ± 23	28 ± 14	38 ± 25	23 ± 15	[a] $p < 0.05$
Estonia	43 ± 21	30 ± 16	45 ± 35	30 ± 26	
Norway	41 ± 19	33 ± 13	42 ± 32	31 ± 21	

[a] difference between time periods
[b] difference between time periods by gender interactio

Taken together, these results suggest that geographical location, including environmental and socio-cultural factors, also contribute to the variation in children's activity levels.

Previous studies examining differences in the amount of PA between weekdays and weekend days are not conclusive. For example, one recent study showed that adolescent girls spend more time in MVPA during weekdays compared to weekends (Treuth et al., 2007). Another study suggested that young children spend more time in MVPA during weekends compared to weekdays, while the opposite was observed in adolescents (Trost et al., 2000). Others have shown that time spent at MVPA was greater during weekdays compared to weekend days in primary school children while no clear difference was indicated in high school students (Gavarry et al., 2003). Additionally, one study reported no differences between weekend days versus weekdays in amount of PA in first-grade school children (Sallo & Silla, 1997). Different assessment methods (e.g. accelerometry vs. heart rate telemetry) and different approaches to define amount of PA (e.g. defining moderate intensity) may partly explain discrepancies between the present and previous studies. Our results suggest that geographical location may significantly influence PA behaviour in children of the same age. Access to sport facilities and time spent outdoors are consistently related to children's physical activity (Sallis et al., 2000), and such environmental determinants may vary between countries. In this study, seasonal variations in PA behaviour are likely to be accounted for since all PA measurements were conducted over a full school year. Hypothetically, differences in average outside temperatures between countries (e.g. Portugal vs. Norway) during the same seasons may affect opportunities to be physically active and thereby influences the between-day variability in PA. However, we controlled for seasonal variations in PA variability by including a variable based on measurement period (autumn, winter, spring) into our statistical model, and our main results were unchanged.

Data from a recent study reported a significant increase in time spent sedentary (e.g. TV/electronic games) during weekend days compared to weekdays in eight-grade adolescents (Jago et al., 2005), which may indicate that these sedentary activities displace time spent at moderate and vigorous levels of activity. In contrast, our results suggested a greater amount of time spent sedentary during weekdays in combination with a greater amount of time spent at MVPA, which was consistent in both age groups (Table 1 and 2). These between-day differences remained statistically significant after further adjustment for differences in registered time between days (data not shown). Hence, a relatively large amount of time spent sedentary does not automatically imply low levels of PA during the same day. For example, 9-year-old Norwegian girls accumulated approximately 50% more time at MVPA compared with Danish girls during weekdays, while the two groups accumulated similar amount of time spent sedentary (Table 1).

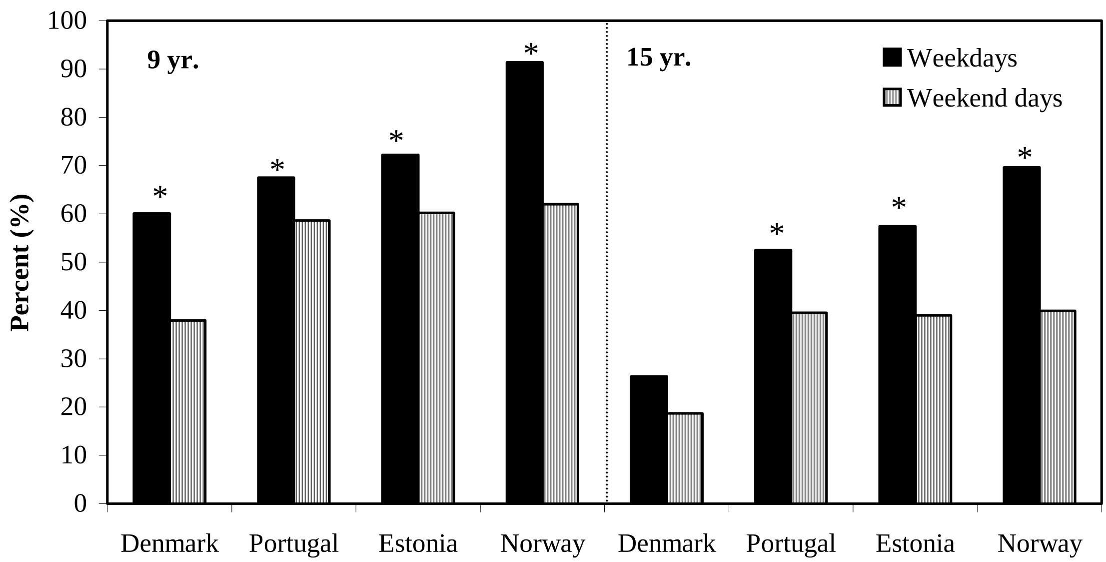

Figure 1. Proportions of children accumulating at least 60 min of MVPA daily during either weekdays or during weekend days stratified by age and country. Significant differences in proportions between days are marked (*p < 0.01).

Our results suggest that a lower average level of PA during weekend days compared to weekdays is explained by less accumulated time spent at MVPA and not by an increase in time spent sedentary during weekend days. The higher amount of time spent at MVPA during weekdays was also reflected in the higher proportion of children accumulating at least 60 minutes of MVPA. Although weekend days likely offer more free time than school days, surprisingly small proportions were able to reach the current recommendation for health enhancing physical activity in youth (Biddle et al., 1998). For example, only a minority of 15-year-olds reached this recommendation during weekend days, regardless of country (Figure 1). Initiatives aiming to promote PA during weekend days seem especially important if the majority of children are expected to achieve the basic 60-min recommendation of daily PA.

Further, although reduced time spent sedentary may not necessarily imply more time spent at MVPA, actions in order to limit sedentary behaviour should still be considered important from a public health point of view. Decreased time spent sitting will promote an increase in total level of PA, which has shown to be inversely related to clustering of cardiovascular risk factors (e.g. systolic blood pressure, triglycerides and insulin resistance) already at early age (Andersen et al., 2006; Ekelund et al., 2006). Furthermore, decreasing TV viewing significantly decreases energy intake in youth (Epstein et al., 2005), and eating frequency while viewing TV may be associated with adiposity independent of physical activity (Ekelund et al., 2006).

Our data suggest that within-day differences in PA levels exist and do not show a consistent pattern between different geographical environments. Opportunities to be physically active during a school day are likely to differ by country. In school, recess time and PE lessons provide the main opportunities for accumulating time at MVPA, and different contents of PE lessons can significantly affect the time in MVPA during school time (McKenzie et al., 1996). Furthermore, recent studies have shown that playground environment at school and accessibility to game equipment affect PA behaviour in primary school children during recess (Ridgers et al., 2007; Verstraete et al., 2006). Thus, differences in school environments, total time in recess and frequency and contents of PE lessons between the present countries in this study may explain the differences observed in PA levels between school and leisure time.

We chose to present accumulated time spent at MVPA and sedentary in absolute values rather than relative to registered time. Regarding school and leisure time, the length of the two time blocks differed on average by 33 minutes in 9-year-olds and 21 minutes in 15-year-olds. This may propose that within-day differences indicated for absolute time spent at MVPA and sedentary may be changed if these analyses were adjusted for registered time. Nevertheless, we believe that showing data on absolute time accumulated during the two time blocks, are more relevant as these provide different opportunities for being physically active. Regardless of the minor differences in time length, leisure time could be expected to be the major contributor to time spent at MVPA given the relatively low levels of PA during recess (Ridgers et al., 2005; Mota et al., 2005) and PE lessons (Fairclough et al., 2005; Nader et al., 2005) previously reported. Moreover, opportunity to be active during school time is likely to be more restricted compared with leisure time. However, observed differences between time blocks for time at MVPA were fairly modest. It is also clear that only small proportions of children in both age groups are able to accumulate 60 minutes of MVPA during leisure time alone. PA during school time seems to contribute, perhaps more than expected, to the total daily amount of time spent at MVPA and subsequently for achieving the 60 minutes MVPA recommendation. Given that school time offers less potential time for PA compared to leisure time, PA promoting efforts including increased opportunities for being active during leisure time seem warranted to support larger proportions of school-age youth to meet the current recommendations.

The definition of school time and leisure time may likely affect interpretation of PA patterns within a day. The time period used as school time was selected to represent an average school day rather than the exact time for a specific day. Obviously, scheduled time in school varies somewhat between days and the exact time points when the children started and finished school cannot be fully ascertained. However, based on information provided by the participating schools within each study location, the four countries shared approximate school systems with regard to average hours of the day, and period of the day, when attending school. We therefore believe our selected time periods represents the absolute majority of average school and leisure time.

The accelerometer used in this study measures vertical accelerations and is likely to underestimate the intensity of specific types of PA, such as biking or walking in hilly terrain. Furthermore, there is no consensus regarding what count threshold to use when expressing time spent at MVPA. Previously published thresholds, proposed to correspond to MVPA, vary substantially depending on activities incorporated during the calibration of accelerometer counts against measures of energy expenditure (e.g. MVPA for 9-year-olds: >900 cnts·min^{-1} [Trost et al., 2002] or >3200 cnts·min^{-1} [Puyau et al., 2002]). We chose a threshold of 2000 cnts·min^{-1} as it roughly corresponds to a walking pace of 4 km/h, based on several studies of children of different ages (Eston et al., 1998; Brage et al., 2003; Puyau et al., 2002). The choice of intensity threshold will affect the estimated amount of time presented. Nevertheless, it seems unlikely that the observed between-day and within-day differences observed for each country in this study are explained by the assessment method or by data handling procedures.

Finally, it should be noted that a 60s epoch setting was used when assessing time in MVPA. Because of children's highly transitory PA patterns, assessment of time in high and very high intensity PA (approximate to 6 and 9 METs) may be underestimated when using a 60s interval (Nilsson et al., 2002). However, no underestimation by epoch setting was observed for moderate intensity (3-6 METs) (Nilsson et al., 2002), and high and very high intensity activity accounts for a small portion of time of total time in MVPA (Nilsson et al., 2002; Baquet et al., 2007). We therefore believe that this had a minor effect on our results.

In conclusion, between- and within-day differences in average level of PA, time spent at MVPA and sedentary exist and differ by age, gender and geographical location. Differences in PA patterns between weekdays and weekend days seem consistent across different geographical locations. Differences in PA patterns between weekdays and weekend days are explained by less accumulated time in MVPA, without increased time spent sedentary, during weekend days. Overall, weekend days and leisure time during weekdays seem appropriate targets when promoting physical activity in order to increase the proportion of children achieving current recommendations on health enhancing physical activity.

Perspectives

To establish healthy lifestyles already at young ages, actions aiming at increasing levels of PA and subsequently decreasing sedentary behaviours in children should be considered a public health priority. In youth, weekdays and weekend days are likely to provide different opportunities for being active, as well as school time compared to leisure time within a weekday. Therefore, assessing time in PA and sedentary both between days and within days is of interest to increase our understanding about variation in PA behaviour, and such information may facilitate the planning of interventions aiming to promote increased levels of PA. Our results show that between- and within-day differences in average level of PA, time spent at MVPA and sedentary exist and differ by age, gender and geographical location. Further, differences in PA patterns between weekdays and weekend days seem consistent across different geographical locations. Differences in PA patterns between weekdays and weekend days are explained by less accumulated time in MVPA, without increased time spent sedentary, during weekend days. Overall, weekend days and leisure time during weekdays seem appropriate targets when promoting physical activity in order to increase the proportion of children achieving current recommendations on health enhancing physical activity.

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