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Original Research Article

School Day and Weekend Patterns of Physical Activity in Urban 11-Year-Olds: A Cross-Cultural Comparison

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Objectives: This multi-center study was conducted to objectively evaluate energy expenditure and physical activity (PA) patterns on school days and weekends in urban 11-year-olds.

Methods: The sample consisted of 241 children from three cities: Zagreb, Ljubljana (both in Central Europe) and Ann Arbor (United States). Energy expenditure and PA were assessed during two school days and two weekend days using a multiple-sensor body monitor.

Results: Differences between the cities were observed for all PA variables. The highest level of moderate to vigorous PA (MVPA) was noted in Ljubljana boys [284 (98) min/day] and the lowest in Zagreb girls [179 (95) min/day]. In Zagreb and Ljubljana, boys were more physically active than girls, while in Ann Arbor the opposite was observed. In contrast, no gender difference in sedentary behavior was observed in any of the cities. A decline in PA from school days to weekends was noted in all city groups in both genders. However, the magnitude of the reduction in daily energy expenditure differed between the cities, with the largest differences being observed in Ljubljana and the smallest in Ann Arbor. In all three city groups, the great majority of boys and girls achieved current recommendations of 60 min of MVPA either during school days or weekends.

Conclusions: Weekends seem to be an appropriate target when promoting PA in 11-year-olds in all the cities included in the study. Increasing vigorous activity on weekends seems to be of particular importance in Zagreb and Ljubljana. Am. J. Hum. Biol. 27:192–200, 2015. © 2014 Wiley Periodicals, Inc.

Poor physical fitness of children and youth is associated with many preventable diseases and presents a serious current and future public health problem (WHO, 2007). Regular physical activity (PA) during childhood is one part of the equation (nutrition being the other) that can lead to improvements in numerous physiological and morphological variables in children and youth (Owen et al., 2010). Recent reports have shown that inactive children are exposed to increased metabolic (Ekelund et al., 2007) and cardiovascular risk (Andersen et al., 2006) irrespective of their weight status. Furthermore, it has been reported that reducing inactivity in obese children can enhance weight loss and reduce morbidity independently of weight loss (Lobstein et al., 2004). PA in childhood and adolescence is also important to attain and maintain appropriate bone strength, and it contributes to normal skeletal development (Dietz, 1998). Active children appear to be engaged in a sufficient variety of activities that enhance multiple components of health-related fitness (Sallis et al., 1993). Moreover, PA has been consistently associated with better psychological health, such as higher levels of self-esteem and lower levels of anxiety and stress. Less PA may predispose young people to develop a sedentary lifestyle in adulthood (Telama, 2009).

Despite these health benefits, a decline in energy expenditure among children can be seen in the past decades (French et al., 2001). Increased opportunities exist for children to be sedentary in their leisure time, and TV viewing and electronic gaming are shown to be positively related to being overweight (Crespo et al., 2001; Stettler et al., 2004; te Velde et al., 2007). Time spent in sedentary behavior is inversely associated with physical exercise among adolescents (Marshall et al., 2004; Stettler et al., 2004; te Velde et al., 2007), particularly among girls (Robinson, 1999); however, this issue remains controversial (Biddle et al., 2004).

Therefore, promoting PA has become a public priority in developed countries worldwide and interventions have been implemented that focus on changing dietary intake and PA levels (Brown and Summerbell, 2009; Camacho-Minano et al., 2011; De Meester et al., 2009; Dobbins et al., 2009; Kriemler et al., 2011; Salmon et al., 2007; Shaya et al., 2008; van Sluijs et al., 2007). Better understanding of the patterns and correlates of PA and inactivity in children is needed to support the development of effective strategies and interventions that promote an active lifestyle and prevent a sedentary one. The question of whether children are more active during the week or on weekends remains unresolved, at least in elementary school children, with some studies showing that children are more active on school days than on weekends and others reporting no difference, or higher levels of activity on weekends (Riddoch et al., 2007; Rowlands et al., 2008; Soric and Misigoj-Durakovic, 2010; van Sluijs et al., 2008).

Previous studies using objective methods to investigate the relationship between PA and adiposity have shown conflicting results. Some studies show overweight status or adiposity to be inversely related to PA measures

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(Ekelund et al., 2002; Trost et al., 2001) and others report no association (Ekelund et al., 2001; Treuth et al., 2005; van Sluijs et al., 2008). In addition, a study by Ekelund et al. (2004) has shown that only obese children, and not overweight children, are involved in less PA than their normal-weight peers. All of these studies are based on either biomechanical (i.e., accelerometers) or physiological (i.e., heart rate monitors or doubly labeled water) data. As no single method can quantify all aspects of PA, a new generation of monitors that combines accelerometry with other physiological signals has contributed to progress in the PA assessment field (Corder et al., 2008). One such device is the SenseWear Armband (SWA), which combines a two-axis accelerometer with heat flux, temperature, and galvanic skin response sensors. These additional physiological data enable the SWA to detect and measure PA of the lower and upper body and to detect the change in energy expenditure associated with load carrying, change of grade, and non-ambulatory PA, thus eliminating the drawbacks of PA assessment based only on accelerometer data (Fruin and Rankin, 2004). Recent studies comparing the SWA with the doubly labeled water method have found that the former yields an accurate estimate of energy expenditure in both adults (St-Onge et al., 2007) and children (Arvidsson et al., 2009).

Therefore, the aims of this study were: (1) to objectively evaluate PA patterns and estimate energy expenditure in urban 11-year-old children in three cultural environments (countries) using the same multiple-sensor body monitor; (2) to assess the differences in PA level between school and weekend days, as well as the possible effect of cultural environment and gender on children's patterns of activity.

METHODS

Settings

This investigation is a part of the Biological and Environmental Correlates of Physical Activity in Children (BEC-PAC) study which is a multi-center, international study conducted in three different urban areas: Zagreb (Croatia), Ljubljana (Slovenia), and Ann Arbor (Michigan, USA). Qualified personnel conducted the testing sessions, with all testing held at approximately the same time of the day. All the measurements in this study were performed during the spring 2006 (end of April till beginning of June).

Zagreb is the largest city and capital of Croatia (CRO) with a population of 686,568. Ljubljana is the largest city and the capital of Slovenia (SLO) with a population of 271,885. Ann Arbor has a population of 113,934, making it the sixth largest city in Michigan. All three cities have four distinct seasons, yet some differences exist, especially in Ann Arbor. Zagreb and Ljubljana are in Central Europe. Since they are only 140 km apart they have similar climate. This part of Central Europe is classified as an oceanic climate (*Cfb* in Köppen climate classification system), near the boundary of the humid continental climate. Summers are warm, and winters are moderately cold, without a discernible dry season. Ann Arbor has a typically Midwestern USA humid continental climate (*Dfa* in Köppen), which is influenced by the Great Lakes. Winters are cold with moderate to heavy snowfall, while summers are very warm and humid; in between, spring and autumn are short but mild. The area experiences lake effect weather, primarily in the form of increased cloudiness during late fall and early winter. Almost the whole population in Zagreb and Ljubljana are White European, while in Ann Arbor European-American represents 69% of the racial makeup of the city, followed by Asian (15%), African-American (9%), and others. Croats and Slovenes also have common genetic roots (Slavs) while high level of immigration to the USA generates a greater genetic mix. The study therefore includes data on urban children who live in somewhat different climate conditions and different cultural environments.

Participants

At each study location, several elementary schools were selected from different districts with the intention of including various types of urban environments and diverse socio-economic background. In all, participants were recruited from 16 different public schools (six schools in Zagreb, six in Ljubljana, and four in Ann Arbor). All children attending fifth grade, aged 10–12 years, were invited to participate in the study. Response rate within the selected schools was around 60% in all study locations and resulted in a total of 368 participants. After 127 children who failed to provide what was considered to be an adequate amount of data were excluded from the data analysis, the final sample consisted of 241 children (116 boys, 125 girls), mean age (SD) = 11.4 (0.4) years. All children were free of known acute or chronic illness at the time of the study.

Each research team complied with the country's ethical regulations. Having fully informed the children and their parents about the aims of the study, its protocol and the possible hazards and discomforts related to the procedures used, written consent was obtained from the parents or legal guardians of all participants. Also, the children gave their verbal assent and were free to withdraw from the study at any time. The study protocols were approved by Ethics Committees of The Faculty of Kinesiology at the University of Zagreb, the Faculty of Sport at the University of Ljubljana and the University of Michigan, Ann Arbor.

Anthropometry

Subjects were weighed barefoot in their shorts and T-shirts with a pre-calibrated portable medical balance scale of various brands to the nearest 0.1 kg. Body height was taken to the nearest 0.1 cm using an anthropometer (GPM; Siber-Hegner & Co., Zurich, Switzerland). Body mass index (BMI) was then calculated as body weight in kilograms divided by body height in meters squared (kg/m^2). Skinfold thickness measures were taken to the nearest 0.2 mm at the triceps, and calf sites using a Harpenden skinfold caliper (British Indicators, West Sussex, UK) on the right side of the body (Lohman et al., 1991). All skinfold measures were taken in triplicate and median values were used for analysis.

Physical activity monitoring

Daily energy expenditure and PA were assessed by the SenseWear Armband^{TM} (SWA) activity monitor (BodyMedia Inc., Pittsburgh, PA, USA). This device is a multisensor body monitor that relies on a pattern recognition approach for energy expenditure and PA estimation. It uses a series of non-invasive biometric sensors to continuously measure different physical parameters (i.e., heat flux, galvanic skin response, skin temperature, near-body temperature, and motion, determined from a biaxial accelerometer). The data from the sensors, together with gender, age, height, weight, and handedness are incorporated into proprietary algorithms to estimate energy expenditure and PA duration, but also to discriminate wakefulness from sleep. The SWA has been validated for measuring daily energy expenditure (Arvidsson et al., 2009; Calabro et al., 2013) and sleep (Soric et al., 2013) among children and adolescents.

The SWA was attached to the back of the subject's upper right arm, over the triceps muscle halfway between the acromion and olecranon processes. The subject's gender, age, height, weight, and handedness were programmed into the SWA before it was activated. Children were instructed to wear the armbands during the entire day for at least four consecutive days (including both weekend days), except during bathing or other water activities. Data from all the sensors were averaged over 1-min periods, and these data were stored in memory and subsequently downloaded to a computer. For the analysis of the SWA data, child-specific exercise algorithms were used (SenseWear Professional software v. 6.1; BodyMedia Inc., Pittsburgh, PA).

Physical activity measures

The intensity of PA was described as metabolic equivalents (METs). Outcome variables were total daily energy expenditure (TEE), physical activity energy expenditure (PAEE; energy expended for PA requiring >3 METs) and the duration of PA performed at various intensities. Time spent in 3–5.9 METs was classified as moderate physical activity (MPA), time spent in >6 METs was classified as vigorous physical activity (VPA). The thresholds of 3.0 and 6.0 METs were selected as they estimate a walking pace of 4 km/h and a running pace of 7 km/h respectively (Arvidsson et al., 2007) and have been frequently used in defining PA intensity in children (Dencker et al., 2006; Riddoch et al., 2004; Trost et al., 2002).

Physical activity report

In addition to objectively measured PA, data concerning various activities (classified in categories of screen time, school responsibilities, domestic chores, sport) were collected by a short parent-directed questionnaire. Specifically, we asked the parents to provide data on the average amount of time devoted to listed activities.

Data reduction and transformation

Trost et al. (2000) reported that in children at least 3 days of monitoring are needed to provide reliable activity data. Thus, 127 children failing to provide a minimum of three separate days of 21 h per day of valid recording were excluded from the study. In an attempt to detect sample bias, we compared these 127 children to children included in the final analysis and found no differences regarding BMI ($P = 0.63$) or subcutaneous fat ($P = 0.94$). The proportion of children achieving the health-related PA recommendations of at least 60 min of moderate to vigorous physical activity (MVPA) every day established by the World Health Organisation (WHO, 2010) was calculated separately for school and weekend days. Further, the proportion of children accumulating at least 20 min of VPA in one and two days of four consecutive measuring days was calculated to evaluate the achieving of recommendations on vigorous-intensity activities (US Department of Health and Human Services, 2004).

Data analysis

Data were tested for normality before analyses using histograms and normal probability plots. In cases when the assumption of normality was not met, appropriate transformation of data was applied. The effects of gender and group (city) on physical characteristics and habitual PA level were analyzed by two-way analyses of variance (ANOVA). When differences between city groups were observed, *post hoc* tests with Bonferroni correction were applied. Furthermore, differences in energy expenditure and PA duration between school days (mean of weekdays) and weekend days (mean of Saturday and Sunday) were assessed using repeated measures ANOVA with city group and gender as between-subject factors. Differences between proportions of children achieving activity recommendations on school days and weekends were analyzed using McNemar's test. This analysis was stratified by city groups and Bonferroni corrected P values are reported. Differences in parent reported activities in city groups were examined using Kruskal–Wallis ANOVA in each gender separately. Differences in proportion of children engaged in organized sports in city groups were assessed by chi-squared test in each gender separately. The data are reported as mean (standard deviation) or median (inter-quartile range) for data that did not follow normal distribution. The level of statistical significance was set at $P < 0.05$ and all statistical analyses were performed using Statistica 10.1 (Stat-Soft Inc., Tulsa, OK).

RESULTS

Before performing main analyses, we explored whether the duration of monitoring had any influence on the recorded level of participants' PA. Out of 241 children, 170 children (71%) completed the full 4 days of valid recording, while 70 children (29%) achieved 3 days. As no differences were found between children with 3 or 4 days of recording for any of the PA measures investigated ($P = 0.097$–0.824), all children were pooled for further analyses.

The physical characteristics of the groups studied are presented in Table 1. Slight differences in age of the children from various centers were found. Significant main effects of city group were found for all physical characteristics, except for subcutaneous fat. Results of the Bonferroni *post hoc* tests indicate that height, weight, and BMI differed only between USA and CRO ($P < 0.001$, $P < 0.001$, $P = 0.02$, respectively). In addition, girls were taller than boys, while for other physical characteristics no gender differences were noted. Finally, no city × gender interactions were found.

Table 2 shows the energy expenditure and PA across the city groups studied. Differences between city groups were observed regarding all measures of PA. More specifically, children from Zagreb had the lowest daily energy expenditure and PA levels ($P < 0.001$ vs. both Ann Arbor and Ljubljana for TEE; $P = 0.002$ vs. Ann Arbor and $P = 0.004$ vs. Ljubljana regarding MVPA), while no differences between

TABLE 1. Age, physical characteristics, and body composition of children stratified by city and gender

	Ann Arbor, USA		Zagreb, CRO		Ljubljana, SLO		P value		
	Boys ($n = 33$)	Girls ($n = 28$)	Boys ($n = 39$)	Girls ($n = 49$)	Boys ($n = 44$)	Girls ($n = 48$)	City	Gender	City × gender interaction
Age (years)	11.1 (0.3)	11.0 (0.3)	11.4 (0.2)	11.3 (0.2)	11.6 (0.5)	11.6 (0.4)	<0.001	0.758	0.543
Height (cm)	145.2 (8.7)	150.7 (7.2)	152.2 (8.2)	154.3 (7.2)	151.4 (6.9)	154.7 (7.3)	<0.001	<0.001	0.402
Weight (kg)	37.5 (8.7)	41.9 (9.3)	47.4 (13.7)	45.9 (10.1)	44.2 (10.7)	45.3 (11.6)	0.001	0.376	0.270
BMI (kg/m^2)	17.6 (2.5)	18.3 (3.1)	20.2 (4.4)	19.1 (3.2)	19.1 (3.7)	18.8 (3.9)	0.019	0.574	0.327
SSF (mm)	27.9 (9.5)	31.0 (10.8)	32.2 (12.9)	31.7 (10.9)	30.2 (11.5)	28.5 (11.8)	0.25	0.85	0.44

Values are means (SD). Significance by ANOVA of the main effects of city and for gender and city × gender interaction.
BMI = body mass index; SSF = sum of skinfolds.

TABLE 2. Daily physical activity levels of children stratified by city and gender

	Ann Arbor, USA ($n = 61$)		Zagreb, CRO ($n = 88$)		Ljubljana, SLO ($n = 92$)		P value		
	Boys ($n = 33$)	Girls ($n = 28$)	Boys ($n = 39$)	Girls ($n = 49$)	Boys ($n = 44$)	Girls ($n = 48$)	City	Gender	City × gender interaction
Total energy expenditure (TEE) (kcal/kg/day)	47.4 (6.1)	46.9 (5.6)	45.0 (7.2)	41.5 (6.0)	49.7 (6.9)	44.5 (6.7)	<0.001	<0.001	0.10
Physical activity energy expenditure (PAEE) (kcal/kg/day)	19.0 (7.5)	18.7 (5.9)	17.6 (9.1)	12.7 (7.2)	19.6 (10.0)	13.4 (6.1)	0.02	<0.001	0.07
Total amount of physical activity (MVPA) (min/day)	258 (92)	260 (80)	238 (111)	179 (95)	284 (98)	221(81)	0.001	0.001	0.08
Moderate physical activity (MPA) (min/day)	227 (77)	243 (76)	210 (95)	169 (87)	231 (80)	202 (75)	0.003	0.081	0.11
Vigorous physical activity (VPA)[a] (min/day)	21 (11–43)	13 (8–24)	20 (8–37)	7 (3–16)	35 (20–73)	13 (6–21)	<0.001	<0.001	0.08
Sedentary time (including sleep) (min/day)	898 (93)	906 (90)	966 (138)	975 (143)	947 (92)	944 (95)	<0.001	0.75	0.91

Values are means (SD).
[a]Median (lower quartile-upper quartile).
Significance by ANOVA of the main effects for city and gender and city × gender interaction.
Analyses were performed on log-transformed values.

Ljubljana and Ann Arbor children were observed. On the other hand, sedentary time was lower in the Ann Arbor children compared to the other two cities ($P < 0.001$ vs. Zagreb and $P = 0.03$ vs. Ljubljana).

In all, girls had lower energy expenditure and engaged in less PA compared to boys. However, significant city × gender interactions indicate that gender differences in PAEE and MVPA are far less pronounced for Ann Arbor children compared to the children from Zagreb and Ljubljana. Moreover, regarding MPA, the differences between genders across cities were not even in the same direction. Namely, while boys in Zagreb and Ljubljana accumulated much more MPA compared to girls, in Ann Arbor the opposite was true. In contrast, sedentary time did not differ between genders.

Table 3 shows differences in PA between school days and weekends. Overall, MPA and VPA were higher on school days compared to weekends ($P < 0.001$ for both MPA and VPA). In contrast, sedentary time was higher on weekends than during the week ($P < 0.001$). This resulted in lower daily energy expenditure on weekends compared with school days ($P < 0.001$ for both TEE and PAEE). Non-significant period × gender interactions ($P = 0.52$ to $P = 0.80$ for various activity endpoints) point to similar magnitude of the decline in activity during weekends in both genders. However, significant period × city interaction effects indicate that the magnitude of the reduction in daily energy expenditure during weekends differs between cities, with the largest difference being observed in Ljubljana and the lowest in Ann Arbor. Similarly, the difference in VPA and sedentary time between school days and weekends across cities seems to depend on gender and is evident in girls only. Notably, the direction of between-day differences in PA was consistent between city groups (Table 3), with the exception of VPA. Within-group analyses showed no difference between school days and weekends VPA in the Ann Arbor ($P = 0.43$), while Zagreb and Ljubljana children accumulated ~30% less VPA on weekend than during school day (−31%, $P < 0.001$ for Zagreb and −35%, $P < 0.001$ for Ljubljana).

In all three city groups, the great majority of children of both genders accumulated at least 60 min of MVPA (>3 METs) on each day during school or weekend days (see upper part of Fig. 1) and therefore achieved recommendations in MVPA. However, while in Ann Arbor and Ljubljana no differences in the proportion of children achieving recommendations on school days and weekends were observed, the proportion of children in Zagreb not conforming to the recommendations in MVPA was higher on weekends compared to school days ($P = 0.02$ overall; $P = 0.06$ in boys and $P = 0.54$ in girls). In regards to VPA (>6 METs), the proportion of children accumulating at least 20 min of VPA on at least one and at least two days is shown in the lower part of Figure 1. There were more boys in all the cities who accumulated more than 20 min of VPA on at least one and two days than girls. On the other hand, differences by city in the proportion of children accumulating at least 20 min of VPA were observed only for at least one day of sufficient VPA and only in boys but not girls.

TABLE 3. Physical activity levels of children during an average school and weekend day stratified by city and gender

	Boys ($n = 116$)		Girls ($n = 125$)		Interactions (P value)	
	School days	Weekends	School days	Weekends	Period × city	Period × city × gender
TEE (kcal/kg/day)					0.03	0.05
Ann Arbor	47.8 (5.8)	46.3 (8.8)	47.3 (6.5)	45.8 (5.7)		
Zagreb	45.8 (7.1)	43.0 (8.9)	41.9 (6.2)	40.6 (6.7)		
Ljubljana	50.4 (7.8)	47.8 (7.8)	46.2 (8.4)	40.3 (5.1)		
PAEE (kcal/kg/day)					0.16	0.28
Ann Arbor	19.3 (7.4)	18.2 (11.1)	18.9 (7.0)	18.0 (6.5)		
Zagreb	18.6 (9.1)	15.3 (10.6)	12.9 (7.5)	12.0 (8.3)		
Ljubljana	20.3 (11.1)	17.6 (10.5)	14.6 (7.5)	10.5 (5.3)		
MPA (min/day)					0.31	0.04
Ann Arbor	233 (76)	214 (107)	250 (88)	225 (81)		
Zagreb	223 (97)	177 (110)	172 (89)	163 (104)		
Ljubljana	239 (90)	210 (86)	218 (91)	164 (66)		
VPA (min/day)[a]					0.12	0.02
Ann Arbor	21 (9–49.5)	20 (6–36)	12 (6–20)	17 (7.5–36.5)		
Zagreb	21.5 (7–37.5)	17.5 (3–44)	8 (3–16)	5 (1–11)		
Ljubljana	39 (18.5–74)	35 (14–72)	14 (7.5–24)	6.5 (3–13.5)		
Sedentary time (min/day)[b]					0.39	0.04
Ann Arbor	878 (87)	949 (131)	882 (104)	964 (105)		
Zagreb	945 (129)	1018 (143)	962 (122)	1004 (129)		
Ljubljana	932 (98)	985 (106)	914 (104)	1018 (97)		

Values are means (SD).
[a]Median (lower quartile-upper quartile).
[b]Including sleep.
Significance by repeated measures ANOVA of the period × city and period × city × gender interactions.

The average weekly time assigned to selected activities by children in all three city groups is shown in Table 4. Children in Zagreb spent the most time in front of a screen, with the difference between the cities being more pronounced in girls ($P = 0.006$ vs. Ann Arbor girls and $P = 0.01$ vs. Ljubljana girls; $P < 0.001$ vs. Ann Arbor boys and $P = 0.17$ vs. Ljubljana boys). At the same time, Zagreb boys, but not girls, devoted more time to sports than their Ann Arbor peers ($P = 0.015$). On the other hand, there was no difference in sports activity between Zagreb and Ljubljana children ($P = 0.24$). Children in Ann Arbor dedicate less time to school responsibilities compared to their peers in other two cities ($P = 0.008$ vs. Zagreb boys and $P = 0.009$ vs. Ljubljana boys; $P = 0.007$ vs. Zagreb girls and $P < 0.001$ vs. Ljubljana girls). Finally, no difference between the city groups in the time committed to various domestic chores was observed in both genders ($P = 0.25$ in boys; $P = 0.608$ in girls).

A vast majority of children was engaged in organized sport in all the city groups investigated. The proportion of boys practicing organized sport was 90%, 84%, and 77% in Ann Arbor, Zagreb, and Ljubljana, respectively ($P = 0.34$). Slightly lower organized sports participation was recorded in girls with 82%, 73%, and 68% of girls being involved in sports in Ann Arbor, Zagreb, and Ljubljana, respectively ($P = 0.42$). The most popular sports differed between the city groups. In Ann Arbor, most boys and girls participated in soccer. In Zagreb, most boys also participated in soccer while girls predominantly chose basketball. On the other side, in Ljubljana, boys preferred basketball and girls were mostly engaged in dance.

DISCUSSION

The results of this study highlight the utility of objective monitoring devices in field-based studies involving children. The main finding of this study was that energy expenditure and PA levels of children estimated using the SWA vary significantly with regard to cultural environment; however, common characteristic existed, e.g., the PA of children is lower during weekend days than on school days. Differences in PA patterns between school days and weekends are explained both by less accumulated time in MVPA and increased time spent sedentary during weekend days.

The physical characteristics data indicated that children from Ann Arbor are shorter and lighter than children from Zagreb and Ljubljana. Therefore, energy expenditure variables relative to body weight were more appropriate for comparison. The Ljubljana boys with the highest TEE (49.7 kcal/kg/day) expended 20% more energy than Zagreb girls with the lowest TEE (41.5 kcal/kg/day). However, variability in PAEE is somewhat different. Ljubljana boys and Zagreb girls kept their difference but Ann Arbor girls stand out with high PAEE, right next to Ljubljana boys. Time spent in different levels of PA reveals some interesting details.

MVPA reported in this study was highest in Ljubljana boys [284 (98) min/day] and lowest in Zagreb girls [179 (95) min/day]. The pattern of PA level of Zagreb and Ljubljana children was similar. Boys were more physically active than girls at all PA intensities, while there was no difference in sedentary behavior (including sleep). A different pattern was seen in Ann Arbor. Girls were more physically active than boys. The difference was attributable entirely to MPA, while they engaged in less VPA.

Time spent in MVPA by Ljubljana boys was 19% greater than by Zagreb boys [284 (98) min/day vs. 238 (111) min/day respectively], which represents a difference of 46 min/day. In girls even bigger differences occurred, since girls from Ann Arbor accumulated 258 (92) min/day of MVPA compared to only 179 (95) min/day by girls in Zagreb, which represents a 79 min/day or 44% difference. Reviews of correlates of PA in youth have shown that one of the most important variables consistently associated with PA is gender, with a tendency for PA levels to be lower in girls than boys (Sallis et al., 2000; Van Der Horst et al., 2007). In our study, the subsample from Ann Arbor differed from these findings. Direct comparison with previous studies is precluded by differences in methodology used to assess PA and the differences in thresholds used to define MVPA. Recent accelerometry-based studies that used the same threshold for moderate intensity as this study reported somewhat lower values of daily PA (Dencker et al., 2006; Riddoch et al., 2004; Trost et al., 2002). The most similar

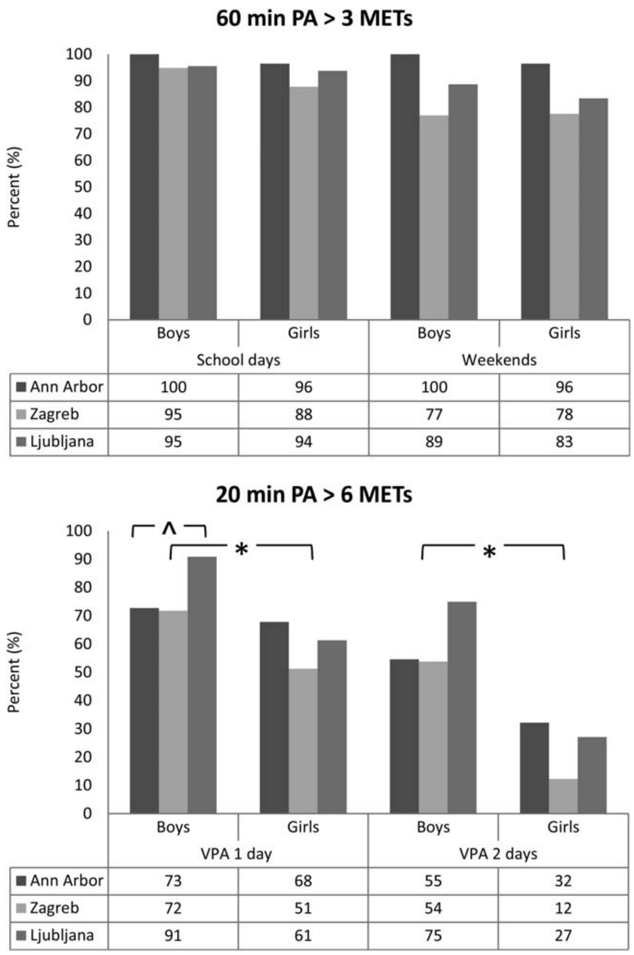

Fig. 1. Proportion of children achieving recommended amount of PA stratified by city and gender. Significant difference within groups. $P < 0.05$; $*P < 0.01$.

PA duration was recorded in Swedish 8- to 11-year-olds (Dencker et al., 2006). In this study, boys achieved 210 min of PA daily, while girls accumulated 190 min. Similar, but slightly lower values were also reported in 9-year-old European boys and girls who engaged in 192 min/day and 160 min/day of PA respectively (Riddoch et al., 2004). The lowest PA time of only around 100 min/day was recorded by Trost et al. (2002) in American children approximating the age of the children in this study (grades 4–6). The higher values of PA noted in this study compared with the one based on accelerometry could be attributed to the different methods used to assess PA and the different timing of the studies. First, compared with accelerometers, the multi-sensor monitor used in this study has proven to be better at estimating energy expenditure during non-weight-bearing activities (e.g., cycling), PA involving upper body, and change in energy expenditure associated with load carrying and graded surface (Fruin and Rankin, 2004). Furthermore, the SWA monitor is worn during day and night which led to the average recording time in this study being 23 h/day as opposed to only 10–12 h/day common to the accelerometry-based studies. The other possible reason for higher values of PA in this study is a difference in the timing of the measurements between the studies. PA has been reported to vary considerably during the year, with the highest levels being documented during spring and the lowest during winter (Tucker and Gilliland, 2007). While in this study PA was assessed during spring, in the aforementioned studies it was measured during autumn in Sweden and the USA (Dencker et al., 2006; Trost et al., 2002) or throughout the year in northern Europe and Portugal (Riddoch et al., 2004).

Generally, a decline in PA from school days to weekend days was noted in all city groups in both genders. The observed decline in MVPA on weekends ranged from 11 min/day in Zagreb girls to 66 min/day in Ljubljana girls. However, PA pattern somewhat differs between countries. The largest differences in PA levels between school days and weekends have been observed in Slovenia and the smallest in Ann Arbor. A different direction of between-day differences in VPA in girls has been also observed. In Zagreb, girls accumulated ~30% less VPA on weekends than during school days, while weekend VPA was less than one half of that during school days in Ljubljana girls. On the contrary, weekend VPA in Ann Arbor girls was 30% higher than during school days. Comparisons with the previous studies for school days versus weekends are somewhat difficult due to different PA assessment method used and the different age range studied. In line with the present study, a study that employed accelerometers in American girls has shown a comparable decrease in PA from school days to weekends, although a higher

TABLE 4. Average weekly hours devoted to selected activities by children stratified by city and gender

	Boys				Girls			
	Ann Arbor, USA ($n = 33$)	Zagreb, CRO ($n = 39$)	Ljubljana, SLO ($n = 44$)	P	Ann Arbor, USA ($n = 28$)	Zagreb, CRO ($n = 49$)	Ljubljana, SLO ($n = 48$)	P
Screen time (h/week)	12.8 (8.8–17.3)	21.9 (16.5–33)	17.8 (14–25.8)	<0.001	12.0 (8.3–18.3)	21.1 (13–26)	12.6 (8.7–21)	0.004
Homework (h/week)	5.0 (3.5–6)	8.0 (4.8–11)	9.0 (5.6–14)	0.01	5.5 (4.3–6)	9.0 (4.8–11.5)	9.3 (7–14)	<0.001
Chores (h/week)	3.0 (2–4)	3.5 (1.5–6.9)	4.5 (1.8–8)	0.25	3.5 (2.0–6.3)	4.3 (2.5–6.5)	5.0 (2.1–8.5)	0.608
Sport (h/week)	4.5 (3–6.5)	7.5 (4.5–9.8)	5.0 (1.1–7.5)	0.019	4.0 (2.3–6)	5.0 (0–7.5)	3.9 (0–8.5)	0.991

Values are medians (lower-upper quartile). Significance by Kruskal–Walllis ANOVA; screen time denotes the sum of TV and computer time; chores represent the sum of time spent helping with family business, babysitting, doing kitchen and house chores.

threshold was used to define MVPA (>4.6 METs) compared to our study (Treuth et al., 2007). Prior studies that used the same threshold for MPA as the present study have produced conflicting results. For example, Trost et al. (2000) found higher values of PA on weekends compared with school days in American 11-year olds, but Nader et al. (2008) reported no between-day difference in children of the same age. Similar discrepancies were observed in English children, with one study reporting higher PA on weekends (van Sluijs et al., 2008), while the other showed the opposite pattern (Rowlands et al., 2008). A large study that compared PA patterns in children across four European countries also found inconsistent results for week day vs. weekend differences (Nilsson et al. 2009). Portuguese children showed a higher average level of PA on weekends, contrary, Danish and Norwegian children showed a decrease in PA during the weekend, while PA of the Estonian children was similar throughout the week. Finally, Kwon and Janz (2012) pooled analyses from the International Children's Accelerometry Database (data from several studies from the UK, Australia and the USA) have shown that MVPA and VPA in boys and girls was higher on the school days than the weekend days. Taken together with the results of this study, it seems that geographical location significantly influences children's weekly activity patterns. The reasons for this variation are not apparent, but may reflect different PA opportunities in study regions.

As the PA levels during school days and weekend days reported in this study are much higher than the currently recommended 60 min of MVPA per day, nearly all children included in this study met the current recommendations. Some other researchers reported similar findings (Deforche et al., 2009; Liou and Chiang, 2004). Furthermore, many studies reported that the prevalence of overweight and obesity among children and adolescents has increased dramatically in recent decades (Kovac et al., 2012; Livingstone, 2001; Moreno et al., 2000; Parrino et al., 2012; Tremblay and Willms, 2000; Wedderkopp et al., 2004; Ying-Xiu and Shu-Rong, 2012) and endurance and strength of children have decreased (Malina, 2007; Strel et al., 2007; Tomkinson and Olds, 2007). This suggests that current recommendations of at least 60 min of MVPA per day might be insufficient for preadolescent children to achieve optimal health benefits. In accordance with this, it has recently been proposed that at least 90 min of MVPA per day is required to prevent clustering of cardiovascular disease risk factors in children (Andersen et al., 2006). This supports recommendations on increasing recommendations to 90 min (Janssen, 2007) or at least 60 min, and up to several hours, of MVPA every day (Corbin and Pangrazi, 2004; Department of Health and Aging, 1999).

With regard to VPA, no city group met the recommendations of three or more days per week of 20 min of VPA. One-quarter to almost half of the boys and two-thirds to almost nine-tenths of the girls in our study did not accumulate 20 min or more VPA in at least two of the four consecutive days assessed. Similar results were found by some other researchers (Colley et al., 2011; Pate et al., 2002). This gap is very important since available information (Janssen and LeBlanc, 2010) suggests that vigorous intensity activities provide additional health benefits beyond modest intensity activities.

Differences in PA levels in city groups are partially explained by parent reports of children's activities. While differences in measured sedentary time are consistent with reported screen time, a discrepancy in city group differences in measured MVPA and reported sports activities is noted. This might be a reflection of the well-known limitations of PA report, or it may emphasize a prevailing influence of other factors on MVPA beside sports activities (e.g., physical education classes, environmental opportunities for playing, commuting to school, and other PA activities).

Strengths and limitation

The strengths of this study included objective evaluation of PA patterns and energy expenditure using the same multiple-sensor body monitor that combines accelerometry with other physiological signals, thus eliminating the drawbacks of PA assessment based only on accelerometer data or different types of activity devices. Further, the length of daily monitoring period in this study (minimum 21 h per day of valid recording) exceeds the one commonly used in previous studies (10–12 h per day), thus minimizing the possibility that some activities are not recorded and increasing the reliability of PA assessment. Last, the present study included a fairly large sample of children with different ethnic, cultural, and racial background.

This study has some limitations that must be considered when interpreting its results. First, the design was cross-sectional, providing only associations and precludes the ability to determine any causality. Secondly, data collection was restricted to a 4-day period. Therefore, this can be considered as only a snapshot of the participant's lifestyle and may not reflect true PA patterns. Increasing data collection to 7 days might reflect usual activity patterns more accurately (Trost et al., 2000). However, due to acceptable between-day intraclass reliability coefficients ($r \approx 0.8$), 3–4 days of activity monitoring have been proposed as a suitable duration for accurately and reliably assessing the usual activity behavior in this age group (Trost et al., 2000). Thirdly, in rare anecdotal reports, coaches prevented study participants from wearing SWAs during some sporting activities (e.g., soccer games). Similar unreported events may have influenced the results. Fourthly, it has been shown that vigorous activities in this age group are rarely sustained for more than 10 s (Baquet et al., 2007). Thus, we must acknowledge the fact that the 1-min sampling interval used in this study might have led to an underestimation of VPA. On the other hand, the majority of MPA is accumulated in 5-min bouts, which makes MPA less prone to underestimation compared to the 1-min sampling interval (Trost et al., 2000). Also, vigorous and very vigorous intensity activity account for only a small portion of the MVPA (Baquet et al., 2007). We therefore believe that this had a minor effect on the conclusions of this study. Finally, as biological age was not assessed, we cannot discard the possibility that different levels of PA, particularly among girls from Ann Arbor, have been mediated by differences in maturation since PA level declines with age in children (Sallis et al., 2000).

CONCLUSIONS

Our results add to the objectively evaluated knowledge about PA patterns of children in different cultural environments. We found similar patterns in PA of children from Zagreb and Ljubljana, representing Central European cultural environment and climate, despite big differences in energy expenditure and the amount of PA between children in the two cities. This is not surprising since PA is a complex multidimensional behavior influenced by various factors. The knowledge about PA of particular children is very important for the planning of interventions aiming to promote increased levels of PA in children. In youth, daily and weekly activity patterns are likely to provide different opportunities for PA. Weekend days seem an appropriate target for promoting higher PA levels in 11-year-olds in Zagreb and Ljubljana. Additionally, special attention should be directed to increasing VPA of children during school days and weekends, especially in girls.

The results of this study also indicate that weekly patterns of children's PA are not universal and that cultural and geographical settings might be important determinants of these patterns. Therefore, national PA recommendations should take this into account and adjust international recommendations that rely on specific national research evidence.

Further studies with longer periods of monitoring that could enable greater accuracy in the evaluation of PA patterns are advocated to corroborate the results of the present study. In addition, similar studies in middle and late adolescence are strongly encouraged.

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