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ORIGINAL RESEARCH

Where Are Czech Adolescents Active? The Patterns of Movement and Transport Behavior in Different Active Living Domains

Michal Vorlíček,[1] Tom Stewart,[2] Jan Dygrýn,[1] Lukáš Rubín,[1,3] Josef Mitáš,[1] Jaroslav Burian,[4] Scott Duncan,[2] Jasper Schipperijn,[5] and Michael Pratt[1,6]

[1]Faculty of Physical Culture, Palacký University Olomouc, Olomouc, Czech Republic; [2]School of Sport and Recreation, Auckland University of Technology, Auckland, New Zealand; [3]Faculty of Science, Humanities and Education, Technical University of Liberec, Liberec, Czech Republic; [4]Faculty of Science, Palacký University Olomouc, Olomouc, Czech Republic; [5]Department of Sport Science and Clinical Biomechanics, University of Southern Denmark, Odense, Denmark; [6]Herbert Wertheim School of Public Health and Human Longevity Science, University of California San Diego, San Diego, CA, USA

To understand the environmental determinants of physical activity (PA), precise spatial localization is crucial. This cross-sectional study focuses on the spatiotemporal distribution of PA among Czech adolescents (n = 171) using Global Positioning System loggers and accelerometers. The results showed that adolescents spent most of their time in sedentary behavior, with 57.2% and 58.5% of monitored time at home and school, respectively. The park and playground had the lowest proportion of sedentary behavior but also the lowest amount of moderate to vigorous PA (MVPA). However, when considering the time spent in each domain, the highest proportion of MVPA was seen in publicly accessible playgrounds (13.3% of the time). Chi-square analysis showed that the relative distribution of different PA intensities did not differ across spatial domains. Based on these results, the authors propose 2 key strategies for increasing MVPA in adolescents: Increase the time spent in activity-supportive environments, such as parks and playgrounds, and design techniques to increase MVPA at home and school settings.

Keywords: GPS, environment, spatiotemporal distribution, school environment, public playgrounds

Regular physical activity (PA) provides a wealth of benefits for children and adolescents, encompassing physical, mental, and preventive health advantages.[1–3] However, 81% of adolescents worldwide do not meet current PA recommendations.[4] Insufficient PA in adolescents is particularly concerning given that this age range is when many individuals form long-term behavioral patterns.[5] Promotion of adolescent PA is particularly relevant in the Czech Republic, where clear downward trends have been observed over time.[6–8]

Previous PA research has typically focused on intrapersonal and interpersonal factors such as age, gender, body composition, attitudes, and self-perception.[9,10] However, it has been shown over the long term that interventions focused on these factors tend to have small to moderate effects, can only influence a small number of people (study participants), and are mostly short-lived.[11] The socioecological approach[12] is based on the premise that the environment and context in which PA takes place play an important role in establishing movement habits and promoting lifestyle changes.[13,14] Adolescents are exposed to interactions with the built environment over long periods of time.[15,16] Understanding the environmental correlates of PA among young people is particularly important because, compared to adults, adolescents tend to be less autonomous in their transport behavior and may be more influenced by the environment in which they move.[17,18]

Analysis of the association between the built environment and PA requires an understanding of the spatial localization of PA. Ideally, objective spatial localization (eg, using portable Global Positioning System [GPS] receivers) provides a means to determine where PA is performed.[19] Most of the current studies in the field combine GPS data with objective PA measurements, such as wearable motion sensors.[20–22] It is this combination of time-aligned data that allow us to analyze the spatial distribution of PA more thoroughly.

Although there has recently been progress in technology for measuring PA and spatial location, certain technological and ethical barriers still persist when combining both instruments in research.[23] No similar study combining accelerometer and GPS data to objectively localize the PA of adolescents in the context of the built environment has been published in Czechia. Such information may be useful for understanding patterns of behavior, not only in Czechia but in contrast to built environments in other countries. Therefore, the purpose of this paper is to examine the distribution of Czech adolescents' PA across the spatiotemporal domains of the built environment.

Methods

Participants

Data collection in this cross-sectional study was conducted in 2 Czech cities: Olomouc and Hradec Králové (Figure 1), between 2014 and 2016 during spring and fall seasons. Data collection was in agreement with the Internatinal Physical Activity and the Environment Network (IPEN) Adolescent protocol.[24] This included a strategy of personal recruitment of participants through schools. Schools were preselected from neighborhoods classified based on

Stewart https://orcid.org/0000-0001-5915-3843
Dygrýn https://orcid.org/0000-0003-1026-1784
Rubín https://orcid.org/0000-0003-4920-1113
Mitáš https://orcid.org/0000-0001-7219-931X
Burian https://orcid.org/0000-0003-0729-9757
Duncan https://orcid.org/0000-0002-8402-2930
Schipperijn https://orcid.org/0000-0002-6558-7610
Pratt https://orcid.org/0000-0002-8939-7715
Vorlíček (michal.vorlicek@upol.cz) is corresponding author, https://orcid.org/0000-0002-8317-9266

Figure 1 — Study areas.

both walkability and socioeconomic status (SES). These neighborhoods fell into one of 4 quadrants: high walkability–high SES, high walkability–low SES, low walkability–high SES, and low walkability–low SES. Adolescents aged 12–18 years were recruited and, based on their home address, were assigned the appropriate quadrant.[24] These 2 regions were chosen as spatial data required for subsequent analysis of the GPS data were available for these regions. The data layers were created in cooperation with representatives of the municipal office of the 2 cities.

Students from 4 primary schools and 1 grammar school were involved in the study. All participants or their legal guardians signed an informed consent form to participate in the research, and the study design was approved by the ethics committee of the Faculty of Physical Culture, Palacký University Olomouc on May 3, 2013, under the number 37/2013. As part of an introductory meeting, the students were given monitoring devices (described below) and all instructions for wearing them. The students wore the accelerometer and GPS logger for 7 days on an elastic belt on their hip (from the time they woke up until they went to bed).

Measures

The Holux RCV-3000 GPS logger (Holux Technology) was used to determine spatial localization. This instrument has been used in research previously.[25,26] The logger includes a highly sensitive Mediatek MT3329 chip with parallel signal search on 66 channels and up to 22 tracking channels for fast position determination and recovery after GPS signal loss. The built-in Wide Area Augmentation System/European Geostationary Navigation Overlay Service (WAAS/EGNOS) demodulator ensures precise operation in densely built-up areas, valleys, and other environments with degraded signal reception. The 4 MB internal memory can record up to 200,000 data points, logged by time or distance (HOLUX Technology, 2017). Sufficient accuracy of the device for localizing human movement in an urban environment has been demonstrated previously.[27,28] The GPS logger had to be charged by the participant each night. The study participants were not reminded or contacted by the researchers during the observed week.

Device-based assessment of sedentary behavior (SB) and PA was conducted using an ActiGraph accelerometer (GT1M or GT3X), worn on the right hip during waking hours and non-water-based activities. These accelerometers have demonstrated no significant intermonitor differences particularly when using only the vertical axis.[29,30] Participants were instructed to wear the accelerometer for 7 consecutive days and document any times and rationale for removing the device. Accelerometers were configured with ActiLife (version 6) software (ActiGraph) to capture data on a single vertical axis for GT1M devices and on 3 axes for GT3X devices. The sampling interval was set to 60 seconds, which was the most commonly used epoch at the time.[31]

Data Processing

The merging and cleaning of the GPS logger and accelerometer data were performed in the Personal Activity Location Measurement System (PALMS) web application.[32,33] By linking the data in PALMS, each identified point carries information about the current intensity of PA (SB, light, and moderate- and vigorous-intensity PA [MVPA]) (Figure 2). The software automatically marked and deleted GPS points between which there was an unrealistic increase in speed or altitude. In addition, the times when not wearing the instruments were identified. The time when the accelerometer was not worn was defined as those periods of time in which the accelerometer showed a reading of 0 counts continuously for at least 60 minutes, which effectively distinguishes between SB and the absence of wearing the device in youth.[31,34] Finally, the Evenson cut points[35,36] were used to classify SB (≤100 counts per minute [cpm]), light PA (101–2295 cpm), and MVPA (>2296 cpm). Only participants whose data contained at least 3 days (2 weekdays + 1 weekend)[37] and at least 8 hours of monitoring per day[38] were included in the final data set (n = 119).

PALMS detected which GPS points were part of a trip. The definition of a trip was a series of points that spanned at least 100 m over a minimum period of 2 minutes. PALMS also assigned a travel mode to each trip depending on the speed: >35 km/h was classified

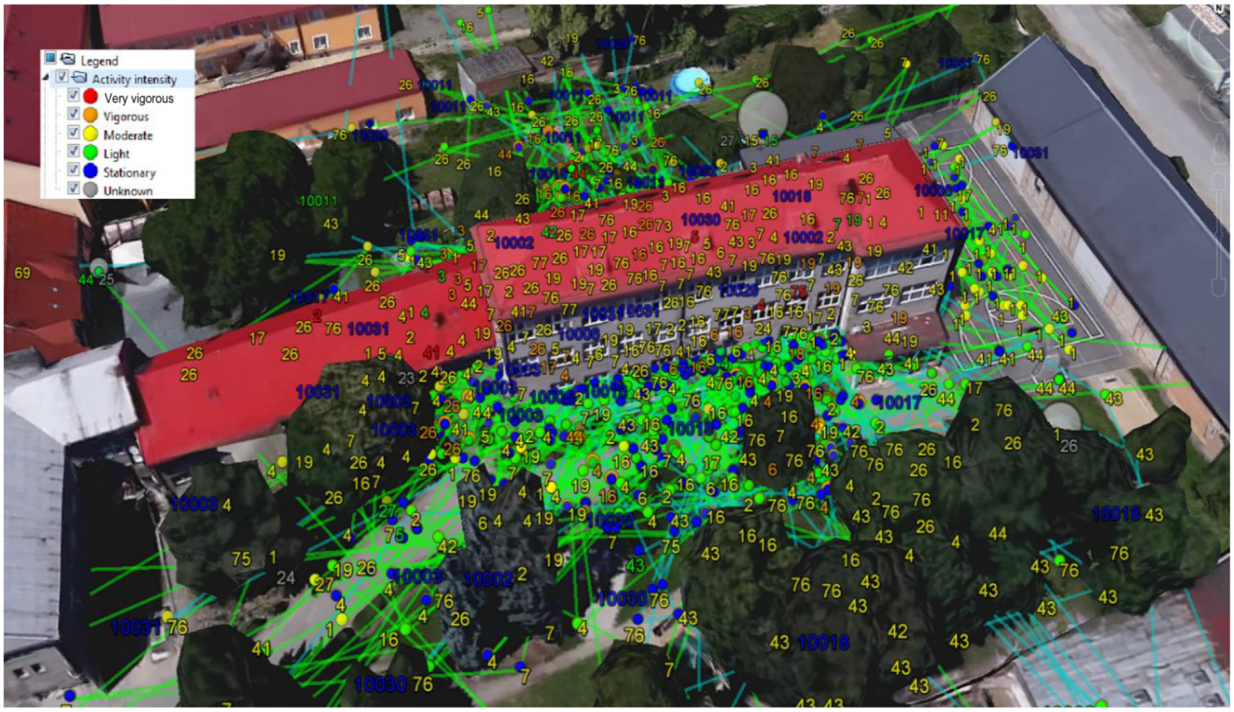

Figure 2 — Visualization of PALMS data outputs (school site)—individual GPS points according to the intensity of PA. GPS indicates Global Positioning System; PA, physical activity; PALMS, Personal Activity Location Measurement System.

as vehicle, >10 km/h as cycling, and > 1 km/h as walking, where the 90th percentile of speeds along the trip was considered.[19,39]

Geographic Information System software was used to create spatial layers that were then used to organize data into spatiotemporal domains. In ArcGIS software (Environmental Systems Research Institute, Inc), spatial data layers were created that defined: a circle with a radius of 100 m centered at the participant's place of residence, the area of the given school (polygon), parks, and playgrounds (polygons). These layers were created for the cities of Hradec Králové and Olomouc based on data from the cadastral office. Each of the almost 3.5 million GPS points was assigned to 1 mutually exclusive spatiotemporal domain by passing each point through a simple decision tree: (1) Points that were inside the area around the residence were classified as "home," (2) points that were inside the school polygon were classified as "school," (3) points that were inside the playground polygons were classified as "playground," (4) points that were inside the park polygons were classified as "park," (5) points that were part of a PALMS-identified trip (vehicle, bicycle, or walking) were classified as "transport," and (6) all remaining points were assigned to the "other" domain (Figure 3). The time spent in sedentary, light, and MVPA was then summarized for each of these spatial domains. The processing of spatial domains was performed using the *PALMSPlusR* R package.

Statistical Analyses

Data were statistically processed using IBM SPSS Statistics (version 23) software. The arithmetic mean (M) and standard deviation (SD) were most commonly used for descriptive purposes. The Kolmogorov–Smirnov and Shapiro–Wilk normality tests were used to assess the normality of the data distribution. Statistical differences in the structure of movement behavior across domains of active living were assessed using Pearson chi-square test.[40]

Results

A total of 171 pupils (12–18 y, 14.22 [1.61]; 100 girls; body mass index = 20.09 [3.34]) actively participated in the study. After applying the inclusion criteria, the data set used for analysis contained 119 pupils. The minutes of wear time and nonwear time for each domain are shown in Table 1. The domain with the most nonwear time was Home (61.2%), but this includes when the devices were removed at night to charge the GPS logger. School and Park had the highest proportion of wear time.

SB in Active Living Domains

Almost half of the monitored time in the playground and parks (8 min) was assessed as SB. Within the transport domain, adolescents were inactive for an average of 67 minutes (51.5% of the monitored time). In the "Other" domain, SB accounted for 53.9% (90 min). Most SB was recorded in the "home" and "school" domains, accounting for 57.2% and 58.5% (182 and 169 min) of the monitored time, respectively (Figure 4).

Light PA in Active Living Domains

As with SB, differences in the relative representation of low-intensity PA across domains were small. We found the lowest proportion of activity with an energy expenditure of up to 3 METs in the playground (33.3%), and conversely, the highest proportion (41.2%) was recorded in parks. A similar pattern at home and at school (34.6% and 33.9%, respectively) was observed, and also within transport and "Other" domains

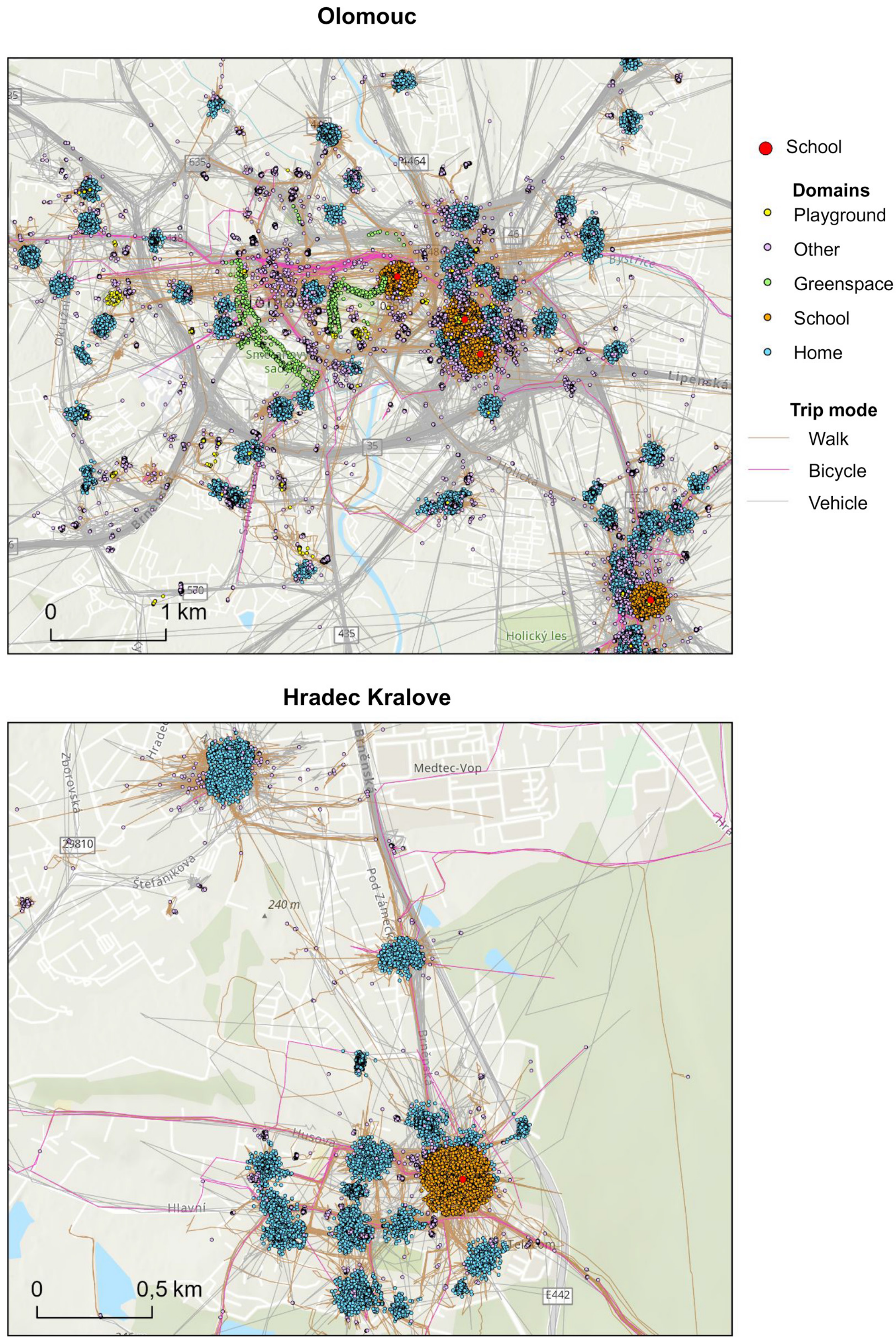

Figure 3 — Identification of individual GPS points according to domains defined in the GIS. Type of domains are shown: school address (red), playground (yellow), other (purple), greenspace (green), school buffer (orange), home buffer (blue). Trip modes are shown: walk (brown), bicycle (pink), vehicle (gray). See online article for color version of figure. GIS indicates Geographic Information System; GPS, Global Positioning System.

(36.9% and 36.5%, respectively). We see much more pronounced differences in absolute terms, which also reflects the time spent by adolescents in these domains. On average, adolescents were lightly active in the playground and park for 5 and 7 minutes per day, respectively. Within transport, it was 48 minutes per day and 61 minutes in the "Other" domain. Most low-intensity activity was undertaken at home and school (110 and 98 min, respectively).

Table 1 Basic Descriptive Statistics

Domain	Number of participants, n	ActiGraph wear time, min/d Mean (SD)	ActiGraph wear time, min/d % of time in the domain	ActiGraph nonwear time, min/d Mean (SD)	ActiGraph nonwear time, min/d % of time in the domain
Home	118	317 (141)	39	500 (149)	61
School	115	289 (72)	95	15 (42)	5
Park	34	16 (28)	94	1 (6)	6
Playground	35	14 (27)	74	5 (16)	26
Transport	119	130 (58)	81	30 (43)	19
Other	119	167 (127)	59	117 (129)	41
Total	119	777 (94)	55	628 (105)	45

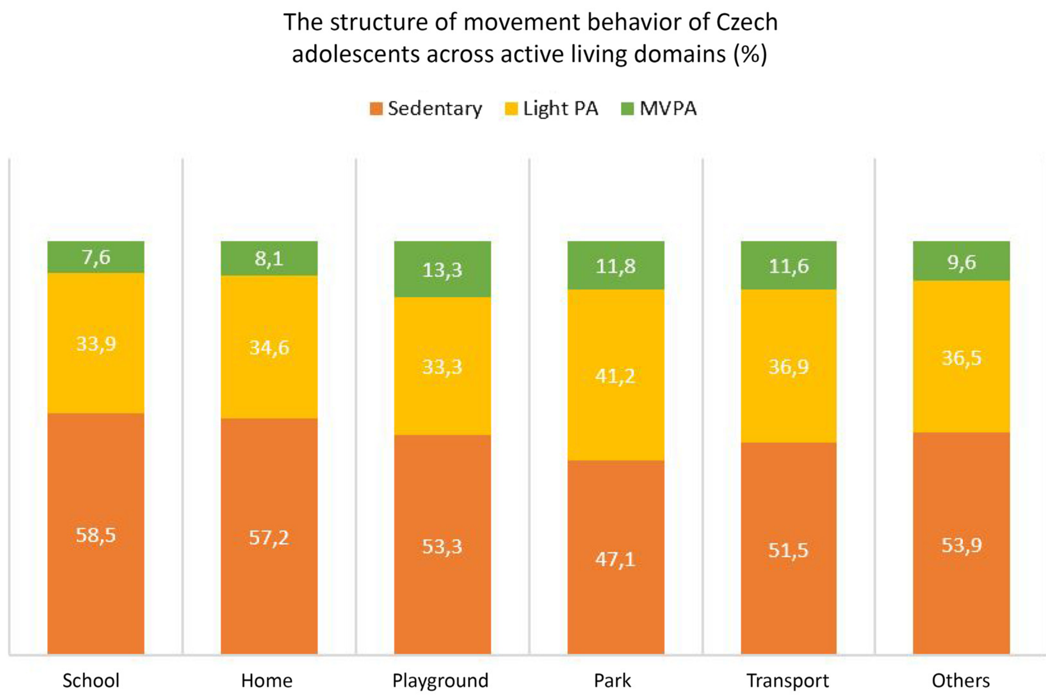

Figure 4 — The structure of movement behavior of Czech adolescents across active living domains (in percentages). The structure of the movement behavior is shown: sedentary (orange), light physical activity (yellow), moderate to vigorius physical activity (green). See online article for color version of figure. MVPA indicates moderate to vigorous PA; PA, physical activity.

MVPA in Active Living Domains

The least amount of MVPA was observed in the home and school domains (8.1% and 7.6% of time in the domain, respectively). In terms of absolute values, this translated to 26 minutes at home and 22 minutes at school. On average, 16 minutes of MVPA (9.6% of the time) per day was performed in the "Other" domain and 15 minutes of MVPA (11.6% of the time) in the transport domain. Nearly 12% of MVPA was also observed in parks. Two minutes of MVPA were also located in outdoor public playground environments. Given the time in which adolescents were monitored in the playground (14 min), the proportion of MVPA (13.3% of the time) is the highest of all the domains. Vigorous-intensity PA was not observed in parks or playgrounds. Relatively, most activity exceeding the energy expenditure of 6 METs was performed during transport (0.8%). High-intensity PA represented 0.6% and 0.3% of time spent in the "Other" and home domains, respectively. Within transport and school, Czech adolescents spent an average of 1 minute per day on high-intensity activity. According to chi-square analysis, the relative distribution of PA of different intensities across spatial domains did not differ ($\chi^2 = 8.697$; $P = .892$).

Different Perspectives on Spatiotemporal PA Data

The entire sample (n = 119) generated a total of 48,380 minutes of MVPA (Table 2), most of which were accumulated at home (17,932 min, 37% of all MVPA). In the "Other" domain, 10,494 minutes were identified as MVPA (22%). The lowest absolute number of MVPA minutes was found in parks (86 min) and playgrounds (132 min), which collectively represented <1% of total MVPA.

When considering the proportion of the average time spent within each domain (rather than the total number of minutes), these patterns across domains change slightly. Two percent of total SB was accumulated in parks and playgrounds, and nearly 13% of SB occurred within the transportation domain. School and home are

Table 2 Spatiotemporal Distribution of PA of Czech Adolescents in Active Living Domains

Active living domain	PA intensity	Minutes per day		Share of time, %	Total minutes	Share of total minutes, %	Average distribution of movement behavior between domains, %
		Mean	SD				
Total	Sedentary	434.6	114.5	56.0	305,586	100	100
	Light	273.8	75.1	35.3	191,537	100	100
	Moderate	64.3	32.4	8.3	45,626	100	100
	Vigorous	3.9	6.0	0.5	2754	100	100
	MVPA	68.2	34.0	8.8	48,380	100	100
Home	Sedentary	181.5	95.1	57.2	125,993	41.2	34.7
	Light	110.2	62.0	34.6	75,224	39.3	33.5
	Moderate	24.0	21.3	7.5	16,896	37.0	31.1
	Vigorous	1.5	3.8	0.6	1036	37.6	33.3
	MVPA	25.6	22.1	8.1	17,932	37.1	31.4
School	Sedentary	169.2	59.5	58.5	77,763	25.4	32.3
	Light	98.1	40.6	33.9	46,150	24.1	29.9
	Moderate	20.8	9.8	7.3	9547	20.9	26.9
	Vigorous	1.1	1.6	0.3	503	18.3	24.4
	MVPA	21.8	10.2	7.6	10,050	20.8	26.7
Playground	Sedentary	7.6	18.8	53.3	522	0.2	1.5
	Light	4.9	8.9	33.3	342	0.2	1.5
	Moderate	1.6	4.3	13.3	125	0.3	2.1
	Vigorous	0.1	0.4	0	7	0.3	2.2
	MVPA	1.7	4.6	13.3	132	0.3	2.1
Park	Sedentary	8.1	14.4	47.1	357	0.1	1.5
	Light	6.6	13.5	41.2	320	0.2	2.0
	Moderate	1.7	3.7	11.8	85	0.2	2.2
	Vigorous	0.0	0.1	0	1	0.0	0.0
	MVPA	1.7	3.7	11.8	86	0.2	2.1
Transport	Sedentary	67.3	31.8	51.5	43,538	14.2	12.9
	Light	47.8	26.1	36.9	30,945	16.2	14.5
	Moderate	13.7	12.4	10.8	8961	19.6	17.7
	Vigorous	1.0	2.0	0.8	664	24.1	22.2
	MVPA	14.6	13.8	11.6	9625	19.9	17.9
Others	Sedentary	89.9	74.7	53.9	56,941	18.6	17.2
	Light	61.0	52.1	36.5	38,465	20.1	18.6
	Moderate	15.4	13.9	9.0	9962	21.8	19.9
	Vigorous	0.8	1.3	0.6	533	19.4	17.8
	MVPA	16.2	14.4	9.6	10,494	21.7	19.9

Abbreviations: MVPA, moderate to vigorous PA; PA, physical activity.

the domains where the largest proportion of SB was observed (32% and 35%, respectively). Most (31%) MVPA took place at home. Schools and transport are also important domains in relation to MVPA, with 27% and 18% of MVPA, respectively. In the playground and in the park, only 2% of MVPA was measured (Table 2).

Discussion

The results of our study indicate that Czech adolescents have the highest amount of SB in their daily routine when at school and at home, accounting for 59% and 57% of their time in these domains, respectively. In nearly all domains (with the exception of public parks), sitting occupies more than half of the time spent in these areas (52%–59%). At home and at school, where adolescents spend the majority of their time, only 8% of the time is devoted to MVPA. The highest proportion of MVPA was observed in publicly accessible playgrounds (13% of the time), followed by parks and transportation (12% of the time), but the absolute amount of time spent in these areas was small. The results illustrate the relative distribution of PA across the domains is similar, but the absolute amount of time spent in these areas differs substantially. As part of considering these results, it is important to also consider the different ratio of non/wear time in individual domains. For example, within the playground domain, 26% of the time was evaluated as nonwear time. We can only speculate as to what exactly led the study participants to put the device down, but if it was some kind of

PA that interfered with the device, it could have affected MVPA results in this domain. It is also necessary to mention that not all realized MVPA is caused by the attractiveness of the given domain but may be prompted by the individual's internal motivation to perform the movement in that setting.

This distinguishes our findings from a Portuguese study[41] involving 374 adolescents with a mean age of 11.7 years. Pizarro reported that 45% of the MVPA of Portuguese adolescents were performed in transport and only 3% around home. According to our results, 18% of MVPA was accumulated in transport and 31% of MVPA in and around the home. This discrepancy may have resulted from differences in active travel behavior (ie, walking/cycling to local destinations) and neighborhood play (ie, playing in the neighborhood around the home) between the 2 samples. The differences in weekend and weekday behavior could have also contributed to this difference (ie, active travel to and from school), but weekends and weekdays were not considered as part of this study. We found the smallest difference in PA within the school. We measured 27% of MVPA in Czech adolescents, while 30% of the total MVPA was registered in Portuguese adolescents. In the context of American schools,[42] the proportion of MVPA was even higher, reaching 42%. The same methods (GPS, Geographic Information System, ActiGraph, and PALMS) were used in a Danish study[43] involving 367 children and adolescents, with a mean age of 13.2 (1.2) years, which categorized PA into 4 domains and 11 subdomains of active living. Only school days were included, and median MVPA minutes per day were presented. While in both school and leisure time, the volume of MVPA significantly decreased with age, and this decrease was not statistically significant at home, in transport, or in parks.

Interestingly, the relative distribution of the various PA intensities did not differ significantly across spatial domains. This result may indicate that adolescents do not change their movement behavior despite the domain they are in or may support the ActivityStat hypothesis.[44] However, determining the specific reasons is beyond the scope of this study as we do not have the complete data to verify these assumptions. Therefore, it should be the focus of future research in our field.

Due to the technical difficulty and considerable data reduction processed in studies using GPS technology, the method of subjective localization of PA using a time diary is often found in the literature.[45–47] Each participant in the study wrote down the times when, for example, they left home, arrived at school, left school, participated in an organized/unorganized activity, arrived home, put the device down, and went to sleep. Based on these data, it is also possible to locate PA (measured by pedometer or accelerometer) to individual domains of active life (home, school, transport, sport, and leisure). This method of subjective localization of objectively measured PA (accelerometer + time diary) has been applied to 542 German children and adolescents.[47] Of the 5 domains used (organized PA, leisure, physical education, school, and transport), only "transport" is relevant for our comparison. The objective location (GPS) of Czech adolescents generates more SB and MVPA in transport, both in absolute and proportion terms (67 min/d [13%] of SB and 15 min/d [18%] of MVPA vs 13 min/d [3%] of SB and 7 min/d [7%] of MVPA in the German study). Within the school site, on the other hand, more SB and MVPA were identified in the sample of German schoolchildren (271 min/d [55%] SB and 41 min/d [46%] MVPA vs 170 min/d [32%] SB and 22 min/d [27%] MVPA). However, these results might be affected by data selection as the German research analyzed only school days.

Increasing the objectivity of PA spatiotemporal localization by linking the accelerometry and geolocation systems carries with it several challenges. Researchers face financial challenges associated with acquiring instruments like GPS loggers and accelerometers, time constraints related to preparing and organizing measurements, and ethical considerations regarding obtaining consent to record location. Participants, on the other hand, encounter challenges such as the frequent charging of GPS instruments every night, wearing a belt with instruments, and adhering to a habitual PA mode—intentionally not altering their normal behavior based on location and PA measurements. Consequently, there are relatively lower participant numbers, compared to questionnaire collection, that can realistically be recruited for this type of study. The second criterion for participant selection is inclusion in the final sample. Currently, no internationally validated and accepted inclusion wear time criteria exist for this type of study, unlike accelerometry without GPS. Following the application of inclusion criteria (at least 2 weekdays and 1 weekend day, plus at least 8 h of wearing both devices per day), 52 participants (30%) were excluded.

The interpretation and comparison of spatiotemporal data in the context of PA also proved to be limiting. Due to the nature of the spatial data (not all participants are located in all spatiotemporal domains on every day), we are faced with inconsistent numbers of participants located in the selected domains. The domains "playground" and "park" proved to be the most problematic in this regard, with only 29% of adolescents located in these domains from the entire sample. On the other hand, we see the fact that there were so few participants in the park and playground in our study as an interesting result that speaks to spatial behavior rather than recruitment or data collection error. This finding raises the question of how effective planners are in designing public space to be activity-friendly for adolescents. If adolescents do not perceive these spaces as safe and enjoyable for engaging in PA, it could partially account for their low presence in these areas. The accelerometers were set to the 60-second epoch. This setting could lead to the averaging of PA intensities, particularly resulting in the underestimation of higher-intensity intermittent activities such as MVPA.[48] In our analysis, we did not consider the number of valid weekdays and weekend days. This oversight could potentially influence the overall patterns and conclusions drawn from the data. The age of the presented data (2014–2016) can also appear to be limiting. Nevertheless, these data are unique and the most up-to-date of this kind regarding the spatial localization of PA among Czech adolescents. In addition, the environmental settings of the monitored cities have not changed significantly, which means that the data and results are still relevant in 2024. Finally, the results are not fully generalizable to other adolescent populations because the spatiotemporal behavior may not be similar across different cultures and countries.[38,49]

Our results highlight the need for international collaboration to better understand the complexity of adolescent PA across multiple domains. Only more robust analyses conducted in different cultures and different types of built environment can offer a higher level of understanding of PA and built environment relationships in the context of behavioral change. The pattern of activity observed in this study also suggests 2 complementary approaches for increasing MVPA among adolescents: (1) increasing the currently very small proportion of time they spend in the MVPA conducive environment of parks and playgrounds, and (2) identifying strategies that can modestly increase the amount of MVPA in the 2 domains (home and school) that account for 80% of the total daily time. Traditionally, PA promotion for adolescents has focused on the domains most conducive to MVPA (parks, playgrounds, and physical education classes), but with a better understanding of the distribution of MVPA across the other domains that account for the great majority of total time, it becomes clear that there is much untapped potential for increasing adolescent MVPA at home and in schools.

Considering the potential for long-term changes in movement behavior among a substantial number of adolescents, the domains of parks and schools offer considerable potential for impact.[50] Although densely built-up urban spaces traditionally may not provide many opportunities to increase the number of parks or expand existing ones, it is feasible to enhance their attractiveness or co-organize activities that attract a broader adolescent audience.[51] Furthermore, in school environments, enhancing MVPA can be effectively achieved through initiatives such as integrating active breaks and movement-based lessons, as well as making school facilities available for community use during nonschool hours and holidays.[52]

Conclusions

Using a combination of GPS technology and accelerometers, we located the PA of Czech adolescents to individual domains of active living (home, school, playground, park, and transport). In parks and outdoor public playgrounds, we observed the least amount of MVPA (2 min/d). However, in proportion to the time spent in these domains, these domains have the highest proportion of MVPA (11.8% of time in the park and 13.3% of time on the playground). Nevertheless, the general structure of the movement behavior of Czech adolescents across the domains of active living is not statistically significantly different. This suggests that the common approach of focusing on parks and playgrounds for PA promotion should be supplemented with efforts to increase MVPA in the school, home, and transport domains as well.

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