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ORIGINAL PAPER

TRENDS IN ADOLESCENT PHYSICAL ACTIVITY IN SOUTHERN AND WESTERN BOHEMIA, 2014-2022

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Summary

Background. This study analyzed long-term trends and gender differences in adolescent physical activity (PA) in Southern and Western Bohemia, the Czech Republic, between 2014 and 2022.

Material and methods. The study was conducted annually in 4 to 6 high schools. In total, 279 boys and 444 girls participated. Weekly PA was assessed using pedometers and Garmin Vivofit devices. In the analysis of weekly PA, a comparison was made between the number of steps taken on individual days of the week.

Results. Girls showed significantly lower PA levels than boys on school days ($F_{(1,709)}$=13.34, p<0.001, ηp^2=0.018). Boys (12,431 steps) and girls (11,737 steps) had the highest average amount of steps/day on Friday. Significant year-to-year differences in PA were also observed ($F_{(6,709)}$=6.83, p<0.001, ηp^2=0.055). Only 54.1% of boys and 40.3% of girls met the recommended 11,000 steps per day (χ^2=13.16, p<0.001, r=0.135).

Conclusions. The findings raise concerns about the negative impact of the COVID-19 pandemic on adolescent PA, particularly among girls. The observed weekly PA structure highlights the need to promote PA among both sexes, especially on Mondays and weekends.

Keywords: motor activity, health behavior, COVID-19, pandemics, lifestyle

Introduction

Globally, adolescent physical activity (PA) levels remain insufficient, with long-term trends showing little improvement [1]. At the European level, the situation is similarly concerning, with low PA levels [2] and increasing sedentary behavior among adolescents [3]. Steene-Johannessen et al. [4] reported that two-thirds of European children and adolescents fail to meet PA recommendations, with sedentary time increasing with age.

Low PA levels are also evident in adolescents' poor adherence to global PA guidelines. Within the European Union, 82% of boys and 89% of girls fail to meet recommended PA levels. Similar trends are seen in Poland, where 84% of adolescents not participating in organized PA fail to meet the combined recommendations of 5 × 60 minutes of moderate-to-vigorous PA (MVPA) and 3 × 20 minutes of vigorous PA (VPA) [5]. In the Czech Republic, 79% of girls and 68% of boys fail to meet these recommendations [6].

Participation in organized PA is the strongest contributor to meeting PA recommendations among Polish adolescents [7]. A long-term decrease in achievement of the

11,000 steps/day recommendation between 2010 and 2017 was observed for Czech boys by 28 percentage points and for Czech girls by 18 percentage points [8]. The percentage of low active Czech boys (achieving less than 10,000 steps/day) increased from 45% in 2009-2010 to 62% (p<0.001) on weekend days and from 27% to 49% on weekdays in 2017-2018 (p<0.001). Similarly, the percentage of girls with low PA increased from 50% to 58.0% on weekend days (p=0.029) and on weekdays from 30% to 42% (p=0.006) [9]. Also noteworthy is that the recommendation of 11,000 steps/day was met by 32% of boys (31% of girls) with the highest depressive symptoms compared to 50% of boys (49% of girls) with the least depressive symptom [10].

Weekend days are particularly critical for adolescents in meeting PA guidelines, with screen time also increasing during these periods [11]. Furthermore, Mondays consistently showed the lowest PA levels during the school week [12], while Fridays exhibited the highest PA levels in both Czech and Polish adolescents [13]. These findings emphasize the need for comprehensive PA programs that address weekly PA distribution, including cooperation between schools and leisure/sports organizations.

The COVID-19 pandemic has further exacerbated the decline in adolescents' PA [14,15]. Significant reductions in light, moderate, and vigorous PA have been reported both globally and in Czech and Polish adolescents [16-18]. Similar declines have been documented in Slovenia through longitudinal PA monitoring [19].

While global evidence highlights these trends, regional differences within countries remain underexplored. Regional research can provide valuable insights to inform targeted interventions and contribute to broader national and international strategies [20,21].

Aim of the work

The aim of the study was to assess gender differences and temporal trends in weekly PA patterns among adolescents in Southern and Western Bohemia between 2014 and 2022.

This study addresses the following research questions:

- Can regional research provide relevant insights into adolescent PA trends in Southern and Western Bohemia?
- Are there regional and national differences in long-term PA trends among adolescent boys and girls?

– How have national COVID-19 pandemic restrictions affected adolescent PA at the regional level?

Material and methods

The socioecological model of health behavior is the theoretical background considering the PA research of adolescents in a specific regional setting, as well as the psychological feedback theory, which makes it possible to solve the issue of effective feedback when changing the movement behavior of adolescents [22].

Participants and procedure

The research was conducted annually in 4 to 6 high schools between 2014 and 2022. In 2020 and 2021, PA monitoring was carried out at a time when the educational process was least disrupted by the negative impacts of the COVID-19 pandemic. Schools were approached based on long-term cooperation with the University of West Bohemia. The schools were selected so that they were of the same type, approximately the same size and in a similar location, and considering the willingness of the school management to carry out research without disrupting the educational program in natural school settings.

A total of 279 boys and 444 girls participated in the research (Table l). At each school, two classes of students were randomly selected for research. 90% to 95% of students agreed to participate in the research at each school. The initial meeting with the students took place in the computer lab, due to the possibility of individual use of computers for records in the web application "International Database for Research and Educational Support" (Indares: www.indares.com). The management of all schools and interested teachers received information on ways to anonymize the obtained data (under the specified code).

Table 1. Sample characteristics

Gender	n	Age (years)		Weight (kg)		Height (cm)		BMI ($kg \cdot m^{-2}$)	
		M	SD	M	SD	M	SD	M	SD
Boys	279	16.8	1.8	70.1	11.2	178.0	8.6	22.1	2.9
Girls	444	17.1	1.7	60.1	9.7	167.3	6.8	21.4	3.0

Notes: M – mean, SD – standard deviation, BMI – Body Mass Index.

Measures

To monitor weekly PA, Digi-Walker SW-700 pedometers (Yamax Co., Yasama Corp., Tokyo, Japan) were used in 2014-2016, and Garmin Vívofit 1 or Garmin Vívofit 3 wearables were used in 2017-2022. Differences between types of Garmin Vívofit 1 and 3 wearables are not significant in the assessment of average steps/day [23,24]. As part of the weekly PA monitoring, the participants kept a record of the daily number of steps, which they then recorded in the Indares system. Participants were reminded to record the number of steps/days before midnight if they did not go to sleep before midnight. At least three school days and one weekend day were required to evaluate the number of weekly steps. Missing data on school days of the week were supplemented by the average of the entered data for individual participants. On weekend days, the missing data was supplemented with the completed weekend day. A minimum daily record of 1,000 steps/day and a maximum of 30,000 steps/day was required for inclusion in the summary results. 37 participants were excluded from the evaluation for not meeting the requirements. As a goal recommendation for daily PA, 11,000 steps/day was set in accordance with earlier research [4].

Data analysis

Statistical version 14 software (StatSoft, Prague, Czech Republic) was used for statistical analysis. Kolmogorov-Smirnov and Lilliefors tests were used to assess the characteristics of the set and the normality of the data. Differences in the amount of steps/day between boys and girls in individual years and individual days of the week were evaluated using repeated-measures ANOVA, with the Scheffe post-hoc test. Box's M test and Mauchly's sphericity test were used to determine whether the ANOVA assumptions were violated. Cross tables with Pearson's χ^2 were used to determine the differences in meeting the recommendation of 11,000 steps/day. For gender differences in days, a test of differences of two ratios was used. The η_p^2, η^2 and r effect size coefficients were evaluated as follows: $0.01 \leq \eta_p^2(\eta^2) < 0.06$ ($0.1 \leq r < 0.3$) small effect size, $0.06 \leq \eta_p^2(\eta^2) < 0.14$ ($0.3 \leq r < 0.5$) medium effect size, $\eta_p^2(\eta^2) \geq 0.14$ ($r \geq 0.5$) large effect size. Statistical significance was set at $\alpha<0.05$.

Results

Differences in the structure of boys' weekly physical activity according to individual years

The results confirmed significantly lower PA levels among girls compared to boys on school days ($F_{(1,709)}$=13.34, p<0.001, η_p^2=0.018) and a significant difference in PA in individual years ($F_{(6,709)}$=6.83, p<0.001, η_p^2=0.055) (Figures 1, 2). However, the differences according to gender, years, and days were not significant ($F_{(36,4254)}$=1.21, p=0.179, η_p^2=0.010).

Between the years 2014 and 2019 before the pandemic, there were significant differences in boys ($F_{(1,71)}$=4.26, p=0.043, η_p^2=0.057) and girls ($F_{(1,132)}$=10.78, p=0.001, η_p^2=0.075). Between the years 2014 (10,773 steps/day) and 2022, after the pandemic (8,790 steps/day), there was a significant difference in total PA in girls ($F_{(1,118)}$ = 10.85, p=0.001, η_p^2=0.084) only.

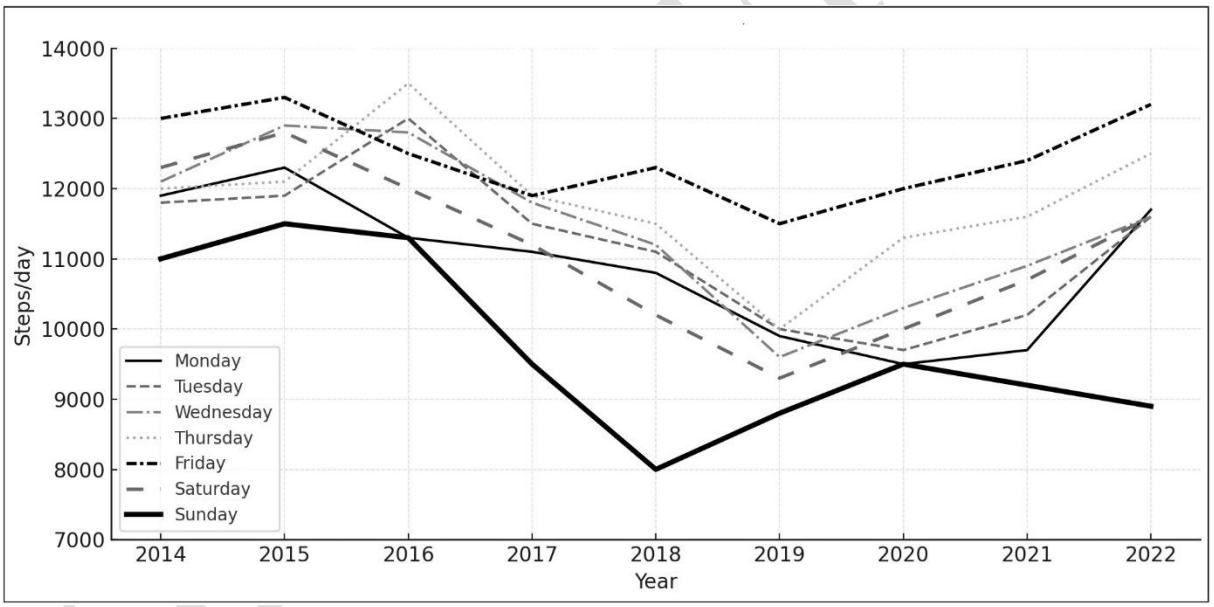

Figure 1. Boys' average daily steps from 2014 to 2022

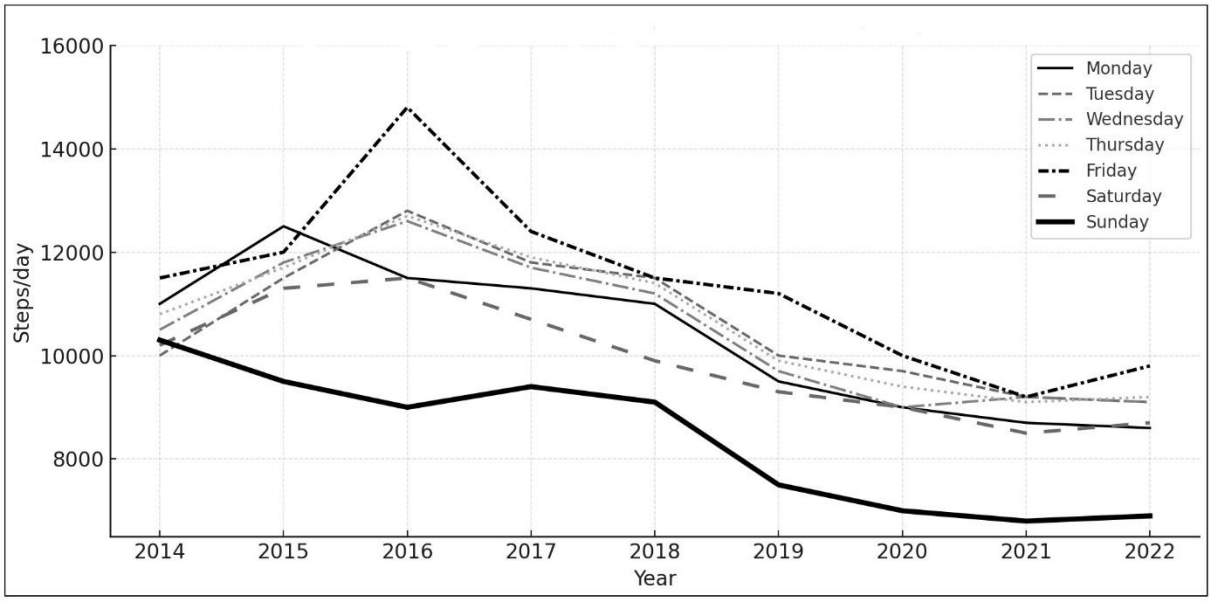

Figure 2. Girls' average daily steps from 2014 to 2022

Overall differences according to gender and days were not significant (Table 2). However, for girls, the differences between steps/day on Sunday versus other days of the week and for boys between Sunday and other days, except Monday and Tuesday, were significant. Boys and girls had the highest average amount of steps/day on Friday.

Table 2. Number of average steps/day of boys and girls on individual days of the week

Physical activity	Gender	Days							F	*p*	η_p^2
		Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday			
		M	M	M	M	M	M	M			
		SD	SD	SD	SD	SD	SD	SD			
Steps/day	Boys	10,984	11,415	11,489	12,012	12,431	11,493	9,855	0.84	0.536	0.001
		5,209	4,663	5,62	5,148	5,718	6,156	5,316			
	Girls	10,406	10,787	10,531	10,89	11,737	10,156	8,829			
		4,641	4,526	4,702	4,545	5,209	5,291	4,905			

Notes: M – mean, *SD* – standard deviation, *F* – ANOVA test, *p* – significance, η_p^2 – effect size coefficient.

Achievement of step-count recommendations for boys and girls according to individual years

In meeting the recommendation of 11,000 steps/day, there was a significant difference between 2014 and the pre-pandemic year 2019 for both boys and girls in steps/week and steps/weekend (Table 3). Between 2014 and 2022 (after the pandemic), there was a significant

difference in steps/week for girls and in steps/weekend for both girls and boys. The highest achievement of the 11,000 steps/day recommendation during the weekdays was shown by 70.7% of boys and 55.4% of girls in 2015, and on weekend days, 56.1% of boys in 2015 and 41.0% of girls in 2014. In total, only 54.1% of boys and 40.3% of girls met the recommendation of 11,000 steps/day (χ^2=13.16, p<0.001, r=0.135).

Table 3. Meeting the 11,000 steps/day recommendation on individual days of the week by time stages in girls and boys

Recommendation 11,000 steps/day	Gender	Years							χ^2	p	r
		2014	2015	2016	2017	2018	2019	2022			
Steps/week	Boys	66.7	70.7	60.4	53.5	40.9	39.1	52.0	14.41a	0.025	0.141*
	Girls	49.4	55.4	52.8	36.4	27.1	25.5	21.6	29.14a,b	<0.001	0.201*
Steps/school days	Boys	59.3	65.8.	60.4	46.5	45.5	45.6	52.0	7.03	0.318	0.099
	Girls	51.8	53.9	66.7	45.5	32.9	35.3	21.6	31.18	<0.001	0.208*
Steps/weekend days	Boys	55.6	56.1	52.8	44.2	36.4	23.9	36.0	14.80a,b	0.022	0.143*
	Girls	41.0	38.5	38.9	31.8	25.7	17.3	13.5	17.89a,b	0.007	0.157*

Notes: χ^2 – Pearson's chi-square, p – significance ($p \leq \alpha \leq 0.05$), r – effect size coefficient, *$0.1 \leq r < 0.3$ small effect size, a – significant difference between years 2014 and 2019, b – significant difference between years 2014 and 2022.

Achievement of physical activity recommendations by day of the week

No significant differences were observed between boys and girls in meeting the recommended 11,000 steps/day on school days (Figure 3). Only on weekend days did boys meet the recommendations significantly more than girls. On school days, there was also significant differences in the achievement of recommendations on Monday (45.2%) and on Friday (54.5%) for boys (p=0.009) and for girls on Monday (41.2%) and Friday (51.4%) (p=0.009).

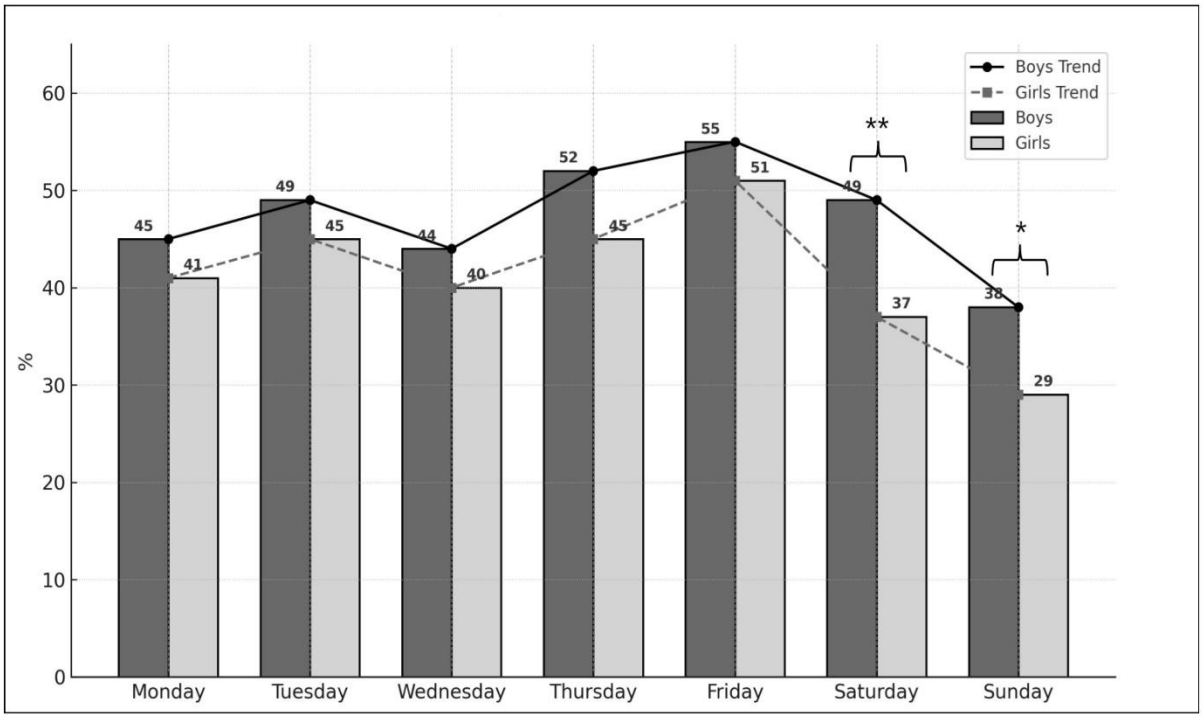

Figure 3. Meeting the recommendation of 11,000 steps/day for boys and girls each day
Notes: *α<0.5, **α<0.01.

Discussion

The most serious finding of the study was the decline in PA in boys and girls between 2014 and 2019 before the pandemic, which corresponds to the decline in adolescents' PA in the Czech Republic [9], Poland [25], or Sweden [26]. In contrast, between 2005 and 2018, there was no significant decrease in the moderate to vigorous PA (MVPA) of Norwegian children and adolescents when monitoring PA with an accelerometer [27]. Guthold et al. [1] indicated globally that between 2001 and 2016, a greater decline in PA was observed in boys than in girls.

Immediately after the pandemic restrictions in 2020, the decline in the number of steps/days continued in the region for girls but not for boys. In South Korean adolescent boys and girls, moderate and vigorous PA was significantly higher after the pandemic, but this compared to PA during the pandemic [28]. In Slovenian children and adolescents, physical fitness did not return to pre-pandemic levels [29]. Desine et al. [30] also noted a persistent decrease in the amount of steps/day in adults after the relaxation of restrictions in the USA.

Unfortunately, to date, there is insufficient global evidence on the level of the in-school and out-of-school PA of adolescents after the pandemic. Fragmentary research highlights a significant decline in PA among Czech and Polish adolescents [31]. It will be crucial to know

whether it is possible to restore or even increase participation in organized PA, which was one of the decisive factors of lower PA during the pandemic [7]. Furthermore, it is important that schools support those types of PA that adolescents consider useful as much as possible [32]. A specific finding of this study is that there was no decrease in the PA of boys immediately after entering the schools. Further research is needed to determine to what extent this finding was a unique response of boys to a significant decrease in opportunities to engage in PA during the pandemic.

The overall results of the study also confirmed less PA in girls compared to boys during school days, which is in line with global research [33], research on children and adolescents at the European level [4], and research in the Czech Republic and Poland [12]. The lowest PA of boys and girls on Sunday and, conversely, the highest PA on Friday coincide with the results of the weekly structure of PA in Czech [9] and Polish adolescents [12]. It emerges that in regional settings in Southern and Western Bohemia, especially in the critical post-pandemic period, it is necessary to solve the distribution of school PE during the week and to respect the greatest PA of adolescents on Fridays even in comprehensive school PA programs.

We consider the achievement of the recommendation of 11,000 steps/day by 54% of boys and 40% of girls to be positive even in this region. At the national level of the Czech Republic, Mitáš et al. [8] found that only 39% of boys and 42% of girls met the recommendation of 11,000 steps/day in 2016-2017. It remains unclear to what extent the higher step count among girls is related to the increase in Czech girls' preferences for tourism activities [6]. Gender differences in meeting the recommendation of 11,000 steps/day on weekend days are quite unique. The observation that boys are more active than girls on weekends warrants long-term monitoring of PA and analysis of boys' involvement in organized sports or the family environment or analysis of different gender preferences for PA.

It is possible to evaluate regional research on adolescent PA as beneficial for providing information to schools to support adolescent PA. School management found the use of technology in supporting their students' PA to be up-to-date and feedback on research results very stimulating. Multi-year monitoring of PA in the region has also highlighted declining levels of PA and a greater focus on schools to prepare for possible future negative restrictions by expanding online PE and home-based PA programs. Compared to national indicators, gender differences in PA after the pandemic appear to be specific to the region, but this requires further and longer-term PA research. Future research in the regions should focus on the expansion of PA level indicators, especially the monitoring of PA intensity and monitoring of 24-hour physical and sedentary behavior in adolescents.

Practice implications

- School administrators should, as far as possible, respect differences in PA between boys and girls on individual school days in the educational timetable.
- In order to respect school specifics in PA, it is desirable for schools to introduce comprehensive school physical activity programs.
- Schools should also intensify cooperation with leisure institutions to promote PA during the weekends.
- In the context of physical literacy, it is desirable to deepen knowledge about the positives and negatives of wearables for monitoring PA and other monitoring technologies.
- The use of feedback from wearables to support the implementation of PA recommendations should also be made more effective.
- Furthermore, it is important that schools support those types of PA that adolescents consider useful as much as possible.

Limitations of the research

A cross-sectional study with a smaller number of probands is limiting for the generalization of research results. It was not possible to implement PA monitoring on a representative set of participants in the region, especially due to the organizational requirements and school approvals. It was also necessary to adjust the PA monitoring schedule in years when the COVID-19 pandemic had a negative impact on the educational process. A limitation is also the fact that in individual years, it was not possible to carry out research in the same schools and in the same grades.

Conclusions

This study confirms concerns regarding the negative impact of the COVID-19 pandemic on adolescent PA, with girls particularly affected. The observed weekly PA patterns highlight the importance of promoting PA on Mondays and weekends for both sexes. Despite these challenges, adolescent PA levels in Southern and Western Bohemia are comparable to or exceed national and international benchmarks. These findings provide valuable insights for school

administrators and policymakers, supporting the development of regional strategies. Although the research was part of nationwide PA monitoring, great caution must be exercised when generalizing the study results to the entire region. However, the main contribution of the study is that it highlights the importance of respecting regional specifics when monitoring PA at the national or global level. Monitoring the specifics and trends in adolescents' physical behavior at the regional level can be an important contribution to addressing the issue of healthy lifestyles of adolescents at the national and international level.

Disclosures and acknowledgements

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Informed consent was obtained from all the individuals included in this study. The research related to human use was complied with all the relevant national regulations, institutional policies and in accordance the tenets of the Helsinki Declaration and was approved by the Ethics Committee of Faculty of Physical Culture, Palacký University Olomouc (No. 49/2019).

The authors declare that artificial intelligence (AI) tools provided by OpenAI were used to improve the formal and linguistic quality of this manuscript and for graphical editing. Specifically, AI was used for: initial linguistic proofreading and stylistic editing of the English text, preparing black-and-white and visually optimised versions of graphical outputs suitable for print publication. All the content, interpretations, and conclusions presented in this manuscript are solely the work of the authors and reflect their scientific expertise and interpretation of the results.

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