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Physical activity and sedentary behavior among adolescents in the Visegrad Group countries: a cross-country comparison

Ferdinand Salonna[1(A,B,C,D,E,F)], **Ján Junger**[1(A,B,E)], **Joanna Baj-Korpak**[2(A,B,C,E)], **Marian Jan Stelmach**[2(A,B,D,E)], **Alexandra Makai**[3(A,B,C,D,E)], **Viktória Prémusz**[3(A,B,C,D,E)], **Zuzana Kuchelová**[1(B,E)], **Ľuboš Vojtaško**[4(B)], **Valérie Tóthová**[5(A,B)], **Pongrács Ács**[1(A,D)]

[1]Pavol Jozef Šafárik University in Košice, Slovakia

[2]John Paul II University in Biała Podlaska, Poland

[3]University of Pécs, Hungary

[4]Technical University in Košice, Slovakia

[5]University of South Bohemia in České Budějovice, Czech Republic

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Address for correspondence: Ferdinand Salonna, Pavol Jozef Šafárik University in Košice, Ondavská 21, 040 11 Košice, Slovakia, e-mail: ferdinand.salonna@gmail.com

ORCID: Ferdinand Salonna https://orcid.org/0000-0002-1597-5770, Ján Junger https://orcid.org/0000-0002-9672-653X, Joanna Baj-Korpak https://orcid.org/0000-0002-6379-2485, Marian Jan Stelmach https://orcid.org/0000-0002-4323-2333, Alexandra Makai https://orcid.org/0000-0002-1907-120X, Viktória Prémusz https://orcid.org/0000-0002-4059-104X, Zuzana Kuchelová https://orcid.org/0000-0002-5017-7117, Ľuboš Vojtaško https://orcid.org/0000-0003-3835-0463, Valérie Tóthová https://orcid.org/0000-0002-7119-8419, Pongrác Ács https://orcid.org/0000-0002-4999-7345

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Abstract

Background. Physical activity levels among adolescents in Central Europe vary substantially by gender and national context, yet comparative analyses across multiple activity domains remain limited. This study examined gender and country differences in domain-specific physical activity and sedentary behavior among adolescents from the Czech Republic, Hungary, Poland, and Slovakia.

Material and methods. Data were collected between March and May 2025 using the International Physical Activity Questionnaire (long form). A total of 2,006 students provided valid physical activity data. Mann-Whitney U and Kruskal-Wallis tests were used to compare gender and country differences, with effect sizes expressed as r and η^2.

Results. Boys were generally more active than girls, particularly in school/work-related, leisure-time, and total physical activity, while girls accumulated more weekday sitting time. Cross-country differences were found, especially among females. Polish adolescents displayed the highest activity levels across several IPAQ domains, whereas Slovak adolescents consistently reported the lowest levels, particularly in transport-related and active transport activity. Sedentary behavior showed fewer cross-country differences, with notable variation only among girls.

Conclusions. These findings highlight substantial gender- and country-specific disparities in adolescent movement behavior across Central Europe. Tailored, context-sensitive interventions and policies are needed to promote physical activity and reduce sedentary time in this population.

Keywords: sedentary behavior, Central Europe, gender differences, physical activity, adolescents

Introduction

Regular physical activity is a key determinant of physical and mental health across all stages of life [1]. Evidence shows that engaging in adequate moderate-to-vigorous activity reduces the risk of chronic conditions such as cardiovascular disease, type 2 diabetes, obesity, and several forms of cancer [2]. In adolescents, physical activity supports healthy growth and development, enhances cardiorespiratory and muscular fitness, and contributes to improved cognitive functioning and academic performance [3,4]. It also plays an essential role in mental well-being, with studies reporting reduced symptoms of depression, anxiety, and stress among more active youth [5]. Given these wide-ranging benefits, promoting physical activity in adolescence is considered a critical public health priority [6].

In Central Europe, and particularly within the Visegrad Group (V4) countries (the Czech Republic, Hungary, Poland, and Slovakia), adolescent physical activity patterns have become a growing public health concern. Although all four countries participate in large international surveillance systems such as HBSC, the available data typically rely on single-item or short physical activity indicators, offering only limited insight into domain-specific or context-specific behavior [7,8].

Furthermore, chronic insufficient physical activity remains a critical public health issue, with patterns observed in the Central European context aligning with global trends [9]. Evidence consistently indicates that a higher proportion of boys achieve recommended physical activity levels compared to girls, underscoring the need for comprehensive strategies aimed at increasing overall youth engagement in sports and exercise.

Coordinated research conducted across the Visegrad region has generated comprehensive evidence on youth physical activity patterns [10]. Comparative analyses indicate that young people in the four countries typically achieve insufficient levels of physical activity, with substantial gender differences, whereby boys report higher levels of moderate-to-vigorous physical activity than girls [11,12]. High levels of sedentary behavior have also been reported across all V4 countries, affecting both secondary-school and university students and frequently co-occurring with low physical activity levels [13]. Further evidence suggests a clear association between body weight and physical activity, with overweight and obese adolescents in the V4 region reporting significantly lower physical activity than their normal-weight peers [14]. Additionally, notable disparities between countries have been documented, highlighting

the importance of social and environmental factors, such as access to facilities and cultural attitudes towards sport, in shaping physical activity levels [15].

According to review focused on physical activity in the Visegrad region from 2021, the need for enhanced physical activity among adolescents is pressing, as the prevalence of insufficient physical activity is alarming across the Visegrad countries. For instance, girls consistently reported lower engagement in physical activities compared to boys, underscoring persistent gender disparities that affect exercise participation. In Hungary, approximately 85.8% of girls did not meet the recommended levels of physical activity, while the figures for Poland, the Czech Republic, and Slovakia were similarly high, with 84.2%, 82.0%, and 77.8%, respectively, of girls reporting insufficient activity. Such results imply a clear need for targeted interventions to promote physical activity, especially among girls [16].

A more recent study compared physical activity levels post-COVID-19 pandemic across the Czech Republic, Slovakia, and Poland. This study specifically highlighted differences in metabolic equivalent (MET) minutes per week, revealing Slovakia's adolescents as the most active, followed by those in the Czech Republic and Poland. The post hoc analysis indicated significant differences in activity levels among these countries, informing potential regional policy initiatives aimed at enhancing youth engagement in physical activities post-pandemic [17].

Aim of the work

Although earlier research provided an important foundation for understanding youth movement behavior in Central Europe, most available studies from the Visegrad region were conducted more than five years ago, and some date back nearly a decade. As a result, the region still lacks recent, harmonized evidence that captures the current patterns of adolescent physical activity across multiple behavioral domains. This creates a persisting monitoring gap and underscores the need for updated, standardized comparisons across the Czech Republic, Hungary, Poland, and Slovakia.

In response to this gap, the present study aimed to generate a contemporary, multi-domain assessment of adolescent physical activity and sedentary behavior in the four Visegrad countries, using unified IPAQ-based methodology and consistent data-collection procedures.

By examining gender and country differences across school/work-related, transport, household, leisure-time, total physical activity, and sitting time, the study provides new, comparable evidence that can support targeted public health actions in the region.

Material and methods

Study design and setting

This cross-sectional study was conducted between March and May 2025 among adolescents from four Central European countries: the Czech Republic, Hungary, Poland, and Slovakia. Data collection was carried out within the framework project titled "Physical Activity Patterns Among High School and University Students in the V4 Countries – a Comparative Study", which examines adolescent physical activity and contextual factors using harmonized protocols. Participating sites included secondary schools located in four municipalities corresponding to the collaborating academic institutions: University of Pécs (Hungary), John Paul II University in Biała Podlaska (Poland), Pavol Jozef Šafárik University in Košice (Slovakia), and University of South Bohemia in České Budějovice (the Czech Republic). Schools were randomly selected within these municipalities to ensure a diverse representation of students. Data were collected during regular school lessons, with students completing the questionnaire in a supervised classroom environment using standardized procedures across all participating sites.

Participants

A total of 2,006 secondary school students participated in the study, with a mean age of 17.03 years (SD=1.37; age range: 14-18 years). The sample included 1,379 females (mean age 17.01; SD 1.34; age range: 14-18 years) and 627 males (mean age 17.07; SD 1.43; age range: 14-18 years). The participants attended vocational schools (27.4%), grammar schools (44.0%), and technical/specialized secondary schools (28.6%), of which 1.0% were sports schools. Most participants were classified as having a normal BMI (76.9%), while 3.9% were underweight, 9.8% overweight, and 9.4% obese (Table 1). Individuals were eligible if they were enrolled in secondary school and provided complete IPAQ data. Missing or inconsistent entries were handled according to IPAQ scoring guidelines.

Table 1. Age and BMI classification of adolescents by gender and country

Variables		N	Age		Underweight		Normal		Overweight		Obese	
			Mean	SD	N	%	N	%	N	%	N	%
Total		2006	17.03	1.365	79	3.9	1542	76.9	196	9.8	189	9.4
Females	**Total**	1379	17.01	1.336	57	4.1	1081	78.4	115	8.3	126	9.1
	Czech Republic	296	17.13	1.249	10	3.4	232	78.4	32	10.8	22	7.4
	Hungary	473	17.2	1.243	11	2.3	347	73.4	45	9.5	70	14.8
	Poland	197	16.42	1.120	10	5.1	170	86.3	9	4.6	8	4.1
	Slovakia	413	17	1.506	26	6.3	332	80.4	29	7.0	26	6.3
Males	**Total**	627	17.07	1.426	22	3.5	461	73.5	81	12.9	63	10.0
	Czech Republic	123	17.77	1.390	1	0.8	89	72.4	16	13.0	17	13.8
	Hungary	130	17.11	1.495	3	2.3	103	79.2	11	8.5	13	10.0
	Poland	129	16.34	1.100	9	7.0	95	73.6	19	14.7	6	4.7
	Slovakia	245	17.08	1.380	9	3.7	174	71.0	35	14.3	27	11.0

Notes: BMI categories were derived from age- and gender-specific international cut-offs. Percentages refer to the proportion of participants within each BMI category. Age is presented as mean and standard deviation (SD). Total values represent combined samples across all four participating countries (the Czech Republic, Hungary, Poland, Slovakia).

Measures

Physical activity was assessed using the International Physical Activity Questionnaire (IPAQ, long form). Students reported the duration and frequency of activities across all standard IPAQ domains, and weekly energy expenditure was calculated in MET-minutes per week according to official scoring guidelines. Sedentary behavior was measured using two items capturing average daily sitting time on weekdays and weekends. All responses were screened and processed following IPAQ data-cleaning recommendations.

Statistical analysis

Descriptive statistics included median, mean, and mean rank for each domain. Gender differences were examined using the Mann-Whitney U test, given the non-normal distribution of IPAQ data. Effect sizes were expressed as $r = |Z| / \sqrt{N}$. Country differences (the Czech Republic, Hungary, Poland, Slovakia) were analyzed using the Kruskal-Wallis test, with effect sizes calculated using $\eta^2 = (H - k + 1) / (N - 1)$, where $k = 4$ groups. A significance level of

$p<0.05$ was applied. The collected data were analyzed using IBM SPSS Statistics version 29.0 (IBM Corp., Armonk, NY, USA).

Results

Gender comparison

The comparison of physical activity levels between female and male adolescents revealed statistically significant differences; however, the observed effect sizes were generally small, indicating modest gender-related differences rather than pronounced patterns (Table 2). Overall, boys accumulated more weekly physical activity than girls, driven largely by higher recreation, sport, and leisure participation. Median weekly leisure-time activity among boys was 522 MET-min/week compared with 420 MET-min/week in girls, a difference that was statistically significant ($p=0.002$) and represented the largest gender discrepancy in the dataset. Boys also reported higher total physical activity, with a median of 2,790 MET-min/week versus 2,575 MET-min/week in girls ($p=0.013$). School/work-related activity was likewise higher among boys (920 vs. 800 MET-min/week; $p=0.018$), although the effect size remained small. In contrast, transport-related physical activity and active transport did not differ significantly by gender, and median values were very similar (780 vs. 780 MET-min/week for transport physical activity; 360 vs. 350 MET-min/week for active transport), suggesting comparable mobility patterns for commuting among adolescent boys and girls. Household-related activity showed a tendency toward higher values in males (322 vs. 270 MET-min/week), but the difference was not significant ($p=0.190$). Patterns in sedentary behavior differed by gender: girls reported substantially more weekday sitting time than boys (median 420 vs. 360 minutes/day; $p<0.001$), representing the strongest gender effect across all variables. Weekend sitting time, however, did not differ between boys and girls (median 300 minutes/day for both; $p=0.203$). Overall, the results indicate that boys reported higher levels of leisure-time and total physical activity. Regarding sedentary behavior, higher weekday sitting time was observed among girls.

Table 2. Gender comparison of IPAQ domains and sitting time among adolescents

IPAQ domain	Total			Females			Males			Z	*p*	r
	N	Median	Mean	Median	Mean	MR	Median	Mean	MR			
School/ work-related PA	2006	840	985.3	800	953	982.8	920	1056.2	1048.9	-2.37	0.018	0.053
Transport PA	2006	780	927.8	780	913.7	998.4	780	958.9	1014.6	-0.579	0.562	0.013
Active transport	2006	358	476.5	350	461.5	1000.9	360	509.6	1009.1	-0.293	0.769	0.007
Household PA	2006	285	547.3	270	518.8	992.1	322	609.8	1028.6	-1.312	0.190	0.029
Recreation/ leisure PA	2006	420	630.9	420	581.6	976	522	739.3	1063.9	-3.155	0.002	0.07
Total PA	2006	2629	3091.3	2575	2967.2	981.9	2790	3364.2	1050.9	-2.471	0.013	0.055
Sitting weekday	1864	405	387.3	420	400	968.3	360	361	858.0	-4.147	<0.001	0.096
Sitting weekend	1898	300	318.4	300	320.1	960.4	300	314.9	926.1	-1.272	0.203	0.029

Notes: MR – Mean Rank; PA – physical activity; *Z* – Mann-Whitney test statistic; r – Effect Size; r = |Z| / √N; PA is reported in MET-min/week; sitting variables are reported in minutes/day.

Country comparison – females

Among female adolescents, levels of physical activity varied markedly across the four participating countries, as shown in Table 3. Polish girls consistently showed the highest activity levels in several domains, particularly in school/work-related (median 960 MET-min/week, mean rank 779.7) and transport-related physical activity (median 890 MET-min/week, mean rank 740.9), where they surpassed their peers from the Czech Republic, Hungary, and Slovakia. In contrast, Slovak girls generally reported the lowest physical activity levels, especially in transport physical activity (median 540 MET-min/week, mean rank 568.8) and active transport, where their median of 135 MET-min/week was far below that of the other countries. Active transport was the domain with the most pronounced cross-country difference ($H=132.49$, $p<0.001$), driven by very low levels in Slovakia compared with consistently higher values elsewhere. Leisure-time activity also showed meaningful variation: Polish girls again reported the highest levels (median 450 MET-min/week), whereas Slovak girls displayed much lower participation (median 315 MET-min/week), reflected in significantly different mean ranks (709.3 vs. 603.9). Total physical activity followed a similar pattern, with Polish girls accumulating more weekly activity overall (median 2,930 MET-min/week, mean rank 766.0),

while Slovak girls reported substantially lower totals (median 1,950 MET-min/week). Sitting behavior, by contrast, showed a different pattern. Slovak and Hungarian girls reported higher weekday and weekend sitting times than their Czech and Polish counterparts, and the differences were statistically significant (weekday H=20.59, weekend H=39.10; both $p<0.001$). Taken together, these findings highlight cross-country contrasts among girls, with Poland tending toward the most active profile and Slovakia consistently showing the lowest activity across several key IPAQ domains.

Table 3. IPAQ-based physical activity domains across the V4 countries in females

IPAQ domain	Total			Czech Republic			Hungary			Poland			Slovakia			H	*p*	η²
	N	Median	Mean	Median	Mean	MR	Median	Mean	MR	Median	Mean	MR	Median	Mean	MR			
School/work-related PA	1379	800	953	840	957.4	694.8	810	949.7	699.8	960	1150.3	779.7	680	859.7	632.6	18.914	<0.001	0.011
Transport PA	1379	780	913.7	955	1053.3	785.3	810	931.3	715.0	890	992.2	740.9	540	756	568.8	60.324	<0.001	0.042
Active transport	1379	350	461.5	420	530.5	770.2	420	507.6	763.3	473	567.6	787.9	135	308.6	501.8	132.491	<0.001	0.095
Household PA	1379	270	518.8	385	607	753.9	300	529.5	697.0	340	616.7	754.4	180	396.8	605.4	31.587	<0.001	0.021
Recreation/leisure PA	1379	420	581.6	540	664.7	771.1	420	590.3	706.4	450	637.2	709.3	315	485.6	604.0	32.833	<0.001	0.022
Total PA	1379	2575	2967.2	3029	3282.5	765.8	2660	3000.7	708.5	2930	3396.4	766.0	1950	2498	578.2	51.457	<0.001	0.035
Sitting weekday	1259	420	400	380	388.1	595.1	420	411.9	665.3	360	357.6	539.1	420	416.1	661.6	20.587	<0.001	0.014
Sitting weekend	1294	300	320.1	240	271.9	559.5	300	303.7	617.9	360	370.3	741.7	300	352.3	704.7	39.095	<0.001	0.028

Notes: MR – Mean Rank; physical activity – PA; PA is reported in MET-min/week; sitting variables are reported in minutes/day; H – Kruskal-Wallis statistic; *p* – two-tailed significance; η^2 – effect size; $\eta^2 = (H - 3) / (N - 1)$.

Country comparison – males

Among male adolescents, cross-country differences were also evident, though generally smaller in magnitude than among females. Polish boys were the most active group across several domains, most notably in school/work-related activity (median 1,157 MET-min/week, mean rank 368.6) and total physical activity (median 3,630 MET-min/week), where they exceeded their peers from the Czech Republic, Hungary, and Slovakia. Active transport showed the strongest country effect among boys (H=45.78, $p<0.001$), with Polish boys again reporting the highest values (median 480 MET-min/week) and Slovak boys the lowest (median 180 MET-min/week), mirroring the pattern observed among girls. Transport-related physical activity also differed significantly across countries (H=18.95, $p<0.001$), with Czech boys showing relatively high medians (880 MET-min/week) while Slovak boys reported lower levels (660 MET-min/week). Leisure-time physical activity followed the same pattern, with Polish boys (median 660 MET-min/week) more active than those in other countries, particularly Slovak boys (median 450 MET-min/week). In most physical activity domains, Hungary and the Czech Republic typically occupied intermediate positions between Poland and Slovakia. Sedentary behavior showed minimal variation across countries: neither weekday nor weekend sitting time differed significantly among boys ($p=0.434$ and $p=0.729$, respectively), and medians were nearly identical across settings. Overall, Polish boys tended to have the highest activity across domains, Slovak boys the lowest, and Czech and Hungarian boys were clustered in the middle, with only modest differences in sedentary time (Table 4).

Table 4. IPAQ-based physical activity domains across V4 countries in males

IPAQ domain	Total			Czech Republic			Hungary			Poland			Slovakia			H	*p*	η^2
	N	Median	Mean	Median	Mean	MR	Median	Mean	MR	Median	Mean	MR	Median	Mean	MR			
School/work-related PA	627	920	1056.2	900	986.7	301.1	813	961.4	293.9	1157	1304.5	368.6	830	1010.7	302.4	14.954	0.002	0.019
Transport PA	627	780	958.9	880	1081.7	346.5	735	914.3	313.4	920	1101.6	351.4	660	845.8	278.3	18.954	<0.001	0.025
Active transport	627	360	509.6	400	583.1	348.7	360	492.3	329.2	480	688.1	375.9	180	387.8	255.9	45.78	<0.001	0.068
Household PA	627	322	609.8	300	549.6	311.3	248	484.2	282.1	480	683.3	359.3	300	667.9	308.5	12.357	0.006	0.015
Recreation/leisure PA	627	522	739.3	480	726.1	311.4	480	693.4	312.5	660	898.7	351.7	450	686.3	296.3	7.969	0.047	0.009
Total PA	627	2790	3364.2	3050	3344	325.2	2400	3053.2	296.8	3630	3988.1	361.4	2467	3210.7	292.6	13.92	0.003	0.017
Sitting weekday	605	360	361	390	370.5	311.2	360	366.6	309.8	300	339.1	280.3	360	364.9	307.5	2.738	0.434	0.003
Sitting weekend	604	300	314.9	300	338.5	312.2	270	306.3	291.4	300	306.2	295.0	300	312	307.4	1.3	0.729	0

Notes: MR – Mean Rank; physical activity – PA; PA is reported in MET-min/week; sitting variables are reported in minutes/day; H – Kruskal-Wallis statistic; *p* – two-tailed significance; η^2 – effect size; $\eta^2 = (H - 3) / (N - 1)$.

Discussion

This study provides the most recent harmonized comparison of adolescent physical activity and sedentary behavior across the Visegrad region and directly addresses the monitoring gap identified in prior research [10].

In our dataset, clear gender disparities in physical activity were observed, with boys accumulating more total and leisure-time physical activity than girls, with the largest differences evident in the recreation and sport domain. These findings are consistent with earlier reports from Central Europe and long-standing patterns documented in HBSC surveillance and other V4 studies, which similarly reported higher moderate-to-vigorous physical activity among boys and persistently lower engagement among girls [15,17-19]. Together, this reinforces previous observations that adolescent girls remain a key target group for physical activity interventions [17], supported by HBSC evidence demonstrating that active commuting to school, especially cycling, is associated with significantly lower levels of somatic and psychological health complaints, underscoring the health relevance of interventions promoting everyday physical activity [19]. In parallel, long-term HBSC trend analyses demonstrate that opportunities for integrating physical activity into daily routines, such as active transport to school, have been steadily diminishing over time, further strengthening the case for targeted, routine-based interventions [20].

Our study confirms and more clearly quantifies cross-country differences previously reported in the V4 region. Consistent with previous regional observations, Polish adolescents in our sample showed the highest levels of physical activity across several domains, whereas Slovak adolescents were the least active, especially in transport-related and active transport activity. These patterns mirror previous findings from V4 and international studies, which have repeatedly reported higher overall activity levels among Polish youth and comparatively lower engagement in active transport and daily movement among Slovak adolescents, underscoring the persistence of country-specific differences in physical activity behavior [10,21]. By providing harmonized, domain-specific data for all four countries, this study extends earlier V4 research, which typically reported low overall activity but did not offer comparable multi-domain analyses. The particularly low levels of active transport observed among Slovak youth represent a notable and previously underreported finding that warrants further attention.

Our results showed that girls demonstrated substantially higher weekday sitting time, while weekend sitting time showed little gender difference. The gender differences in sedentary

behavior patterns identified in our study are consistent with earlier findings from the Visegrad region. Prior research reported that adolescent girls tend to accumulate more sedentary time than boys and that this imbalance coexists with lower physical activity in girls [18,22]. Similar trends were also described by Šimůnek et al., who found high levels of sitting among Czech and Slovak adolescents, with girls spending more time in sedentary activities than boys [13]. Junger et al. similarly observed that sedentary behavior was prevalent across V4 youth and showed weaker country-level variation compared with physical activity indicators [23].

In our findings, boys in the Visegrad countries accumulated more total and leisure-time activity than girls, whereas girls reported higher sedentary time during school days. These patterns are broadly consistent with international evidence on adolescent physical activity. Global surveillance data, including the WHO reports and repeated HBSC cycles, consistently show that the majority of adolescents worldwide do not meet recommended levels of moderate-to-vigorous physical activity, with girls being less active than boys in nearly all regions [6,24-26].

Cross-country differences within the V4 region also reflect broader international variation reported in large multinational datasets. International comparisons frequently demonstrate that active transport, recreation, and sport participation differ substantially between countries, influenced by cultural norms, school policies, and the built environment [2]. The markedly lower active transport levels observed among Slovak adolescents, compared with their peers in the Czech Republic, Hungary, and Poland, align with global observations that walking and cycling to school are highly context-dependent and vary widely across settings [6,25]. Recent school-based evidence from the Czech Republic and Poland further indicates a significant post-pandemic decline in transport-related physical activity to and from school, suggesting that disruptions of school-day routines may have contributed to persistently lower levels of active commuting in some countries [27]. These differences are further contextualized by long-term HBSC evidence showing a substantial decline in active school transport over the past two decades. For example, nationally representative HBSC data from Czech adolescents indicate that the prevalence of walking or cycling to school declined by more than 15 percentage points between 2006 and 2022, suggesting that the low levels of active transport observed in some V4 countries may reflect longer-term structural trends rather than short-term behavioral change [20].

Overall, the present results fit within the established international picture of low global adolescent activity, persistent gender inequalities, and strong environmental influences on movement behaviors, while providing new region-specific evidence for Central Europe.

Our study has several strengths and limitations that need to be acknowledged when interpreting the results. One important limitation is related to the sampling strategy. The study sample was drawn from selected secondary schools located in four university cities and is therefore not nationally representative. Consequently, the generalizability of the findings to the national adolescent population may be limited, particularly for students attending schools in non-university cities or rural areas.

Another limitation is the cross-sectional design of the study, which does not allow causal inferences to be drawn. In addition, physical activity and sedentary behavior were assessed using the self-reported IPAQ-LF. Self-reported measures are subject to recall bias and may lead to overestimation of physical activity levels, particularly in older adolescents. Furthermore, sedentary behavior assessment using the IPAQ-LF was based on overall sitting time on weekdays and weekends, which does not allow for differentiation between specific sedentary activities (e.g. screen-based, educational, or leisure-time sitting).

Finally, the gender imbalance in the sample, with a higher proportion of female participants, should be considered when interpreting gender-specific findings.

A key strength is the use of a harmonized methodological approach across all four Visegrad countries, which enabled direct cross-country comparisons of adolescent physical activity within a single analytical framework. Unlike much of the earlier V4 research, which often relied on country-specific analyses or aggregated indicators, this study provides domain-specific insights into total, leisure-time, and transport-related physical activity, allowing for a more nuanced interpretation of movement behaviors.

Another strength is the focus on multiple physical activity domains, which strengthens the interpretation of gender- and country-level differences by identifying where disparities are most pronounced. By situating the findings within established HBSC and international surveillance evidence, this study contributes updated, region-specific data that help to address the documented monitoring gap in Central Europe and provide a relevant evidence base for targeted public health and school-based interventions.

Conclusions

This study aimed to provide an updated, harmonized comparison of physical activity and sedentary behavior among adolescents in the four Visegrad countries and to examine how these patterns differ by gender and country. The findings show gender differences: boys engaged in more total and leisure-time physical activity, while girls accumulated substantially more weekday sitting time. A marked cross-country variation was also observed, particularly among girls, with Polish adolescents reporting the highest levels of activity across several domains, and Slovak adolescents the lowest. Among boys, the differences between countries were smaller but followed a similar pattern. Sedentary behavior showed limited variation across countries, indicating that sitting time is a widespread issue in the region regardless of national context.

Taken together, the results highlight inequalities in adolescent movement behavior within the Visegrad region and emphasize the need for targeted, context-specific strategies to support physical activity and reduce sedentary time, particularly for girls and for adolescents in countries with the lowest reported activity levels.

Disclosures and acknowledgements

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References:

1. Guthold R, Stevens GA, Riley LM, Bull FC. Global trends in insufficient physical activity among adolescents: a pooled analysis of 298 population-based surveys with 1·6 million participants. Lancet Child Adolesc Health. 2020; 4(1): 23-35. https://doi.org/10.1016/S2352-4642(19)30323-2
2. Liu L, Xin X, Zhang Y. The effects of physical exercise on cognitive function in adolescents: a systematic review and meta-analysis. Front Psychol. 2025; 16. https://doi.org/10.3389/fpsyg.2025.1556721
3. Wilhite K, Booker B, Huang BH, Antczak D, Corbett L, Parker P, et al. Combinations of physical activity, sedentary behavior, and sleep duration and their associations with physical, psychological, and educational outcomes in children and adolescents: a systematic review. Am J Epidemiol. 2023; 192(4): 665-679. https://doi.org/10.1093/aje/kwac212
4. Recchia F, Bernal JDK, Fong DY, Wong SHS, Chung PK, Chan DKC, et al. Physical Activity Interventions to Alleviate Depressive Symptoms in Children and Adolescents. JAMA Pediatr. 2023; 177(2): 132-140. https://doi.org/10.1001/jamapediatrics.2022.5090
5. Pinto AA, Marques APC, Pelegrini A. Secular trends in physical activity in adolescents: a systematic review. J Taibah Univ Med Sci. 2023; 18(2): 207-216. https://doi.org/10.1016/j.jtumed.2022.09.004
6. Inchley J, Currie D, Budisavljevic S, Torsheim T, Jåstad A, Cosma A, et al., editors. Spotlight on adolescent health and well-being. Findings from the 2017/2018 Health Behaviour in School-aged Children (HBSC) survey in Europe and Canada. International report. Volume 2. Key data. Copenhagen: WHO Regional Office for Europe; 2020.
7. Bucksch J, Sigmundova D, Hamrik Z, Troped PJ, Melkevik O, Ahluwalia N, et al. International trends in adolescent screen-time behaviors from 2002 to 2010. Journal of

Adolescent Health. 2016; 58(4): 417-425. https://doi.org/10.1016/j.jadohealth.2015.11.014

8. Frömel K, Mitáš J, Tudor-Locke C. time trends of step-determined physical activity among adolescents with different activity levels in Czech Republic. J Phys Act Health. 2022; 19(9): 592-598. https://doi.org/10.1123/jpah.2022-0205
9. Ács P, Niźnikowska E, Stelmach MJ, Weiner M, Makai A, Prémusz V, et al. Physical activity patterns among high school and university students in the V4 countries: a comparative study. Health Prob Civil. 2024; 18(4): 370-372. https://doi.org/10.5114/hpc.2024.144705
10. Bergier B, Bergier J, Niźnikowska E, Junger J, Salonna F, Ács P, et al. Differences in physical activity and nutrition and silhouette-related behaviours in male and female students in selected European countries. Ann Agric Environ Med. 2018; 25(1): 176-181. https://doi.org/10.26444/aaem/80988
11. Ács P, Bergier J, Salonna F, Junger J, Melczer C, Makai A. Gender differences in physical activity among secondary school students in the Visegrad countries (V4). Health Prob Civil. 2016; 10(3): 21-29. https://doi.org/10.5114/hpc.2016.61363
12. Šimůnek A, Frömel K, Salonna F, Bergier J, Junger J, Ács P. Sedentary behaviour and selected aspects of physical activity in students of secondary schools and universities. Tělesná kultura. 2018; 40(2): 105-111. https://doi.org/10.5507/tk.2016.011
13. Junger J, Salonna F, Bergier J, Junger A, Fromel K, Acs P, et al. Physical activity and Body-Mass-Index relation in secondary-school students of the Visegrad region. Journal of Physical Education and Sport. 2019; 19(Suppl. 1): 235-241. https://doi.org/10.7752/jpes.2019.s1035
14. Niznikowska E, Bergier J, Bergier B, Acs P, Junger J, Salonna F. Diversity of factors determining physical activity in youth in Visegrad countries. Balt J Health Phys Act. 2017; 9(2017): 125-134. https://doi.org/10.29359/BJHPA.09.4.10
15. Kantanista A, Tarnas J, Borowiec J, Elegańczyk-Kot H, Lubowiecki-Vikuk A, Marciniak M, et al. Physical activity of children and adolescents from the Czech Republic, Hungary, Poland, and Slovakia: a systematic review. Annals of Agricultural and Environmental Medicine. 2021; 28(3): 385-390. https://doi.org/10.26444/aaem/125557
16. Líška D, Rutkowski S, Oplatková L, Sýkora J, Pupiš M, Novák J, et al. Comparison of the level of physical activity after the COVID-19 pandemic in Poland, Slovakia and the

Czech Republic. BMC Sports Sci Med Rehabil. 2024; 16(47): 1-9. https://doi.org/10.1186/s13102-024-00833-5

17. Kalman M, Inchley J, Sigmundova D, Iannotti RJ, Tynjala JA, Hamrik Z, et al. Secular trends in moderate-to-vigorous physical activity in 32 countries from 2002 to 2010: a cross-national perspective. The European Journal of Public Health. 2015; 25(suppl. 2): 37-40. https://doi.org/10.1093/eurpub/ckv024
18. Bergier J, Niźnikowska E, Bergier B, Acs P, Salonna F, Junger J. Differences in physical activity, nutritional behaviours, and body silhouette concern among boys and girls from selected european countries. Human Movement. 2017; 18(1): 19-28. https://doi.org/10.1515/humo-2017-0009
19. Kleszczewska D, Mazur J, Bucksch J, Dzielska A, Brindley C, Michalska A. Active transport to school may reduce psychosomatic symptoms in school-aged children: data from nine countries. International Journal of Environmental Research and Public Health. 2020; 17(23): 8709. https://doi.org/10.3390/ijerph17238709
20. Vorlíček M, Sigmundová D, Baďura P, Dygrýn J, Kleszczewska D, Sigmund E. Active school transport among Czech adolescents declined between 2006 and 2022: HBSC study findings. 2025; 33(4): 267-272. https://doi.org/10.21101/cejph.a8713
21. Kantanista A, Osiński W. Physical activity of Poles – critical analysis of research 2010-2014. Annals of Agricultural and Environmental Medicine. 2014; 21(4): 839-843. https://doi.org/10.5604/12321966.1129944
22. Ács P, Bergier B, Bergier J, Niźnikowska E, Junger J, Salonna F. Students leisure time as a determinant of their physical activity at universities of the EU Visegrad group countries. Health Prob Civil. 2016; 10(4): 31-41. https://doi.org/10.5114/hpc.2016.63569
23. Junger J, Frömel K, Bergier J, Ács P, Bergier B, Salonna F, et al. Physical activity in students from the Visegrad countries by BMI status. Health Prob Civil. 2018; 12(1): 41-48. https://doi.org/10.5114/hpc.2018.74191
24. Bucksch J, Kopcakova J, Inchley J, Troped PJ, Sudeck G, Sigmundova D, et al. Associations between perceived social and physical environmental variables and physical activity and screen time among adolescents in four European countries. Int J Public Health. 2019; 64: 83-94. https://doi.org/10.1007/s00038-018-1172-9
25. Reilly JJ, Barnes J, Gonzalez S, Huang WY, Manyanga T, Tanaka C, et al. Recent secular trends in child and adolescent physical activity and sedentary behavior

internationally: analyses of active healthy kids global alliance Global Matrices 1.0 to 4.0. J Phys Act Health. 2022; 19(11): 729-736. https://doi.org/10.1123/jpah.2022-0312

26. Aubert S, Barnes JD, Demchenko I, Hawthorne M, Abdeta C, Nader PA, et al. Global Matrix 4.0 physical activity report card grades for children and adolescents: results and analyses from 57 countries. J Phys Act Health. 2022; 19(11): 700-728. https://doi.org/10.1123/jpah.2022-0456
27. Frömel K, Welk G, Groffik D, Jakubec L, Dygrýn J, Mitáš J. Adolescent physical activity during school days: a comparative study before and after COVID-19 pandemic restrictions. Front Public Health. 2025; 13. https://doi.org/10.3389/fpubh.2025.1488153