

POSTURE IN RELANTION TO BMI AMONG 10-YEAR-OLD PRIMARY SCHOOL PUPILS

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Abstract We are currently seeing an increase in poor posture and body weight. The aim of the study was to determine the relationship between proper posture and the Body Mass Index (BMI) among pupils in primary education. We applied ex post facto research. The study sample consisted of a total of n=559 pupils. We compared the groups of boys (n=127) and girls (n=138) from 2015 with the group of boys (n=143) and girls (n=151) studied in 2025 from 26 primary schools in the regions of Western and Central Slovakia. When assessing the overall posture in relation to the BMI of primary school girls in selected regions of Slovakia in 2015 and 2025, we found a significant increase in the BMI of 0.52, as well as a deterioration in overall posture by an average of 1.5 points. Among primary school boys from selected regions of Slovakia tested in 2025, we found a significant increase in the BMI of 0.88 compared to boys tested in 2015. These findings indicate that an elevated BMI negatively impacts overall posture in both boys and girls in primary schools in selected regions of Slovakia.

Key words: primary school, posture, BMI, musculoskeletal health, child development

Introduction

In Slovakia, over the past two decades, there has been an increasing trend in illnesses and health disorders among the school population. Bendíková (2020) points out an unfavourable situation in the area of postural health in the school population.

However, there is little longitudinal evidence showing how these trends have evolved over the past decade in Central European countries. The period 2015–2025 is particularly important, as it includes major changes in society, from the increase in the use of digital devices to the COVID-19 pandemic (2020–2021) which have significantly influenced children's physical activity levels and sedentary behaviours (Neville et al., 2022; Pfefferbaum, & Van Horn, 2022; Faust et al., 2024).

The school environment can pose a health risk for some pupils. Reduced physical activity due to sedentary behaviour and carrying school bags increase the risk of poor posture, a higher BMI, and rising obesity among pupils (Kabatová et al., 2012; Rozim et al., 2022; Hojker et al., 2023).

Correct posture in pupils depends on the spine, the body's axis that bends, rotates, and stretches. Its elementary function is precisely the support and holding of the body (Kabatová et al., 2012; Repko, 2017).

Spinal deformities have various forms and causes. They belong to groups of diseases that are often associated with a primary condition. Pupils in primary schools often avoid physical education classes (Arufe-Giráldez et al., 2022; Shimon, 2025). The absence of physically active role models among parents contributes to a large proportion of pupils having poor posture accompanied by pain. Up to 85% of cases of poor posture in youth in Slovakia are idiopathic scoliosis (Vojtaššák, 2000; Prieto-González et al., 2021).

Many postural problems begin during periods of growth and physical development (Bendíková, 2016; Desouzart, & Figueiras, 2023).

The biomechanical relationship between increased BMI and poor posture is well established: excess abdominal adipose tissue shifts the centre of gravity anteriorly, requiring compensatory postural adjustments in the kinetic chain (Calcaterra et al., 2022). In growing children, these compensatory mechanisms can become stable patterns, which can lead to structural changes in the developing musculoskeletal system over time.

Similarly, obesity represents a significant global health problem today. From a biological perspective, it is a metabolic disease with an excess of adipose tissue in the body, assessed according to the child's age, height, and sex.

In obese pupils, excessive fat mass leads to a reduction in coordination abilities and a decline in health-related fitness. Their ability to perform physical activity decreases (Cvejic, & Ostojić, 2018; Chen et al., 2018). Scientific studies in this area show that up to 80% of obese children become obese adults (Zhu, & Yin, 2023; Ng et al., 2024).

Despite the growing evidence on the relationship between obesity and posture, few studies have simultaneously examined the temporal trends of both indicators within the same population. This study addresses this gap by comparing BMI and postural quality in primary school children in Slovakia over a 10-year period (2015–2025).

Beyond its scientific relevance, the study is highly valuable for education and public health. Monitoring posture and BMI in schools provides key information for adapting physical education programs and identifying pupils at risk. For teachers, especially in physical education, the findings can guide interventions to prevent postural imbalances and promote an active lifestyle. At the public health level, understanding long-term trends in children's posture and weight supports preventive strategies, reduces musculoskeletal risks, and helps curb rising obesity rates among youth.

We hypothesized that: (1) BMI would be significantly higher in 2025 compared to 2015, (2) postural quality would be significantly lower in 2025, and (3) higher BMI would be correlated with poorer posture in both periods, with stronger associations in the obesity category.

The aim of the study was to expand knowledge about posture depending on the BMI in the school population of younger school-aged boys and girls. We compared the results of research on primary education pupils in 2015 and 2025. Highlights:

- Higher BMI is associated with poorer posture in 10-year-old pupils.
- Posture quality declined between 2015 and 2025 in Slovak primary schools.
- BMI increased significantly in both boys and girls over the 10-year period.
- Excess weight negatively affects musculoskeletal alignment in children.
- Findings highlight the need for school-based preventive interventions.

Material and Methods

Participants

The monitored sample consisted of a total of $n=559$ pupils. We compared groups of boys ($n=127$) and girls ($n=138$) diagnosed in 2015 with a group of boys ($n=143$) and girls ($n=151$) diagnosed in 2025 from 26 primary schools in the western and central regions of Slovakia.

Ethical Approval. This study was approved by the Ethics Committee of University CU (Decision No. CZ 03113/2025 RE, 04. September 2025).

The research and measurements were conducted in accordance with ethical principles of the Declaration of Helsinki as well as GDPR. All the participants, including school officials, teachers, parents and pupils, signed a consent to voluntarily participate in the research. This implies that the study only involved schools and pupils representative of the general population. Participants were not exempt from physical and sports education at school. Pupils with special educational needs, as defined by the Schools Act (No. 245/2008 Coll. in Slovakia), were excluded from the study. Furthermore, the sample only included pupils for whom complete data were available in accordance with the methodology section.

The average age of the research sample of boys and girls in 2015 was 10.49 ± 0.63 and 10.62 ± 0.51 years, respectively, and the average age of the research sample of boys and girls in 2025 was 10.64 ± 0.59 and 10.69 ± 0.56 years, respectively. The basic characteristics of the sample of boys and girls are presented in Tables 1 and 2.

Table 1. Basic Characteristics of the Sample of Boys from Selected Primary Schools in Western and Central Slovakia in 2015 and 2025

Sample	S.ch.	Posture [points]	BMI [index]	Height [cm]	Weight [kg]
Boys (2015)	n	127	127	127	127
	x	12.45	21.38	143.51	44.04
	SD	6.14	9.24	11.21	14.31
Boys (2025)	n	143	143	143	143
	x	14.65	22.26	148.02	48.78
	SD	7.41	8.61	10.74	16.74

Note. n – sample size, x – arithmetic mean, SD – standard deviation

Table 2. Basic Characteristics of the Sample of Girls from Selected Primary Schools in Western and Central Slovakia in 2015 and 2025

Sample	S.ch.	Posture [points]	BMI [index]	Height [cm]	Weight [kg]
Girls (2015)	n	138	138	138	138
	x	13.97	20.85	142.29	42.21
	SD	5.94	8.86	10.12	15.12
Girls (2025)	n	151	151	151	151
	x	15.47	21.37	148.23	46.96
	SD	7.05	9.41	11.94	16.13

Note. n – sample size, x – arithmetic mean, SD – standard deviation

Procedures

We applied an ex post facto research design. When comparing the average height (Tables 1 and 2) of the pupil research sample in 2015 (Boys=143.51cm; Girls=142.29 cm) and the pupil research sample in 2025 (Boys=148.02 cm; Girls=148.23 cm), we recorded an increase in average height of 4.51 cm (3.04%) for boys and 5.94 cm (4.01%) for girls.

When comparing the average weight of the pupil research sample in 2015 (Boys=44.04 kg; Girls=42.21 kg) and the pupil research sample in 2025 (Boys=48.78 kg; Girls=46.96 kg), we recorded an increase in average weight of 4.74 kg (9.71%) for boys and 4.75 kg (10.11%) for girls.

Comparing the average Body Mass Index of the pupil research sample in 2015 (Boys=21.38 index; Girls=20.85 index) and the pupil research sample in 2025 (Boys=22.26 index; Girls=21.37 index), we recorded an increase in the average Body Mass Index of 0.88 index (3.95 %) for boys and an increase of 0.52 index (2.43 %) for girls.

When comparing the average values of correct posture of the pupil research sample in 2015 (Boys=12.45 points; Girls=13.97 points) and the pupil research sample in 2025 (Boys=14.65 points; Girls=15.47 points), we recorded a deterioration in the average values of correct posture of 2.20 points (15.01 %) for boys and 1.50 points (9.69 %) for girls.

The main indicators we monitored in the research (correct posture and BMI) were compared with the values given for correct posture (Šeráková, 2006) and the BMI values divided into four bands (Tables 3 and 4). To assess the level of somatic indicators and the BMI of boys and girls, we used norms for the 10-year-old population of children in Slovakia (Ševčíková et al., 2004).

Table 3. Norms for Posture Assessment (Šeráková, 2006) and BMI for 10-year-old Girls in Slovakia

Posture (Šeráková, 2006)	Norm (posture)	Band	Norm (BMI)	BMI (Ševčíková et al.,2004)
5 points	Perfect posture	1st band	Underweight	≤2.7
6–10 points	Good posture	2st band	Ideal weight	12.8–17.2
11–15 points	Poor posture	3st band	Overweight	17.3–19.0
16–20 points	Incorrect posture	4st band	Obesity	19.1≥

Table 4. Norms for Posture Assessment (Šeráková, 2006) and BMI for 10-year-old Boys in Slovakia

Posture (Šeráková, 2006)	Norm (posture)	Band	Norm (BMI)	BMI (Ševčíková et al., 2004)
5 points	Perfect posture	1st band	Underweight	≤12.9
6–10 points	Good posture	2st band	Ideal weight	13.0–17.1
11–15 points	Poor posture	3st band	Overweight	17.2–19.0
16–20 points	Incorrect posture	4st band	Obesity	19.1≥

To assess the values of correct posture, we applied the standardized method according to Thomas – Klein modified by Mayer (Šeráková, 2006). The evaluation of the individual areas was expressed as the sum of points, each area being evaluated by points 1, 2, 3, and 4 according to the current level of body posture. We assessed the qualitative level of posture based on the points achieved: I. Correct body posture (5 points), II. Good (almost correct) body posture (6–10 points), III. Bad body posture (11–15 points), IV. Incorrect body posture (16–20 points).

The assessment of the musculoskeletal system was carried out in cooperation with a physiotherapist, who has more than 25 years of experience.

Data Analysis

For the verification of the obtained data, we used standardized measurement and testing methods applicable to school practice. In the processing and evaluation of the obtained data, we used basic methods of exploratory analysis: (n) frequency, (x) arithmetic mean, (s) standard deviation, (min.). In terms of normality of data distribution, the Kolmogorov-Smirnov test was used. The differences between the groups were evaluated using basic statistical methods and the statistical methods of Kruskal-Wallis H-test and Mann-Whitney U-test ($p < 0.05$)*. The effect size was evaluated as follows: Effect size r : $r = 0.10$ (small effect), $r = 0.30$ (medium effect), $r = 0.50$ (large effect). We formulated the findings and conclusions based on a logically sound evaluation of the obtained results. The statistical analyses were performed using MS Excel 2016, IBM SPSS 22, and JASP 0.16.4.0 software.

Results

When evaluating changes in posture, depending on the Body Mass Index (BMI) in primary education pupils from selected primary schools in Slovakia in 2015 and 2025, we divided the pupil samples into four bands based on the average BMI values.

We compared the correct posture of girls from selected primary schools in Slovakia in 2015 and the average Body Mass Index values (Table 5).

Table 5. Posture Assessment and BMI of Girls (2015) from Selected Primary Schools in Western and Central Slovakia

Girls 2015 (n=138)								
Zone	1st band (n=10)		2nd band (n=14)		3rd band (n=65)		4th band (n=49)	
Sample								
S.ch.	Posture	BMI	Posture	BMI	Posture	BMI	Posture	BMI
x	5.0	12.2	9.4	16.5	14.7	18.4	18.9	24.5
SD	-	4.57	3.54	5.28	5.34	6.37	6.49	8.58
test	p>0.05		p<0.05*		p<0.05*		p<0.05*	

Note. Posture [points], BMI - Body mass index, n – sample size, x – arithmetic mean, SD – standard deviation

Band 1 (underweight) included 10 girls (7.24 %) with an average BMI (M=12.2 index; SD=4.57) and an average correct posture score of (M=5.0 points). Band 2 (ideal weight) included 14 girls (10.14 %) with average BMI values (M=16.5 index; SD=5.28) and their average correct posture score was (M=9.4 points; SD=3.54), which were statistically significant at the 0.05 significance level ($r=0.619$ – large effect). Band 3 (overweight) included 65 girls (47.12 %) with average BMI values (M=18.4 index; SD=6.37) and their average correct posture score was (M=14.7 points; SD=5.34), which were statistically significant at the 0.05 significance level ($r=0.300$ – medium effect).

Band 4 (obesity) included 49 girls (35.50 %) with average BMI values (M=24.5 index; SD=8.58) and their average correct posture score was (M=18.9 points; SD=6.49), which were statistically significant at the 0.05 significance level ($r=0.345$ – medium effect).

In 2025, we repeatedly evaluated the correct posture of girls from selected primary schools in Slovakia and the average BMI values (Table 6).

Table 6. Posture Assessment and BMI of Girls (2025) from Selected Primary Schools in Western and Central Slovakia

Girls 2025 (n=151)								
Zone	1st band (n=7)		2nd band (n=19)		3rd band (n=67)		4th band (n=58)	
Sample								
S.ch.	Posture	BMI	Posture	BMI	Posture	BMI	Posture	BMI
x	5.0	12.6	9.9	17.0	14.6	18.9	19.4	25.7
SD	-	5.49	4.23	6.24	4.21	4.42	5.28	9.53
test	p>0.05		p<0.05*		p<0.05*		p<0.05*	

Note. Posture [points], BMI - Body mass index, n – sample size, x – arithmetic mean, SD – standard deviation

Band 1 (underweight) included only 7 girls (4.51 %) with an average BMI (M=12.6 index; SD=5.49) and an average correct posture score of (M=5.0 points). Band 2 (ideal weight) included 19 girls (12.58 %) with average BMI values (M=17.0 index; SD=6.24) and their average correct posture score was (M=9.9 points; SD=4.23), which were statistically significant at the 0.05 significance level ($r=0.554$ – large effect). Band 3 (overweight) included 67 girls (44.60 %) with average BMI values (M=18.9 index; SD=4.42) and their average correct posture score was (M=14.6 points; SD=4.21), which were statistically significant at the 0.05 significance level ($r=0.445$ – medium effect). Band 4 (obesity) included 58 girls (38.31 %) with average BMI values (M=25.7 index; SD=9.53) and their average

correct posture score was ($M=9.4$ points; $SD=5.28$), which were statistically significant at the 0.05 significance level ($r=0.378$ – medium effect).

We also compared the correct posture of boys in selected primary schools in Slovakia in 2015 and the average Body Mass Index values (Table 7). Band 1 (underweight) included 11 boys (8.66 %) with an average BMI ($M=12.8$ index; $SD=4.57$) and an average correct posture score of ($M=5.0$ points). Band 2 (ideal weight) included 16 boys (12.60 %) with average BMI values ($M=16.1$ index; $SD=6.68$) and their average correct posture score was ($M=9.4$ points; $SD=5.54$), which were statistically significant at the 0.05 significance level ($r=0.479$ - medium effect). Band 3 (overweight) included 49 boys (38.59 %) with average BMI values ($M=18.2$ index; $SD=6.87$) and their average correct posture score was ($M=14.7$ points; $SD=6.51$), which were statistically significant at the 0.05 significance level ($r=0.252$ - small effect). Band 4 (obesity) included 51 boys (40.15 %) with average BMI values ($M=22.4$ index; $SD=5.78$) and their average correct posture score was ($M=18.9$ points; $SD=5.40$), which were statistically significant at the 0.05 significance level ($r=0.346$ - medium effect).

Table 7. Posture Assessment and BMI of Boys (2015) from Selected Primary Schools in Western and Central Slovakia

Boys 2015 (n = 127)								
Zone	1st band (n = 11)		2nd band (n = 16)		3rd band (n = 49)		4th band (n = 51)	
Sample	Posture	BMI	Posture	BMI	Posture	BMI	Posture	BMI
S.ch.								
x	5.0	12.8	9.4	16.1	14.7	18.2	18.9	22.4
SD	-	4.57	5.54	6.68	6.51	6.87	5.40	5.78
test	p > 0.05		p < 0.05*		p < 0.05*		p < 0.05*	

Note. Posture [points], BMI – Body mass index, n – sample size, x – arithmetic mean, SD – standard deviation

In 2025, we repeatedly assessed the average values of correct posture in selected primary schools in Slovakia and the average BMI values for boys (Table 8). Band 1 (underweight) included only 7 boys (4.89 %) with an average BMI ($M=12.9$ index; $SD=5.28$), and the average correct posture score was ($M=5.0$ points). Band 2 (ideal weight) included 22 boys (15.38 %) with average BMI values ($M=18.7$ index; $SD=6.24$) and their average correct posture score was ($M=9.9$ points; $SD=5.13$), which were statistically significant at the 0.05 significance level ($r=0.610$ – large effect). Band 3 (overweight) included 52 boys (36.36 %) with average BMI values ($M=18.9$ index; $SD=5.41$) and their average correct posture score was ($M=14.8$ points; $SD=4.21$), which were statistically significant at the 0.05 significance level ($r=0.389$ – medium effect). Band 4 (obesity) included 62 boys (43.37 %) with average BMI values ($M=24.1$ index; $SD=7.51$) and their average correct posture score was ($M=19.2$ points; $SD=5.28$), which were statistically significant at the 0.05 significance level ($r=0.353$ – medium effect).

Table 8. Posture Assessment and BMI of Boys (2025) from Selected Primary Schools in Western and Central Slovakia

Boys 2025 (n = 143)								
Zone Sample S.ch.	1st band (n = 7)		2st band (n = 22)		3st band (n = 52)		4st band (n = 62)	
	Posture	BMI	Posture	BMI	Posture	BMI	Posture	BMI
x	5.0	12.9	9.9	18.7	14.8	18.9	19.2	24.1
SD	-	5.28	5.13	6.24	4.21	5.41	5.28	7.51
test	p > 0.05		p < 0.05*		p < 0.05*		p < 0.05*	

Note. Posture [points], BMI – Body mass index, n – sample size, x – arithmetic mean, s – standard deviation

Discussion

Our study highlights a significant degradation of both body mass index (BMI) and posture quality in 10-year-old Slovak children between 2015 and 2025. The increase in BMI (0.88 in boys and 0.52 in girls), together with the trend of increasing postural deficiencies (2.20 points in boys and 1.50 points in girls), suggests the cumulative influence of several interdependent factors: the intensification of sedentary behaviours associated with the use of various types of screens, the reduction of physical activity during the period of restrictions imposed by the COVID-19 pandemic (2020–2021), as well as the maintenance of unfavourable lifestyle behaviours after its end.

The more pronounced impact observed in boys, compared to girls, can be attributed to gender-specific differences in participation in physical activities and in the stage of biological development (Lombardo et al., 2024; Delas-Kalinski et al., 2025). At the age of 10, most boys have not yet entered puberty, while some girls are already in this process, which can generate different patterns of physical activity and distinct postural adaptations. Comparable trends have been reported in other Central and Eastern European countries, where rising overweight prevalence has been accompanied by a deterioration in postural parameters. Studies from Poland, Hungary, and Serbia show similar patterns, suggesting that the situation observed in Slovakia reflects a broader regional trend influenced by shared lifestyle and environmental changes (Grabara, 2014; Jakab et al., 2018; Halasi et al., 2018).

By comparing the average differences in the body mass index in 2015 and 2025, we observed the highest increase in the average body mass index in boys in 2025 in the second band by 2.6 (index) (13.90 %) and in the fourth band by 1.7 (index) (7.05 %) among primary school boys and girls from the western and central regions of Slovakia. In girls in 2025, we also recorded an increase in the average body mass index in the fourth band by 1.2 (index) (4.66 %) and in the second band by 0.5 (index) (2.94 %). We observed a deterioration in the average values of correct posture in boys in 2025 compared to 2015 in the second band by 0.5 points (5.05 %) and in the fourth band by 0.3 points (1.56). In girls in 2025, we recorded a deterioration in the average posture values compared to 2015 in the fourth band by 1.2 points (6.18%) and in the second band by 0.5 points (5.05 %).

By evaluating the results of the average BMI values depending on the average correct posture values of boys and girls from primary schools in the western and central regions of Slovakia, we state a significant dependence of the increased body mass index and correct posture in boys and also in girls in 2015 and in 2025.

Similar significant associations between the BMI and correct posture are stated in the studies by authors (Gajewska, et al., 2015; Faik et al., 2017; Marsigliante et al., 2023).

Limitations

Several limitations should be acknowledged. First, the cross-sectional design prevents causal inference; we cannot definitively determine whether increased BMI causes poor posture or vice versa. Second, our sample was limited to Western and Central Slovakia, which may limit generalizability to the entire country or to other regions in Central Europe. Third, we did not measure important confounders, including physical activity levels (accelerometry), screen time, socioeconomic status, pubertal maturation (Tanner stages), or family history of obesity/postural problems. Finally, our 2025 data may reflect the effects of the COVID-19 pandemic that are not representative of typical secular trends; longitudinal follow-up is needed to determine whether the observed changes persist or reverse in a relevant way post-pandemic.

Conclusions

Based on the results of our study focused on the assessment of BMI and correct posture in boys and girls from primary schools in the western and central regions of Slovakia in 2015 and 2025, we conclude that with an increased body mass index, the posture values of pupils are significantly worsened at the 5 % ($p < 0.05$) level of statistical significance.

We also consider the fact that in 2015, only 19.24 % boys and girls had perfect and good posture (Level 1 and Level 2), and as many as 80.76 % boys and girls had poor and incorrect posture (Level 3 and Level 4) as a serious finding. In 2025, 18.71 % boys and girls had perfect and good posture (Level 1 and Level 2), and as many as 81.29 % boys and girls had poor and incorrect posture (Level 3 and Level 4).

Based on our findings, we consider the current state of the increase in the BMI depending on incorrect posture in boys and girls in primary schools from the western and central regions of Slovakia from 2015 to 2025 to be unsatisfactory and health-threatening. These facts need to be further addressed, and systemic preventive measures need to be sought.

Appropriate preventive intervention is needed to ensure healthy growth and prevent comorbidities in childhood and adulthood.

A suitable solution may be to limit pupils' sedentary behaviour by including physical education classes in the curriculum every day, with the aim of reducing the unfavourable occurrence of overweight and obesity in pupils during their school attendance (Trecroci et al., 2021).

Practical Implications

Pedagogical diagnostics in the school environment is the primary factor that can point to changes in the area of health-oriented fitness as the basis of a pupil's health. The above findings point to the importance of monitoring the above factors from a preventive perspective and supporting the health of pupils.

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References

- Arufe-Giráldez, V., Sanmiguel-Rodríguez, A., Ramos-Álvarez, O., & Navarro-Patón, R. (2022). Gamification in physical education: A systematic review. *Education Sciences*, 12(8), 540.
- Bendíková, E. (2016). Changes in the posture of students due to equipment-aided exercise programs that are applied in physical and sport education. *Journal of Physical Education and Sport*, 16(2), 281–286.
- Bendíková, E. (2020). Diversification of the physical and sport education syllabi and its effects on the musculoskeletal system in young female students. *Trends in Sport Sciences*, 27(3), 149–155.
- Calcaterra, V., Marin, L., Vandoni, M., Rossi, V., Pirazzi, A., Grazi, R., ... & Zuccotti, G. (2022). Childhood obesity and incorrect body posture: impact on physical activity and the therapeutic role of exercise. *International journal of environmental research and public health*, 19(24), 16728.
- Cvejic, D., & Ostojić, S. (2018). Effects of the FITT program on physical activity and health-related fitness in primary school age children. *Facta Universitatis, Series: Physical Education and Sport*, 15(3), 437–451.
- Chen, W., Hammond-Bennett, A., Hypnar, A., & Mason, S. (2018). Health-related physical fitness and physical activity in elementary school students. *BMC Public Health*, 18(1), 1–12.
- Delas-Kalinski, S., Ljubica, B., & Babic, V. (2025). Adolescence as a Critical Period: Gender Differences in Nutrition, Physical Activity and Sedentary Behavior. *The Eurasia Proceedings of Educational and Social Sciences, (EPESS)*, 45, 98–105.
- Desouzart, G., & Filgueiras, E. (2023). Posture Mind - Postural Education in Back Pain and Postural Habits of Children and Teenagers. In: *Occupational and Environmental Safety and Health V*, (pp. 31–41). Cham: Springer Nature Switzerland.
- Faik, A., Vanderhulst, E., Rossem, V. I., & Devroey, D. (2017). Influence of physical activity and interest for food and sciences versus weight disorders in children aged 8 to 18 years. *Journal of Preventive Medicine and Hygiene*, 58(2), E105–E113.
- Faust, A. M., Auerbeck, A., Lee, A. M., Kim, I., & Conroy, D. E. (2024). Passive sensing of smartphone use, physical activity and sedentary behavior among adolescents and young adults during the COVID-19 pandemic. *Journal of Behavioral Medicine*, 47(5), 770–781.
- Grabara, M. (2014). Postural variables in girls and boys aged 10–12 years. *Biomedical Human Kinetics*, 6(1), 66–70. <https://doi.org/10.2478/v10101-009-0017-7>
- Gajewska, E., Kalinskam K., Bogdanskim P., & Sobieskam M. (2015). Cardiorespiratory endurance in relation to body mass in Polish rural children: Preliminary report HOMO- *Journal of Comparative Human Biology*, 66(3), 278–285.
- Halasi, S., Lepes, J., Stajer, A., & Cvetković, M. (2018). Relation between body composition and HRQOL in primary school children. *Croatian Journal of Education - Hrvatski časopis za odgoj i obrazovanje*, 19(2), 125–133. <https://doi.org/10.15516/cje.v19i0.2699>
- Hojker, M., Vaishnav, J., & Dobravec, S. (2023). Effectiveness of the prevention programme on posture and the incidence of back pain in primary school children: a pilot study. *Slovenian Medical Journal*, 92(9–10), 1–9. <https://doi.org/10.6016/ZdravVestn.3388>
- Jakab, A. E., Hidvégi, E. V., Illyés, M., Cziráki, A., & Bereczki, C. (2018). Prevalence of overweight and obesity in Hungarian children and adolescents. *Annals of Nutrition & Metabolism*, 72(4), 259–264. <https://doi.org/10.1159/000487929>
- Kabatová, H., Kopecký, M., Strnisková, D., & Tomanová, J. (2012) Těžké školní aktovky jako další možný faktor ovlivňující výskyt vadného držení těla. *Hygiena*, 57(3), 89–93.
- Lombardo, M., Feraco, A., Armani, A., Camajani, E., Gorini, S., Strollo, R., ... & Bellia, A. (2024). Gender differences in body composition, dietary patterns, and physical activity: insights from a cross-sectional study. *Front. Nutr.*, 11, 1414217. <https://doi.org/10.3389/fnut.2024.1414217>
- Marsigliante, S., Gómez-López, M., & Muscella, A. (2023). Effects on children's physical and mental well-being of a physical-activity-based school intervention program: a randomized study. *International Journal of Environmental Research*, 20(3), 1927. <https://doi.org/10.3390/ijerph20031927>
- Neville, R. D., Lakes, K. D., Hopkins, W. G., Tarantino, G., Draper, C. E., Beck, R., & Madigan, S. (2022). Global changes in child and adolescent physical activity during the COVID-19 pandemic: a systematic review and meta-analysis. *JAMA Pediatrics*, 176(9), 886–894.
- Ng, M., Dai, X., Cogen, R. M., Abdelmasseh, M., Abdollahi, A., Abdullahi, A., ... & Khan, M. S. (2024). National-level and state-level prevalence of overweight and obesity among children, adolescents, and adults in the USA, 1990–2021, and forecasts up to 2050. *The Lancet*, 404(10469), 2278–2298.
- Pfefferbaum, B., & Van Horn, R. L. (2022). Physical activity and sedentary behavior in children during the COVID-19 pandemic: Implications for mental health. *Current Psychiatry Reports*, 24(10), 493–501.

- Prieto-González, P., Šutvajová, M., Lesňáková, A., Bartík, P., Buřáková, K., & Friediger, T. (2021). Back Pain Prevalence, Intensity, and Associated Risk Factors among Female Teachers in Slovakia during the COVID-19 Pandemic: A Cross-Sectional Study. *Healthcare*, 9(7), 860. <https://doi.org/10.3390/healthcare9070860>
- Repko, M. (2017). Nejčastější vady páteře u dětí školního věku [The most common defects of the spine in children of school age]. *Pediatric pro praxi*, 18(4), 212–218.
- Rozim, R., Daubnerová, J., Slovákova, M., & Bendiková, E. (2022). *Changes in somatic characteristics and indicators of physical ability, physical performance, and body posture in 10- and 11-year-old pupils*. In *INTED2022 Proceedings*, (pp. 547–556).
- Šeráková, H. (2006). Aktuální poznatky k problematice vadného držení těla [Current knowledge on the issue of poor posture]. In 2. konference Škola a Zdraví. Retrieved from: http://www.ped.muni.cz/z21/2006/konference_2006/sbornik_2006/pdf/059.pdf
- Ševčíková, L., Rovný, I., Nováková, J., Hamade, J., Tatara, M., Janechová, H., & Šedová, M. (2004). *Physical development of children and youth in Slovakia*. Bratislava: Public Health Office of the Slovak Republic.
- Shimon, J. M. (2025). *Introduction to teaching physical education: Principles and strategies*. Human Kinetics.
- Trecroci, A., Invernizzi, P. L., Monacis, D., & Colella, D. (2021). Actual and perceived motor competence in relation to body mass index in primary school-aged children: A systematic review. *Sustainability*, 13(17), 9994.
- Vojtaššák, J. (2000). *Ortopédia* [Orthopedics]. Bratislava: Slovak Academic Press.
- Zhu, Z., & Yin, P. (2023). Overweight and obesity: the serious challenge faced by Chinese children and adolescents. *Journal of Global Health*, 13, 03036.

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