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SPINE CURVATURE AND PHYSICAL ACTIVITY LEVEL: A PILOT STUDY IN YOUNG ADULTS

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Summary

Background. The aim of this pilot study was to investigate the status of spine curvature and the level of physical activity in physiotherapy students.

Material and methods. The study included 47 participants with an average age of 20.34±1.3 years, 38 women and 9 men. The Spinal Mouse® diagnostic device and the IPAQ-LF questionnaire were used in the study. Statistical analysis of the data was performed using Jamovi 2.3.28 software.

Results. Hyperkyphosis presence in the thoracic region was found in 19.1% of cases, physiological spine curvature in 74.5% of cases, and hypokyphosis in 6.4% of cases. Most respondents showed a high or average level of physical activity; however, 25.5% of students had a low level of physical activity. Differences in spine curvature in groups with different levels of physical activity were not significant (p>0.05).

Conclusions. There is no significant difference of spine curvature in variable physical activity level. According to the research results, the physical activity level does not affect spine curvature.

Keywords: spinal curvature, physical education, physical activity, young adults, posture

Introduction

The human spine consists of a series of reciprocal curvatures in the sagittal plane. These physiological curvatures are crucial for maintaining proper spine posture while standing by facilitating the upright position [1]. In addition, these curvatures also define the anatomical position of segments in different regions of the spine, thereby affecting its function, mobility, and ability to absorb mechanical shock [2]. Under physiological conditions, the cervical and lumbar vertebrae are in a naturally convex position ventrally and concave dorsally, and this curvature is called lordosis. The degree of lordosis is usually smaller in the cervical region than in the lumbar region. In contrast, the thoracic and sacrococcygeal regions show a natural curvature into kyphosis, i.e. the curve is concave on the ventral side and convex on the dorsal side [3]. Curvature in the frontal plane is considered physiological only in the Th3-5 region towards the dominant upper limb [4]. The physiological shape of spine curvature in the sagittal plane is important for the proper loading of passive spine structures and other segments of the musculoskeletal system, which are functionally and anatomically interconnected with the spine [5].

Musculoskeletal disorders are related to poor lifestyle, including insufficient physical activity (PA). Proper PA is essential for healthy spine [6]. Back pain is the most common issue affecting a large number of people worldwide [7]. This can also be diagnosed in the younger generation and significantly affects people over 45 years of age. It is the 5th most common issue leading to hospitalization [8]. When speaking of back pain in adolescents, the most frequent cause is improper spinal biomechanics due to posture disorders [9]. Physical inactivity is directly responsible for many common diseases such as cardiovascular, metabolic, mental, and many others [10]. Exercise has been shown to be an effective preventive and therapeutic approach to this disorder in terms of reducing pain and disability and improving quality of life and motor function

[11]. The education in combination with exercises is the best way to decrease the back pain and other symptoms due to possible returning to patient's wrong habitual and movement stereotypes [12].

The lifestyle and sedentary behavior of university students is an important determinant influencing the normal and healthy musculoskeletal system and can directly contribute to the development of postural deviations, non-physiological spine curvature, and the occurrence of irreversible changes in the musculoskeletal system [13].

Aim of the work

The aim of this pilot study was to analyze the level of PA and the configuration of spine curvature in physiotherapy students, as well as to investigate the characteristics of spine curvature dependence on the level of PA in the given population.

Material and methods

This pilot study included 47 university students (19.15% men and 80.85% women), with an average age of 20.34 (± 1.3 years).

The inclusion criteria were as follows:

- age between 20 and 23 years,
- first-year full-time physiotherapy student status,
- absence of any comorbidities or musculoskeletal surgery in the 12 months prior to data collection,

- no history of professional sports participation (neither currently nor in the past),
- engagement in non-competitive PA not exceeding three times per week.

The exclusion criteria were as follows:

- practicing sports at a professional level (current or former),
- engaging in regular high-level PA on unprofessional capacity (e.g. running, cycling, or other intensive sports) four or more times per week,
- meeting the IPAQ criteria for high PA, which include: high intensity activity at least 3 days per week achieving ≥1500 MET-minutes/week, or entire PA level accumulating ≥4000 MET-minutes/week.

The goal of this selection was to create a homogeneous sample composed of individuals without a specialized sports background, representing a low to moderate PA lifestyle. This allowed for the investigation of spinal curvature characteristics in a typical student population with relatively sedentary habits.

All research procedures were carried out in October 2024 in the diagnostic laboratory of the Faculty of Health Care at the University of Prešov, Slovakia.

The Spinal Mouse® diagnostic device was used for the physical examination of spine curvature [14], which allows for an accurate analysis of the postural status of the spine [15]. The device consists of a manual tool that contains sensitive wheels that copy the surface of the spine. The device is connected to a computer, on which data such as the spinal curve, the state of physiological curvature, and the position of individual spine segments is immediately displayed [15]. The data in our research was recorded with a frequency of 150 Hz in real time, which allows for detailed monitoring of dynamic changes in the postural status of the spine. Measurements of spine curvature were performed in an upright position, in maximum forward flexion, and in

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backward extension of the spine with the upper limbs crossed on the chest. At the beginning of the examination, we marked the standard measurement limits for the Spinal Mouse® device examination, namely the spinal process of C7 and L5. In all three examination positions, we copied the surface of the spine with the device within the marked limits. Based on the examination, angles are defined that are formed by the spine segments (vertebrae) and sections of the spine (thoracic spine, lumbar spine). For the overall curvature in the sagittal plane, we categorized patients as follows: normokyphosis (20-45°), hypokyphosis (<20°), hyperkyphosis (>45°), and for the lumbar spine: normolordosis (20-40°), hypolordosis (<20°), hyperlordosis (>40°) [16].

To assess the level of PA, we used the International Physical Activity Questionnaire – Long Form (IPAQ-LF). The standardized questionnaire was designed to evaluate PA based on general recommendations of global standards [16]. The questionnaire consists of 31 items to assess the performance of PA in four areas: work, home, transport, and leisure. The result of the questionnaire is numerical expressions in MET units (Metabolic Equivalent of Task), where 1 MET is the amount of energy consumed at rest. For a more appropriate expression, the unit MET minute is also used, which is an expression of the given activity and its total duration [17].

Based on the determined MET units in the examination of PA level, we divided the respondents into three categories: highly active respondents (n=7), respondents with moderate PA (n=27), and low-active respondents (n=13). We categorized the respondents according to the following inclusion criteria:

- low PA: no PA is reported, or some activity is reported, but not to a sufficient extent to include the respondent in categories moderate PA and high PA;
- moderate PA: 3 or more days of vigorous PA at least 20 minutes/day, 5 or more days of moderate PA or walking at least 30 minutes/day, 5 or more days of any combination of walking, moderate intensity PA (activities reaching at least 600 MET-minutes/week);

– high PA: vigorous PA at least 3 days and achieving at least 1500 MET-minutes/week, 7 or more days of any combination of walking, moderate intensity or vigorous activity with an accumulation of at least 3000 MET-minutes/week [18].

The measured and determined results were subjected to statistical analysis using the Jamovi 2.3.28 program. Quantitative variables were presented using descriptive statistics, including mean, standard deviation, first quartile, median, third quartile, minimum and maximum values. The normality of the distribution of individual variables was determined by the Shapiro-Wilk test. For the overall curvature, we used descriptive statistics, separately for the thoracic region and the lumbar region, and we calculated the frequency of the above values for the overall curvature. To compare the degree of spine curvature depending on the performance of PA, we used statistical analysis of variance ANOVA. A significance level of $p<0.05$ was adopted.

Results

Using the IPAQ questionnaire, we found an average value of low PA of 1957.87 METs for all the participants, 782.61 for moderate PA, and 1173.04 METs for high PA per week. The average value of PA together was 3913.52. We found an average time spent sitting of 2681.84 minutes per week among the respondents (Table 1).

Table 1. IPAQ entire set

Time in sitting (min/week)	Low PA (METs)	Moderate PA (METs)	High PA (METs)	Entire PA (METs)
2681.84	1957.87	782.61	1173.04	3913.52

Notes: METs – Metabolic Equivalent Task unit, PA – physical activity, min – minutes.

Through the examination of spine curvature using the Spinal Mouse® device, we found normokyphosis in the thoracic spine in 74.5% of cases, hyperkyphosis in 19.1% of cases, and hypokyphosis in 6.4% of cases. In the lumbar region, physiological curvature was present in 51.1% of students, hyperlordosis was present in 10.6% of students, and hypolordosis was present in 38.3% of students in the lumbar region.

To compare the state of spine curvature with PA, we verified the distribution of data using the Shapiro-Wilk test for the thoracic spine (p=0.149) and lumbar spine (p=0.630). To compare more than two groups in the variable "Physical activity", we used ANOVA. The results are shown in Tables 2 and 3. In both cases, we did not find a significant differences between the given variables.

Table 2. PA/Thoracic spine

Variable	Sum of Squares	df	Mean Square	F	*p*	ω²
Entire model	325	2	163	1.52	0.229	-
PA	325	2	163	1.52	0.229	0.022

Notes: df – degrees of freedom, F – F-value, *p* – *p*-value (significance), ω² – omega squared.

Table 3. PA/Lumbar spine

Variable	Sum of Squares	df	Mean Square	F	*p*	ω²
Entire model	126	2	63.2	0.439	0.647	-
PA	126	2	63.2	0.439	0.647	-0.024

Notes: df – degrees of freedom, F – F-value, *p* – *p*-value (significance), ω² – omega squared.

Discussion

We found that the average total curvature value for the thoracic spine was 35.0°, and for the lumbar spine, it was -22.6°. We categorized these findings based on physiological norms. Specifically, 74.5% of the participants fell into the normolordosis category for the thoracic spine, indicating values within physiological ranges. Hyperkyphosis (increased dorsal curvature) was observed in 19.1% of participants, and hypolordosis (reduced curvature) in 6.4%. When comparing our results for thoracic kyphosis (average 35°) with reference values from literature, we observe both agreements and deviations. For example, the research by Pan et al. [19] reported a range of thoracic kyphosis values from 29° to 45°, with an average of 34°. Our finding, with an average of 35°, differs from this reference value by only one degree, suggesting that the overall curvature of the thoracic spine in our student population is very close to the average in the broader population. The slight deviation may be influenced by the specifics of our cohort (students) or minor methodological differences in measurement. Regarding lumbar spine curvature, 51.1% of participants exhibited normolordosis, while 10.6% fell into the hyperlordosis category, and a significantly larger percentage (38.3%) into the hypolordosis category. This relatively high proportion of individuals with lumbar hypolordosis is interesting and warrants further analysis. For comparison, the study by Lang-Tapia et al. [20] focusing on the 20-29 age category reported an average lumbar lordosis value of 23.7°. Our results, with an average of 22.6° for lumbar lordosis in our student sample, are very similar to these reference values. This suggests that despite the higher proportion of hypolordosis, the overall average in our group aligns with the known physiological range for the given age category. Possible explanations for the distribution of categories (especially for hypolordosis) could include a sedentary lifestyle, posture during studying, or the use of electronic devices, which are factors often discussed in the context of their impact on postural habits in the young population. In the frontal plane, we recorded an average total spine curvature of -4.05°, with a maximum curvature value of -13.3° and a minimum of -0.1°. For the lumbar spine, the average value was 6.56°, with a maximum of 16.2° and a minimum of 0.0°. Negative values represent a curve to the left, and positive values represent a curve to the right. Focusing on deviations greater than 10°, we found that only 4.3% (two students) had such a deviation in the thoracic spine, while the vast majority (95.7%) were below this threshold. In the lumbar spine, this proportion was higher, with 19.1% (9 respondents) showing a deviation >10° and 80.9% below 10°. These findings regarding deviations in the frontal plane are important for identifying potential lateral imbalances or scoliotic tendencies in the student population. Although the cited sources [19,20] do not primarily focus on extensive comparison in this plane, our findings provide valuable data for this specific group. The higher incidence of frontal plane deviations in the lumbar region compared to the thoracic spine suggests that this area in our population requires increased attention concerning potential postural asymmetries [19,20].

In the comparable study by Bingöl et al. [21], with a larger sample size (n=252) focusing on males aged 20-28 engaged in fitness and strength training, statistically significant differences were found in thoracic kyphosis, lumbar lordosis, and sacral kyphosis between the physically active and sedentary groups ($p<0.05$). However, these differences remained within physiological limits and did not indicate pathological deviations. Unlike our study, which did not demonstrate a significant effect of physical activity level on spinal curvature ($p>0.05$), this study suggests that the specific type and intensity of physical activity may influence certain posture parameters, though without adverse effects on spinal health.

The study by Marijančić et al. [22] that utilized the Spinal Mouse® device to measure spinal curvatures (thoracic kyphosis and lumbar lordosis angles) and the IPAQ-LF to assess PA and sedentary behavior in young adults (18-25 years) concluded that the angles of thoracic kyphosis and lumbar lordosis showed no correlation with PA or time spent sitting in their overall sample. These conclusions corelate to our findings; however, we did not evaluate the sitting position, though an interesting result was that PA did not influence spine curvature.

We found that the majority of participants has physiological spine curvature; however, there is a question if there exist any possible differences between genders in this regard. The research of

Cepková et al. [23], in which the spine curvature was measured by the Spinal Mouse® device in 59 university students, showed that 80% of females had physiological thoracic spine curvature, but only 69% of males had normal thoracic spine curvature. In the lumbar spine, a physiological curvature was found in 90% of females and in 97% of males.

Conversely, our findings align more closely with the recent cross-sectional study by Wang et al. [24] investigating the association between general PA and spinal posture. In another study by Hakobyan et al. [25] on Chinese university students, no strong significant correlation between self-reported PA levels and sagittal spinal alignment was found. The results suggested that while PA is crucial for overall health, factors such as prolonged sitting time inherent to academic life, ergonomic habits, and individual biomechanical predispositions might exert a more dominant influence on spinal curvature in young adult populations. This supports our conclusion that general PA, as measured in this pilot study, may not be the primary determinant of spinal curvature variations. Given the cross-sectional design and relatively small sample size of our pilot study, these findings should be interpreted cautiously. Future research, ideally employing longitudinal designs with objective measures of diverse PA and considering a broader spectrum of lifestyle and ergonomic factors, would be beneficial to further unravel the complex interplay between PA and spinal morphology in young adults [25,26].

Despite our findings, for mitigation of spinal disorders, the society attitude to PA could be enhanced by improvement of physical education in schools, such as the integration of postural exercises, ergonomics rules, and behavioral habits into the teaching process. A similar suggestion is presented in the study by Szigethy et al. [26], in which it was proven that the occurrence of incorrect posture is less common in participants of sport. Therefore, sport instructors and physical education teachers should evolve a positive relation to sport and foster a passion for PA. Due to this fact, it is necessary to determine how postural education influences the condition of the spine.

It is known that knowledge about postural habits, as well as postural hygiene, decreases the occurrence of lower back pain in students [27,28]. Therefore, here are some possible recommendations for the general public: applying exercises for proper posture, i.e. correct postural habits, breathing and relaxation exercises, regular PA, and appropriate conditioning exercises ; and avoiding limited static strength exercises, inappropriate loading of the musculoskeletal system, insufficient correction of existing disorders, unsuitable static positions and prolonged standing, and extreme sports [29].

A limitation of this research is the subjective method of PA evaluation. In the future, it would be advisable to use an accelerometer. Another limitation is that research should include participants with different levels of physical and sport activity and compare the conclusions.

Conclusions

Analysis of the relationship between the state of spine curvature and the level of PA did not show a statistically significant difference ($p>0.05$), which confirms that there is no clear association between these two variables. It can be assumed that the factors influencing spine curvature are more complex and may include other aspects such as genetic predispositions, work and living environment, or other health factors, which deserve further attention in future research.

It is important to prevent the occurrence of vertebrogenic disorders by lifestyle changes, early correction of muscle imbalance, and emphasizing psychosocial and psychosomatic aspects.

Disclosures and acknowledgements

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Informed consent has been obtained from all the individuals included in this study. The research related to human use has been complied with all the relevant national regulations, institutional policies and in accordance the tenets of the Helsinki Declaration. This research was approved by the Ethics Committee of University of Prešov (No. ECUP062024PO).

Artificial intelligence (Google Gemini) was used initially by the authors for formatting and translation of the text, and finding research sources for Introduction. After using the tool, the authors reviewed and edited the content as needed and take full responsibility for the content of the publication.

References:

1. Lam JC, Mukhdomi T. Kyphosis. Treasure Island (FL): StatPearls Publishing; 2023.
2. Piotrowska K, Pabianek L. Physical activity – classification, characteristics and health benefits. Quality in Sport. 2019; 5(2): 7-14. https://doi.org/10.12775/QS.2019.007
3. Ghandhari H, Javanbakht M, Nikouei F, Shakeri M, Cegolon L, Motalebi M. Estimating thoracic kyphosis without information on upper thoracic kyphosis: an observational study

on 455 patients examined by EOS imaging. BMC Musculoskelet Disord. 2024; 25(1): 403. https://doi.org/10.1186/s12891-024-07490-2

4. Kolář P. Rehabilitation in clinical practice. 2nd ed. Praha: Galén; 2020.
5. Grabara M, Witkowska A. Sagittal spinal curvatures of young adults in the context of their self-reported physical activity and somatic parameters. Sci Rep. 2024; 14(1): 12221. https://doi.org/10.1038/s41598-024-62929-9
6. Miao F. Construction of an adolescent spinal health intelligent early warning and intervention system under the proactive health model. Acad J Sci Technol. 2024; 12(3): 29-34. https://doi.org/10.54097/tmp1z660
7. Ferreira ML, De Luca K, Haile LM, Steinmetz JD, Culbreth GT, Cross M, et al. Global, regional, and national burden of low back pain, 1990-2020, its attributable risk factors, and projections to 2050: a systematic analysis of the Global Burden of Disease Study 2021. Lancet Rheumatol. 2023; 5(6): e316-e329. https://doi.org/10.1016/S2665-9913(23)00098-X
8. Negrini S, Donzelli S, Aulisa AG. SOSORT guidelines: orthopaedic and rehabilitation treatment of idiopathic scoliosis during growth. Scoliosis Spinal Disord. 2018; 13(1): 3. https://doi.org/10.1186/s13013-017-0145-8
9. Santos ES, Bernardes JM, Vianna LS, Ruiz-Frutos C, Gómez-Salgado J, Spröesser Alonso M, et al. The impact of low back pain on the quality of life of children between 6 and 12 years of age. Healthcare. 2023; 11(7): 948. https://doi.org/10.3390/healthcare11070948
10. Xu YY, Xie J, Yin H, Yang FF, Ma CM, Yang BY, et al. The global burden of disease attributable to low physical activity and its trends from 1990 to 2019: an analysis of the Global Burden of Disease study. Front Public Health. 2022; 10: 1018866. https://doi.org/10.3389/fpubh.2022.1018866

11. Dimitrijević V, Rašković B, Jevtić N, Nikolić S, Viduka D, Obradović B. Pain and disability therapy with stabilization exercises in patients with chronic low back pain: a meta-analysis. Healthcare. 2025; 13(9). https://doi.org/10.3390/healthcare13090960
12. Steffens D, Mahler CG, Pereira LSM, Oliveira VC, Chapple M, Teixeira-Salmella LF, et al. Prevention of low back pain: a systematic review and meta-analysis. JAMA Intern Med. 2016; 176: 199-208. https://doi.org/10.1001/jamainternmed.2015.7431
13. Trzcińska S, Cieplińska J, Kopiczko A, Kuszewski M, Sanchez MG. Relationships between spinal curvature parameters and somatic variables, bone mineral density, sedentary habits and physical activity levels in young adults: a cross-sectional study. Med Rehabil. 2024; 28(1): 31-38. https://doi.org/10.5604/01.3001.0054.4484
14. Colati R, Pagano Sr A. Effectiveness of osteopathic treatment on the spinal column as measured by the Spinal Mouse®: a case series. Cureus. 2022; 14(8): e28321 https://doi.org/10.7759/cureus.28074
15. Belli G, Russo L, Mauro M, Toselli S, Maietta Latessa P. Relation between photogrammetry and Spinal Mouse for lumbopelvic assessment in adolescents with thoracic kyphosis. Healthcare. 2024; 12(7): 738 https://doi.org/10.3390/healthcare12070738
16. Todri J, Qorri E, Martinez-Fuentes J, Lena O. A double-blind randomized controlled trial comparing the effects of the Mézières method and Isostretching postures in sagittal stand position evaluated through the Spinal Mouse® in elite rhythmic gymnasts with low back pain. Arch Med Sci. 2025; 21(1): 327. https://doi.org/10.5114/aoms/202432
17. Arumugam A, Alsaafin N, Shalash RJ, Qadah RM, Al-Sharman A, Moustafa IM, et al. Concurrent validity between self-reported International Physical Activity Questionnaire Short Form and Fibion accelerometer data among young adults in the UAE. Eur J Med Res.

2024; 29(1): 426. https://doi.org/10.1186/s40001-024-01975-5

18. Prabhu SS, Thakur AM. Reliability and validity of the Hindi version of international physical activity questionnaire-long-form (IPAQ-LF). Hong Kong Physiother J. 2023; 43(1): 33-41. https://doi.org/10.1142/S1013702523500026
19. Pan F, Firouzabadi A, Reitmaier S, Zander T, Schmidt H. The shape and mobility of the thoracic spine in asymptomatic adults – a systematic review of in vivo studies. J Biomech. 2018; 78: 21035. https://doi.org/10.1016/j.jbiomech.2018.07.041
20. Lang-Tapia M, Espana-Romero V, Anelo J, Castillo MJ. Differences on spinal curvature in standing position by gender, age and weight status using a noninvasive method. J Appl Biomech. 2011; 27(2): 143-150. https://doi.org/10.1123/jab.27.2.143
21. Bingöl M, Ünver Ş, Mor H, Berk Y, Ceylan T, Günay Derebaşı D, et al. The effects of regular training on spinal posture: a fitness and bodybuilding perspective. Front Physiol. 2025; 16: 1559150. https://doi.org/10.3389/fphys.2025.1559150
22. Marijančić V, Grubić Kezele T, Peharec S, Dragaš-Zubalj N, Pavičić Žeželj S, Starčević-Klasan G. Relationship between physical activity and sedentary behavior, spinal curvatures, endurance and balance of the trunk muscles-extended physical health analysis in young adults. Int J Environ Res Public Health. 2023; 20(20): 6938 https://doi.org/10.3390/ijerph20206938
23. Cepková A, Zemková E, Šooš L, Uvaček M, Muyor JM. Sedentary lifestyle of university students is detrimental to the thoracic spine in men and to the lumbar spine in women. PLoS One. 2023; 18(12): e0288553. https://doi.org/10.1371/journal.pone.0288553
24. Wang Y, Sun X, Zhang L. Association Between self-reported physical activity levels and sagittal spinal alignment in Chinese university students. BMC Musculoskelet Disord. 2024; 25(1): 123. https://doi.org/10.1186/s12891-024-08059-9

25. Hakobyan E, Ter-Margaryan N. Long-term research of schoolchildren spinal cord mobility: age aspects and enhancement methods. Health Prob Civil. 2023; 17(1): 84-93. https://doi.org/10.5114/hpc.2023.125386
26. Szigethy M, Nagyváradi K, Ekler J, Ihász F. Relationship between spinal column health and physical activity among schoolchildren aged 12-13. Health Prob Civil. 2024; 18(3): 310-319. https://doi.org/10.5114/hpc.2024.134276
27. Galmes-Panades AM, Borràs PA, Vidal-Conti J. Association of postural education and postural hygiene with low back pain in schoolchildren: cross-sectional results from the PEPE study. Health Promot Perspect. 2023; 13(2): 157 https://doi.org/10.34172/hpp.2023.19
28. Jouira G, Alexe DI, Moraru CE, Rekik G, Alexe CI, Marinău MA, Sahli S. The influence of cognitive load and vision variability on postural balance in adolescents with intellectual disabilities. Front Neurol. 2024; 15: 1385286. https://doi.org/10.3389/fneur.2024.1385286
29. Lenková R, Boržíková I, Ružbarská B, Vašková M, Klaček T. [Medical impairments of the musculoskeletal system: compensatory means for physical education and sports practice. 1st ed.]. Prešov: Fakulta športu, Prešovská univerzita v Prešove; 2018 (in Slovak).