FUNCTIONAL ASYMMETRY OF THE SPINE IN STANDING AND SITTING POSITIONS

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BACKGROUND: A sedentary lifestyle, together with functional asymmetry of the body, are potentially dysfunctional factors.

OBJECTIVE: In this project, the authors are trying to identify the connections between a sedentary lifestyle and the amount of functional asymmetry of the spine.

METHODS: Sixteen male volunteers aged 19–25 participated in the experiment. All of them were students of the University of Physical Education in Katowice. To measure trunk movement, the BTS Smart system was used. The quantity of functional asymmetry was described as a Functional Asymmetry Ratio (FAR), calculated using the trunk range of motion on the frontal and horizontal planes.

RESULTS: Larger FARs values were registered in a sitting position ($p < 0.01$). Frontal plane functional asymmetry was greater than the asymmetry on the horizontal plane ($p < 0.05$) and the asymmetry of the lumbar spine exceeded that recorded for the thoracic section ($p < 0.05$).

CONCLUSIONS: The association between a sedentary lifestyle and the functional asymmetry of the body is possible. Together with the increased use of sitting positions in daily life, the asymmetric load exerted on the spine may increase as well.

Keywords: Range of motion, rotation, lateral flextion, thoracic, lumbar.

INTRODUCTION

Symmetry is one of the basic features of the human body and of most animals. It is understood as regularity in spatial structure and is characterized by the possibility of the presence of at least one axis or plane of symmetry in the given organism. The most common type of symmetry is bilateral symmetry, which means that the organism can be divided into two parts: right and left; which are their mirror reflections.

Minor asymmetry of the body is treated as normal, but we must consider to what degree this structural and functional asymmetry could be interpreted in light of physiological categories.

The functional asymmetry of the human body is frequently presented in a negative light. For example Cibulka et al. (2002) points out that asymmetry of the pelvic bones introduces changes in soft tissue tightness and accompanies dysfunctions of the motor system. Bernard et al. (1987) demonstrated that a disrupted pelvic symmetry may promote development of overstrain changes in the lower back at an elderly age. The evidence of an association existing between asymmetry and low back pain have also been shown (Al-Eisa et al., 2006; Gomez, 1994; Mellin et al., 1995)

However, some degree of asymmetry is typical for healthy populations as well. For example, in a group of children and teenagers aged 7–15 years the frequency of pelvic asymmetry was estimated as 41% in boys and 40% in girls (Saulicz, 2003). Other good examples are disproportions in the hip joints' range of motion (Ellison et al., 1990) and leg length discrepancies recorded in healthy subjects (Bluestein & D'Amico, 1985; Okun et al., 1982). Inequality of the leg length of 2.33 cm is rarely a cause for gait asymmetry (Liu X-C et al., 1998).

According to McGill (2002) the risk of sustaining tissue damage increases in situations when the load exerted on a given tissue exceeds its tolerance. It's clear that a greater chance for this exists when the organism is asymmetrically loaded, e.g. during heavy lifting activity.

One should also take into account that, together with civilization development, the sitting position has become the dominant position of the modern human. This results in a considerable reduction of gravity loading and provokes plastic adaptation of the muscular and nervous systems (Richardson et al., 2004; White & Davies, 1984; Appell, 1990; McComas, 1996). In this process one of the crucial factors is tissue crawling while assuming flexed positions which is likely to disrupt the passive prevention of spinal segments. A sitting position was also presented as being disadvantageous in William's opinion (2000), who stated that maintaining the lumbar spine in flexion causes meaningful changes in multifidus muscle control occurring in the form of losing the protective tonic function.

All the facts mentioned above suggested two types of risk factors linked to the dysfunction of the motor system common at this time. These are: the structural and functional asymmetry of the human body as well as a sedentary lifestyle. This led the authors to a hypothesis that potentially these two factors may be interrelated.

OBJECTIVES

The objective of the experiment was to verify the hypothesis that among young, healthy, active people without any pain within the motor system, the degree of functional asymmetry of the spine is dependent on body position.

The following research questions are proposed:

- Is the degree of the functional asymmetry of the spine dependent on the position of the body (standing vs. sitting)?
- Are there any differences in the degree of functional asymmetry between the frontal and transverse planes? Is this difference more distinct in sitting or in a standing position? Is this difference more distinct in the thoracic or in the lumbar section of the spine?
- Are there any differences in the degree of functional asymmetry between the lumbar and thoracic section of the spine? Is this difference more distinct in sitting or in a standing position?

MATERIAL AND METHODS

Design of the experiment

Repeated experimental measures were used. The degrees of the functional asymmetry of the lumbar and thoracic section of the spine were measured in transverse (rotation) and frontal (lateral flexion) planes and served as dependent variables. The position of the subject (standing *vs.* sitting) was repeatedly measured and taken into consideration as a factor. Sections of the spine and planes of movement were considered independent factors. Repeated measurements enabled the minimization of the influence of between subject variance. The sequence of testing positions (first standing then sitting) and the plane of movement (first rotation then lateral flexion) were administered in a constant order. The direction of the movement to start the procedure with (left *vs.* right) was randomized.

Material

Forty male volunteers aged 19–25, students of the University of Physical Education, expressed their will to participate in the experiment. They must have met the following inclusion criteria:

- Lack of major injuries of the spine and lower limbs requiring any medical intervention.
- Lack of any surgery performed on the spine and lower limbs.
- Lack of any pain in the region of the lower back or lower limbs lasting more than two weeks, or pain requiring medical intervention (e.g. by a GP, nurse, or physiotherapist) at least during the three months before recruitment.
- Lack of any (even minor) injuries in the mentioned areas during the period of two weeks before the examination.

Out of the group of 40 volunteers, 16 subjects aged (mean ± SD) 21.87 ± 1.5 years, with a height of 179.09 ± 4.55 cm, and abody mass of 73.16 ± 8.19 kg were qualified. All of them signed the Informed Consent Form. The study was approved by the Institutional Ethical Committee.

Equipment

To measure the trunk range of motion, the BTS Smart (three dimensional biomechanical movement analyzer) was used (BTS Bioengineering S.p.a, Milan, Italy). The BTS Smart unit emits infrared beams that are reflected by the markers mounted on the surface of the body back to the capturing cameras.

The accuracy of linear and angular measurements was verified using mechanical models (micrometric screw, Saunders inclinometer). Using six cameras and the frequency of 60 Hz, a precision of 0.1 mm and 0.5^0 was achieved.

The measuring tool (basic software) contains three integrated computer programs: Smart Capture, Smart Tracker and Smart Analyzer.

The markers used were a custom made version of standard semi-spherical markers of 1 cm in diameter. Each of them consisted of a plastic base with a small nut inside and a head with a small screw.

Procedure

During the preparation stage it was important to position the cameras so that each marker was visible for at least two of them at every point of the movement trajectory. Then the tool was calibrated. A square was also drawn on the floor to mark the desired position of the subject's feet.

Before the commencement of the procedure, each of the participants received information concerning the flow of the examination. Everyone was told that all movements should be performed at a comfortable speed and with a maximal, but not forced range; and that all unpleasant sensation should immediately be reported to the researcher.

On the back of the subject, points were marked, on which semi spherical markers were mounted. Researchers measured the distance from the C7 spinous process to the line joining the two posterior superior iliac spines (PSIS). This distance was divided into three equal sections giving rise to 4 points in effect. The three lowest of them were used to attach central markers: upper thoracic, lower thoracic and lumbar. The sacral central point was located 5 cm below the lumbar central point. Horizontal distances of 10 cm to the right and to the left were taken both from the central upper thoracic and central lower thoracic points. At their ends, the thoracic left and right markers and the lumbar left and right markers were assembled, respectively. The left and right PSIS served as attachment points for the "so called" left and right sacral markers. This way the three triangles were created: lower thoracic, lumbar and sacral (Fig. 1).

The operation of mounting the markers was an important element of the process. First the points were marked on the skin and pieces of double sided sticky tape were stuck onto them. Then the base of each marker was attached and secured with a layer of Kinesiology Tape (K-Active Tape, Japan). The semi spherical head of the marker was screwed onto the base. This construction prevented markers from any undesired displacement on the surface of the skin.

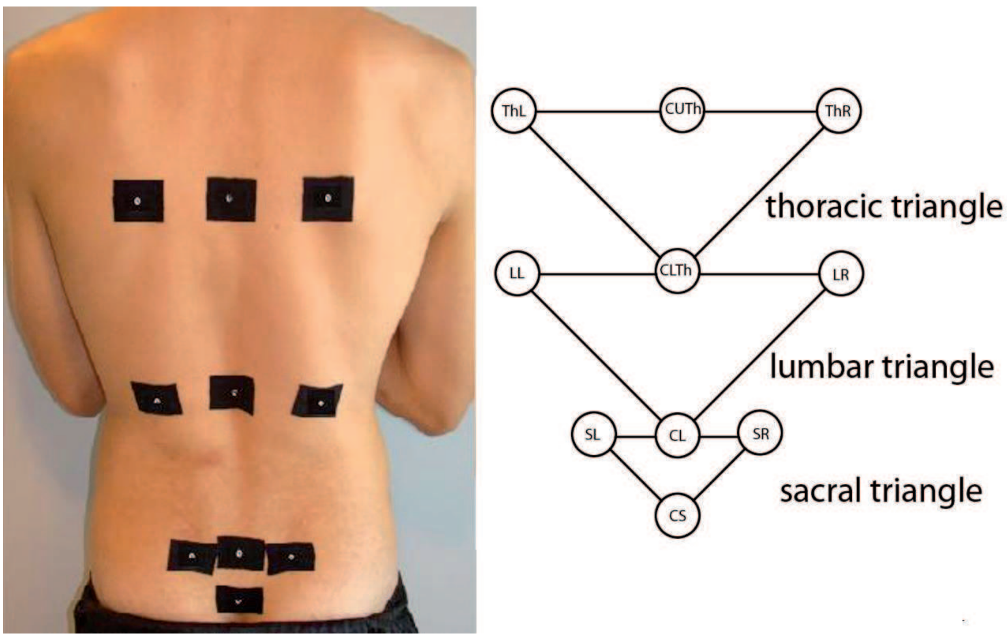
Each subject assumed a standing position on the marked square and a test series of movement sequence was carried out. Each movement proceeded as far as possible and at a comfortable, self administered pace. The order of performing individual movements was constant – rotation was always executed first. Each subject crossed his arms on the chest and the movement was started from the cervical spine then spread to the thoracic and lumbar spine, and finally involved pelvic rotation. From this end position each subject rotated his body maximally towards the opposite side (with no stopping at zero) and after reaching his end range went back to zero position. This sequence was repeated six times. After completing three trials the side to start the movement with was changed (e.g. the first three trials starting to the left, the three others – to the right). Particular attention was focused on maintaining the clear transverse plane of this motion, bending the knees, taking their feet off the floor and standing "as erectly as possible". Using the same position each subject performed the sequence for lateral flexion. The test trial was done first – initiating movement from the cervical spine going down to the thoracic and finishing with the lumbar – and the six experimental sequences were performed later.

The same movement sequences were administered in a sitting position. The only difference was that while performing rotation, the subject was not allowed to move the pelvis and during lateral flexion he might lift his buttocks from the couch. Thanks to this, a full range of lumbar motion was available.

Functional asymmetry of the spine

To describe the degree of the functional asymmetry of the thoracic and lumbar spine, mean ranges recorded

Fig. 1
The three triangles created by the markers on the subject's back (markers: CUTh – central upper thoracic; ThL – left thoracic; ThR – right thoracic; CLTh – central lower thoracic; LL – left lumbar; LR – right lumbar; CL – central lumbar; SL – left sacral; SR – right sacral; CS – central sacral)



during 6 trials were used. Both for rotation and lateral flexion the Functional Asymmetry Ratio (FAR) was used in the following form: FAR = [|R – L|/(R + L)]*100 where R – range of right rotation/lateral flexion (mean of 6 records), L – range of left rotation/lateral flexion (mean of 6 records).

This way FARs for rotation and lateral flexion in the thoracic and lumbar spine in both sitting and standing positions were calculated.

Statistical analysis

A database was created using Statistica software (Version 6.0, StatSoft, Inc.) which automatically calculated the mean values of the desired ranges of motion and FARs. Differences between standing compared to a sitting position were investigated using variance analysis (ANOVA) with three explanatory variables. Independent factors were: the spinal section (L vs. Th) and the plane of the movement (frontal vs. transverse). The repeated measurements factor was the position of the body (standing vs. sitting). A post hoc investigation using Tukey's test was also performed. For all calculations a critical α level was set at 0.05.

RESULTS

To demonstrate differences in individual components of our FAR formula between standing and sitting positions we performed ANOVA for both the absolute difference of the right and left ranges of motion (|R – L|) as well as the sum of the right and left ranges of motion (R + L). This should explain whether eventual differences in FAR were introduced by increasing/decreasing absolute differences between the sides or increasing/decreasing the total range of motion. Below (TABLE 1)

TABLE 1

Results of ANOVA for interaction: spinal section × plane of movement × body position; the absolute difference between the right and left ranges of motion (|R – L|) as well as the sum of the right and left ranges of motion (R + L). Presented are mean values [degrees] of the two parameters together with 95% confidence intervals (CI) and p levels of the Tukey test.

Plane of movement	Spinal section	Parameter	Standing mean (95% CI)	Sitting mean (±95% CI)	p level
		|R – L|	2.32 (1.68–2.96)	2.16 (1.56–2.77)	NS
	TH	R + L	36.16 (32.82–39.50)	39.38 (36.25–42.52)	NS
		|R – L|	1.16 (0.52–1.80)	1.23 (0.62–1.83)	NS
Transverse	L	R + L	25.52 (22.18–28.86)	28.90 (25.76–32.04)	NS
		|R – L|	1.13 (0.49–1.77)	1.74 (1.14–2.35)	NS
	TH	R + L	41.46 (38.12–44.80)	41.16 (38.02–44.29)	NS
		|R – L|	1.60 (0.97–2.24)	1.49 (0.88–2.09)	NS
Frontal	L	R + L	23.61 (20.27–26.95)	12.83 (9.69–15.97)	< 0.001

TABLE 2

Detailed results of variance analysis

Effect	SS	Df	MS	F	p
Plane	189.167	1	189.167	4.2581	0.043396*
Spinal section	275.971	1	275.971	6.2121	0.015467*
Plane × spinal section	436.335	1	436.335	9.8219	0.002668*
Error	2665.479	60	44.425		
Position	167.431	1	167.431	9.6348	0.002912*
Position × plane	206.172	1	206.172	11.8642	0.001050*
Position × spinal section	35.908	1	35.908	2.0663	0.155779*
Position × plane × spinal section	106.850	1	106.850	6.1487	0.015977*
Error	1042.663	60	17.378		

Legend:
SS – *sum of squares*
Df – *degree of freedom*
MS – *mean square*
F – *F statistic results*
* – *statistically significant*

we demonstrate the results for interaction: spinal section × plane of movement × body position; which seems most important for the further analysis of the FARs. Presented are the mean values of the two parameters together with 95% confidence intervals and p levels of the Tukey test for this interaction.

In this study the most important parameter was FAR. Below presented are all the main effects of variance analysis for this dependent variable and their interactions: plane of movement × spinal section, body position × plane of movement. Interaction: body position × spinal section did not occur in a statistically significant manner, whereas the interaction: spinal section × plane of movement × body position did not give any additional information and thus the authors decided to skip that. Detailed results of the analysis are shown in TABLE 2.

Main effect – body position

Functional asymmetry of the spine increased significantly in a sitting position ($p < 0.01$). In standing, FAR was about 5.06 (95% confidence interval (CI) 3.80–6.31), however in sitting it reached the level of 7.34 (95% CI 5.83–8.86).

Main effect – plane of movement

Variance analysis demonstrated significant differences between FARs in both the frontal and transverse planes ($p < 0.05$). For rotation the mean FAR was about 4.98 (95% CI 3.32–6.65), whereas for lateral flexion it was 7.41 (95% CI 5.75–9.08).

The main effect – the spinal section

The lumbar and thoracic sections FAR were significantly different ($p < 0.05$). The mean of FAR in the lumbar spine was equal to 7.66 (95% CI 6.00–9.33) and was lower than that of the thoracic section FAR – 4.73 (95% CI 3.06–6.40).

Interaction – body position × plane of movement

For this interaction ANOVA demonstrated a significant outcome ($p < 0.01$). Post hoc Tukey's test reveled a lack of significant differences in FAR between the transverse ($\bar{X} = 5.11$; 95% CI 3.34–6.88) and frontal planes ($\bar{X} = 5.00$; 95% CI 3.23–6.77) in standing ($p > 0.05$). In sitting this difference was, however, of significant relevance (respectively: $\bar{X} = 4.86$; 95% CI 2.72–7.00; $\bar{X} = 9.83$; 95% CI 7.69–11.97; $p < 0.05$) (Fig. 2).

Interaction: plane of movement × spinal section

In this case we can demonstrate a significant outcome of ANOVA as well ($p < 0.01$). The post hoc Tukey's test revealed a lack of significant differences of FAR between the thoracic ($\bar{X} = 5.36$; 95% CI 3.00–7.72) and lumbar sections ($\bar{X} = 4.61$; 95% CI 2.25–6.96) in the transverse plane but proved them to be significant in the frontal plane (respectively: $\bar{X} = 4.10$; 95% CI 1.17–6.46; $\bar{X} = 10.73$; 95% CI 8.37–13.09; $p < 0.01$) (Fig. 3).

Fig. 2
Mean values of the Functional Asymmetry Ratio (FAR) for ANOVA interaction: body position × plane of movement (whiskers indicate 95% confidence interval)

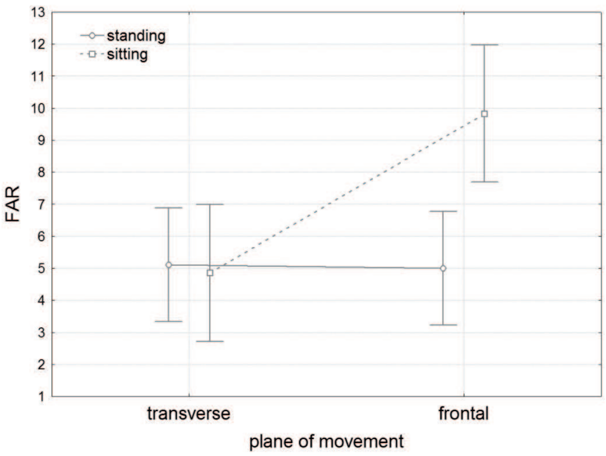
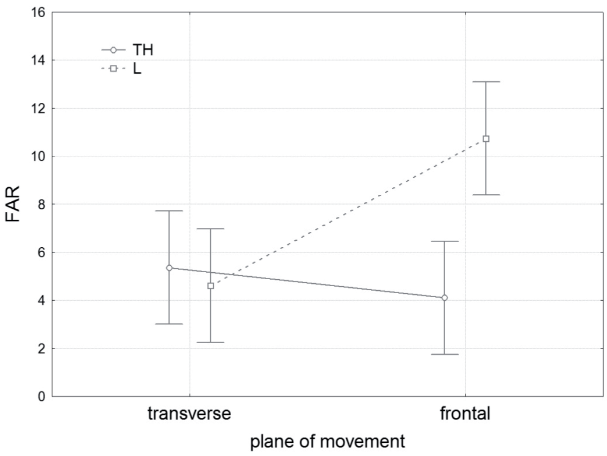


Fig. 3
Mean values of the Functional Asymmetry Ratio (FAR) for ANOVA interaction: movement plane of movement × spinal section (whiskers indicate 95% confidence interval)



DISCUSSION

The results obtained seem to prove the hypothesis that two potential negative factors – sitting position and the functional asymmetry of the human body – have something in common. Asymmetry in a sitting position is significantly larger than in a standing position. Besides this we discovered that the asymmetry of the lumbar section outnumbers the asymmetry recorded in the thoracic spine and asymmetry on the frontal plane exceeds transverse plane asymmetry. It is possible, however, to develop the idea that these differences could be associated with a significant decrease in the total range of lumbar spine motion on the frontal plane (TABLE 1) which would influence the denominator of our formula in cases of almost all individual comparisons following ANOVA. Our evidence concerning the association between functional asymmetry and a sitting position must be therefore treated as speculative and this issue needs further investigation. Asymmetry ratios increase, but this seems more likely to be associated with a decreasing range of motion rather than an increase in the absolute difference between mobility towards the right and left sides. In several cases we were able to observe an increase in the absolute difference between sides, but this was always lacking statistical significance.

Nevertheless we will try to speculate slightly on our results which may provide valuable input for the reader struggling with similar problems.

It seems also that actions taken to reduce the influence of personal variability in the positioning of the spine and trunk during the procedure requiring subjects to perform movement in an erect position (spine elongation) might have played an important role. This position was unnatural and it is not really used in everyday life. The next standardizing procedure was that subjects were forced to perform movement as parallel as possible to the given plane reference. Here, we must consider the fact that everyday motor performance consists of complicated three dimensional spinal trajectories, not "right-angle" movements. These two factors could exert some impact on the results.

In the introduction two opposing points of view on the human body asymmetry were presented. One of them suggests that asymmetry constitutes a common and physiological phenomenon, the other claims that asymmetry is associated with pathology. Taking into account all these contradictory arguments, the authors' will is to maintain a neutral attitude. After a critical look at the recorded results (possibly a larger functional asymmetry in a sitting position) we also offer the opposite thesis: if the spine of young, healthy and active persons starts to function in more asymmetric patterns in sitting than in standing positions, maybe we should consider this phenomenon within the category of usefulness?

We can presume that increased functional asymmetry in a sitting position is used as a means for energetic cost optimization while sitting for a long time. Over the time period of billions of years, organisms on Earth were adapting to their changeable environment gaining in this way their right to survive. This is why the form and function of an organism are constantly changing in pursuit of using the energetic potential in the most rational way. Every human being from birth to death is also constantly utilizing this law, either consciously or not. Maybe the greater functional asymmetry observed in the lumbar spine section in a sitting position constitutes a manifestation of the above mentioned mechanism.

In a standing position, our nervous system has greater freedom in motion control due to the possibility of engaging hip and ankle joints. A greater degree of freedom may cause reduced differences between the dominating and non dominating sides of the body as a result. We may speculate that more symmetrical ranges of motion in a standing position are an outcome of this fact. In a more restricted sitting position the nervous system has fewer possibilities of completing any motor task and thus it chooses those patterns which it can control more easily.

The presented speculations can be considered to be an interesting source of further research problems. Investigating the phenomenon of functional asymmetry in connection with body lateralization seems to be a significant issue. Experiments exploring this field would make it possible to verify the hypotheses mentioned above and contribute to the knowledge of the functional asymmetry of the human body.

CONCLUSIONS

- Functional asymmetry of the spine in a sitting position seems to be greater than in standing.
- This may be, however, associated with a decreasing range of motion rather than increasing the absolute difference between mobility towards the right and left side.
- In a sitting position, a significant decrease in the lumbar spine range of motion was recorded in the frontal plane.
- The recorded frontal plane functional asymmetry of the spine was greater than the transverse plane asymmetry and the functional asymmetry of the lumbar section of the spine was larger than the asymmetry of the thoracic section. Again, these differences may have occurred due to a decrease in the total range of the frontal plane motion of the lumbar spine.
- Results suggest that a sedentary lifestyle may add to the functional asymmetry of the spine increasing the risk of excessive load and making tissue prone to injury. This issue may be addressed in prophylactic and therapeutic protocols.

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FUNKČNÍ ASYMETRIE PÁTEŘE VSTOJE A VSEDĚ

(Souhrn anglického textu)

VÝCHODISKA: Sedavý styl života a funkční asymetrie těla představují potenciálně dysfunkční faktory.

CÍL: V tomto projektu se autoři snaží zjistit vztah mezi sedavým stylem života a mírou funkční asymetrie páteře.

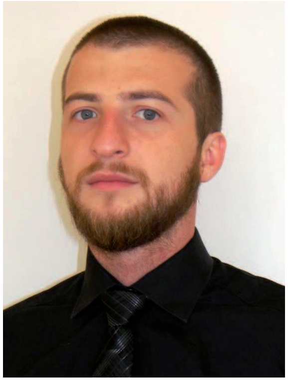
METODY: Experimentu se zúčastnilo šestnáct mužů – dobrovolníků ve věku 19–25 let. Šlo o studenty Akademie tělesné výchovy v Katovicích. K měření pohybů trupu byl použit system BTS Smart. Míra funkční asymetrie byla popsána jako koeficient funkční asymetrie (Functional Asymmetry Ratio, FAR), vypočtený z rozsahu pohybů trupu ve frontální a horizontální rovině.

VÝSLEDKY: Vyšší hodnoty FAR byly zjištěny v poloze vsedě ($p < 0,01$). Funkční asymetrie ve frontální rovině byla vyšší než asymetrie v horizontální rovině ($p < 0,05$) a asymetrie bederní páteře převýšila hodnotu zaznamenanou u hrudní části ($p < 0,05$).

ZÁVĚRY: Spojení mezi sedavým stylem života a funkční asymetrií těla je možné. Společně se zvýšeným užíváním sedavých poloh v každodenním životě se může také zvyšovat asymetrické namáhání páteře.

Klíčová slova: rozsah pohybu, rotace, laterální flexe, hrudní, bederní.

Maciej Biały, PT



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