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**ORIGINAL PAPER**

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# Statodynamic characteristics of the spine in a sitting position

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**ABSTRACT**

**Introduction.** Due to the unprecedented development of media and information technology, modern lifestyles have been changing from active to passive (sedentary). A sitting position dominates today both in the professional and the non-professional sphere of people's life. It seems that a human does not realize what is the position of individual segments of his body, especially the torso while sitting. The torso, as the segment with the highest mass, is the source of the highest mechanical loads acting on the spine. Hence, in the habitual sitting posture, the optimal spine position has been lost.

**Objective.** The aim of this study is to analyze statodynamic parameters of the spine in a sitting position and answer the question which of them determine the habitual sitting posture.

**Material and methods.** The study included 372 people declaring themselves as healthy. The research program consisted of statodynamic parameters of the spine in a standing position and in 6 sitting positions: sitting position freely, favourite sitting position, sitting position with a crossed leg over the right and left thigh, and sitting position with a feet resting on the left or right knee.

**Results.** The conducted research has shown that setting the spine in a habitual sitting posture is determined only by a change in the statodynamic parameters in the sagittal plane and generally does not depend on the range of motion in other planes.

**Conclusions.** Habitual sitting postures are determined by the size of angles of the *thoracocervical* and thoracolumbar transitions as well as the size of the amplitude of the pelvic movements. The research has indicated worrying trends to misuse of kinematic redundancy in the spine while sitting in the sagittal plane.

**Keywords**. maladaptive postural behaviour, statodynamic parameters, sitting position

## Introduction

Due to the unprecedented development of media and information technology, a modern lifestyle has been changing from active to passive (sedentary). A sitting position dominates today both in a professional sphere and in non-professional parts of life.[12,3,4,5] It is also visible in our country due to the fact that about 40% of Poles work in a sitting position and over 60% spend their free time in a passive way. [6] Therefore, we can see that mental activity and intellectual effort replace the physical activity and physical effort that shape human health to a large extent. It is obvious that sitting is an essential and natu-

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ral element of a human life from an early age. However, a permanent sitting with elimination of all types of physical activity impairs the adaptive mechanisms of a human body. This is particularly visible in an organ of movement and concerns the main axis of the body, i.e. the spine. The human body, as a self-regulating system with a multi-element structure, reaches various compromises associated with minimization of functional costs while sitting. We can notice this phenomenon especially in the sagittal plane in which the asymmetric mass distribution of the upper body is balanced. It seems that a human does not realize the positioning of individual segments of his body while sitting, especially when we consider the torso. The torso, as the segment with the largest mass, is the source of the greatest mechanical loads, i.e. forces and their moments acting on the spine. It is worth mentioning that the most important element that arranges the human body in a sitting posture is the position of the head and the need to meet visual requirements. We cannot disregard the significance of postural behaviour and space geometry in the process of adapting the human body to the sitting position. That is why, in a habitual sitting posture the maladaptive torso position and the optimal spine position are lost in the hypothetical neutral zone of Panjabi[7]. It leads to postural disorders and in time to overload and pain changes of the spine, which constitute a significant medical disorder. At the same time, overload and pain problems due to their prevalence constitute a significant socio-economic problem.[8,9]

## Objective of the work

The aim of this study is to analyze the statodynamic parameters of the spine in a sitting posture and answer the question which of them determine the habitual sitting posture.

## Material and test method

372 people, who declare healthy and professionally active lifestyles, have been examined. Participation in the research was voluntary. The inclusion criteria were a lack of diseases of the locomotor system and surgical procedures and spinal injuries. The studied group included 212 women and 160 men aged 20-50 years ($\bar{x} = 36{,}55$), with people under 40 years of age, accounting for 60.22% of respondents, i.e. 224 people. The average body weight of the subjects was 71.51 kg and the average height was 169.63 cm, while the average BMI was 24.76 and WHR 0.83. The research program consisted of statodynamic measurements of the spine in a standing position and in 6 sitting positions: sitting position freely, favorite sitting position, sitting position with a crossed leg over the right and left thigh, and sitting position with a foot resting on the left or right knee. These were the measurements taken:

- angles of particular transitions of the spine in the sagittal plane measured with the V-Rippstein plurimeter with an accuracy of ± 1 °. The plurimeter was placed at the base of the sacrum and the segment $L_4$-$L_5$ in the measurement of the lumbosacral transition. The angle of the thoracolumbar segment was measured at the level of the $Th_{12}$-$L_1$ segment. The *thoracocervical* transition was measured by placing the base of the plurimeter at the level of the $Th_1$-$C_7$ segment, whereas the craniocervical angle was measured at the base of the cranium ($O_{cc}$-$C_1$ segment)
- angular size of curvatures of the spine, which were calculated by summing up the angles of the vertebral column transitions in the sagittal plane. The angle of lumbar lordosis was formed by the sum of the lumbosacral and thoracolumbar angles, the angle of thoracic kyphosis gave the sum of the thoracolumbar and *thoracocervical* angles, whereas and the cervical lordosis angle was formed by the sum of the *thoracocervical* and craniocervical angles
- pelvic flexion and extension are also measured by a plurimeter placed at the height of the sacral segments
- ranges of three-dimensional motion of the spine in the cervical and lumbar segments are determined by the use of the Zebris CMS 10 set based on signals received from ultrasonic sensors with an accuracy of 0.1 ° fixed at the occipital protuberance and segment $C_7$-$Th_1$ and at the base of the sacrum and vertebra $Th_{12}$
- projection lengths of the spine in the habitual posture and during auto-elongation were measured with the anthropometer with an accuracy of ± 1 mm. On their basis, the kyphotisation indicators have been calculated on the basis of the formula (authorship of researchers)

$$K = \frac{w - z}{w} \times 100\%$$

where: w = the projection length of the spine in auto-elongation

z = the projection length of the spine in the habitual posture.

All the research procedures were carried out with the approval of the University Bioethics Committee for Scientific Research and according to the Declaration of Helsinki 1978, amended in 1983.

The obtained results were used for statistical analysis, in which the descriptive statistics were first used in order to present the study group and determine its statistical features. Then, a test statistic was applied, suitable for the objectives set for this research. This was the analysis of variance for repeated measurements of the projection lengths of the spine and factor analysis, which allowed to assess the sitting posture and identify indicators determining the orthogonal space and describing the phenomenon of a human kyphotisation. Further, factor analysis of other statodynamic parameters was performed in order to determine their impact on spinal setting (kyphotisation) at various positions. Statistical significance was set at $p < 0.05$.

## Results

A kyphotisation indicator, which describes a certain situation important for clinical diagnosis consists of seven components, that is one indicator in a standing position and six indicators in sitting positions: sitting position freely, sitting position with a crossed leg over the left or right thigh, sitting position with a foot resting on the left or right knee and favourite sitting position. It turned out that all components of the kyphotisation indicators are variables with factor loading values > 0.7. Among them, three most representative indicators were selected by factor analysis, which do not correlate with each other and describe the phenomenon of spinal kyphotisation. They are: a kyphotisation indicator in a sitting position with a foot resting on the knee, an indicator in a favourite sitting position and a kyphotisation indicator in a standing position. Then, the remaining statodynamic parameters of the spine were subjected to factor analysis in order to determine their effect on the components of the kyphotisation indicator. As a result of this analysis, variables with absolute values of factor loadings > 0.7 were derived. Among them there were nine independent variables with the highest values of factor loadings, which describe the statodynamic variability of the spine in 83.2%. Then, in the course of multiple regression by means of backstep analysis, the effect of selected statodynamic parameters on the kyphotisation of the subjects, based on the previously determined components of kyphotisation, was investigated. In the final step, three variables have been left that have a significant (directly proportional) effect on the kyphotisation in a standing position. They are: angle of *thoracocervical* transitions in a sitting position with a leg on the thigh (THC), pelvis flexion in a sitting position with a crossed leg over the thigh (ZM) and pelvic extension in a sitting position with a foot resting on the knee (WM) (Fig. 1). In other words, the indicator of kyphotisation in a standing position depends on the mentioned predictors, i.e. angle of *thoracocervical* segment and pelvis rotation in the sagittal plane. A similar analysis of multiple regression was carried out for the dependent variable of the kyphotisation indicator in the sitting position with a foot resting on the opposite knee, directly proportional by the variables: angle of thoracolumbar transition in the sitting position with a foot resting on the knee (LTH), angle of *thoracocervical* transition in the sitting position with a leg crossed over the thigh (THC) and pelvis flexion in a sitting position with the leg on the thigh (ZM) (Fig. 2). They favour the spine kyphotisation in this sitting position, i.e. the higher they are, the greater chance of kyphotisation in the sitting position. On the other hand, as for kyphotisation in a favourite

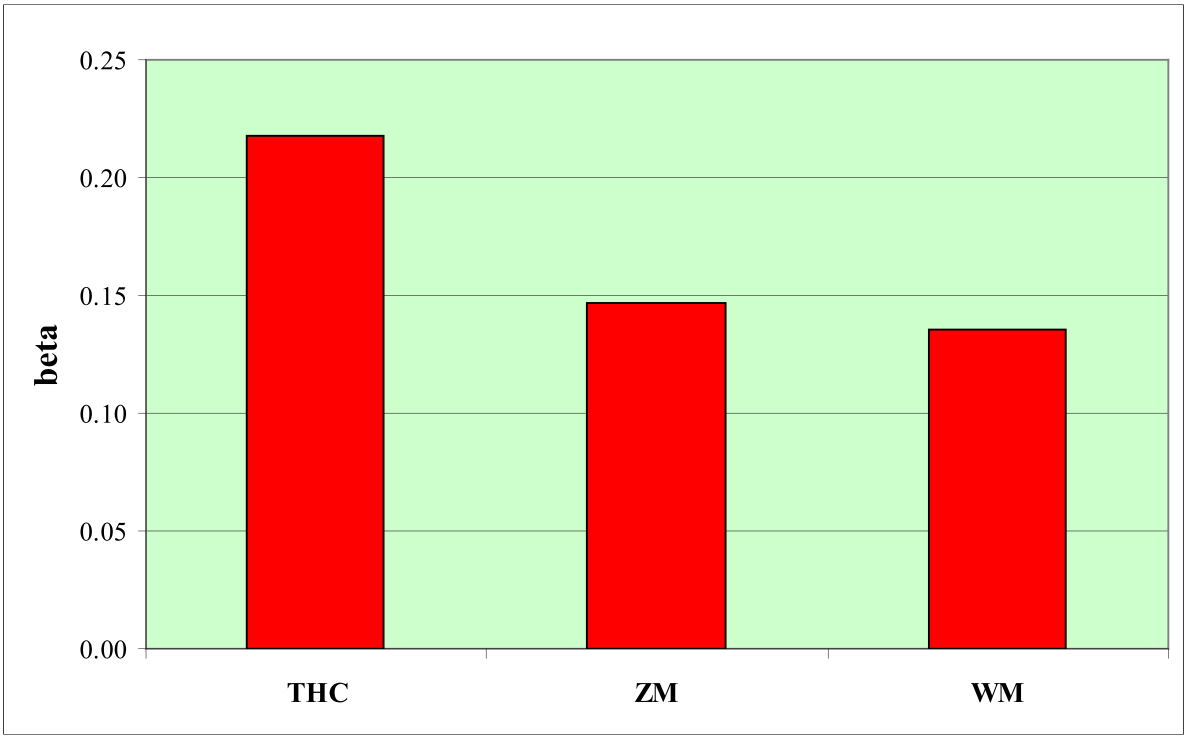


**Figure 1.** The influence of statodynamic parameters on kyphotisation in a standing position

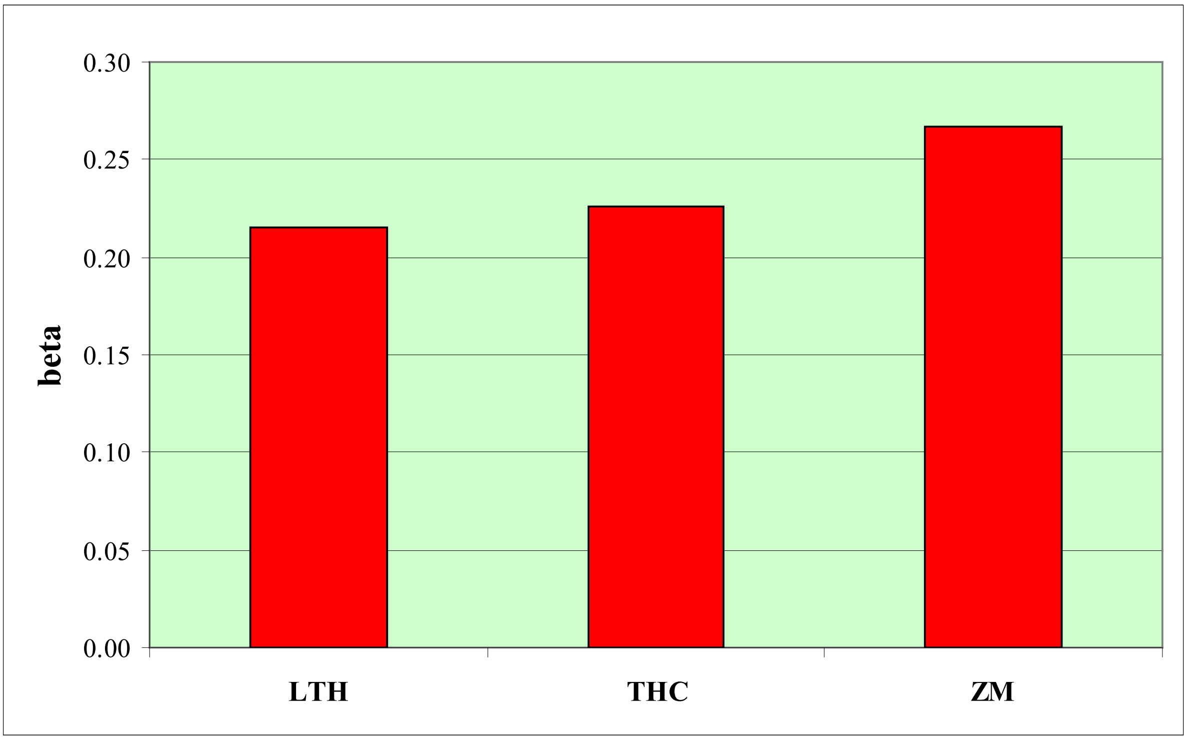


**Figure 2.** Influence of statodynamic parameters on kyphotisation in a sitting position with a foot resting on the knee

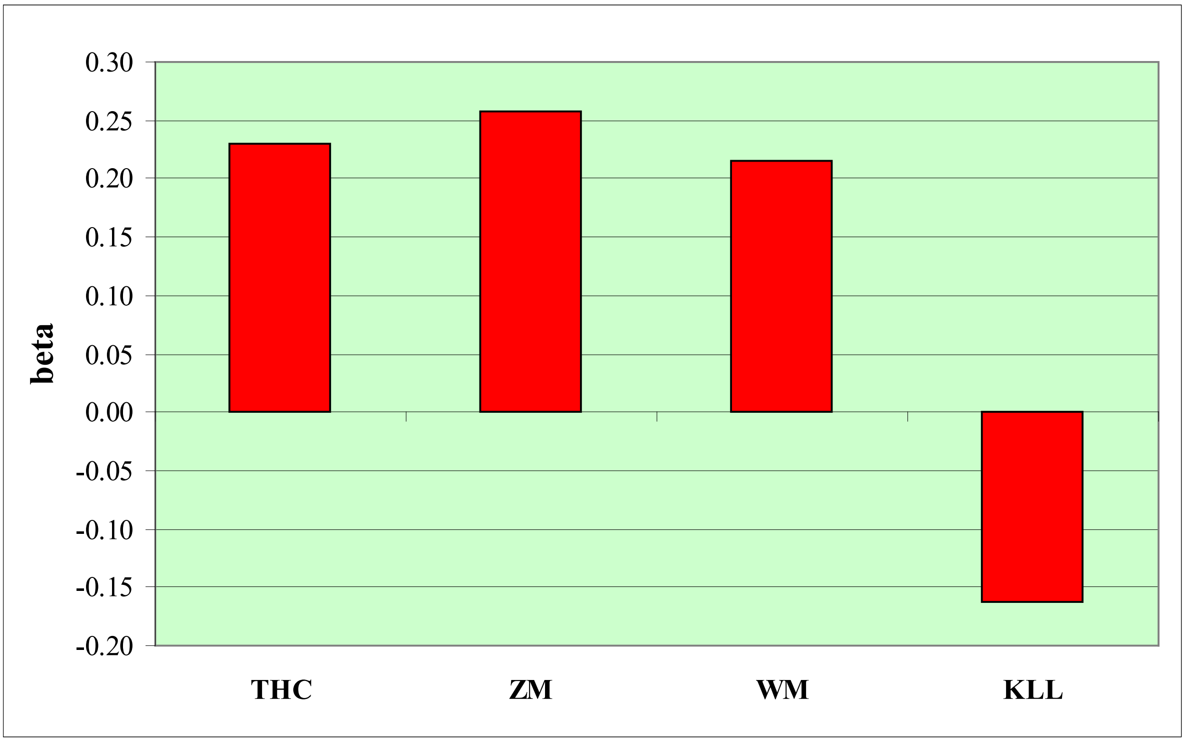


**Figure 3.** Influence of statodynamic parameters on kyphotisation in a favourite sitting position

sitting position, the regression analysis revealed a significant directly proportional influence of independent variables: angle of the *thoracocervical* transition in a sitting position with a crossed leg over the thigh (THC), pelvic flexion in the sitting position with a crossed leg over the thigh (ZM), pelvic extension in the sitting position with a foot resting on the knee (WM) and inversely proportional dependence on the variable of angle of lumbar lordosis in a sitting position with a foot resting on the knee (KLL), therefore the kyphotisation in a favourite sitting position is determined by the size of inclination of the *thoracocervical* transition and pelvic

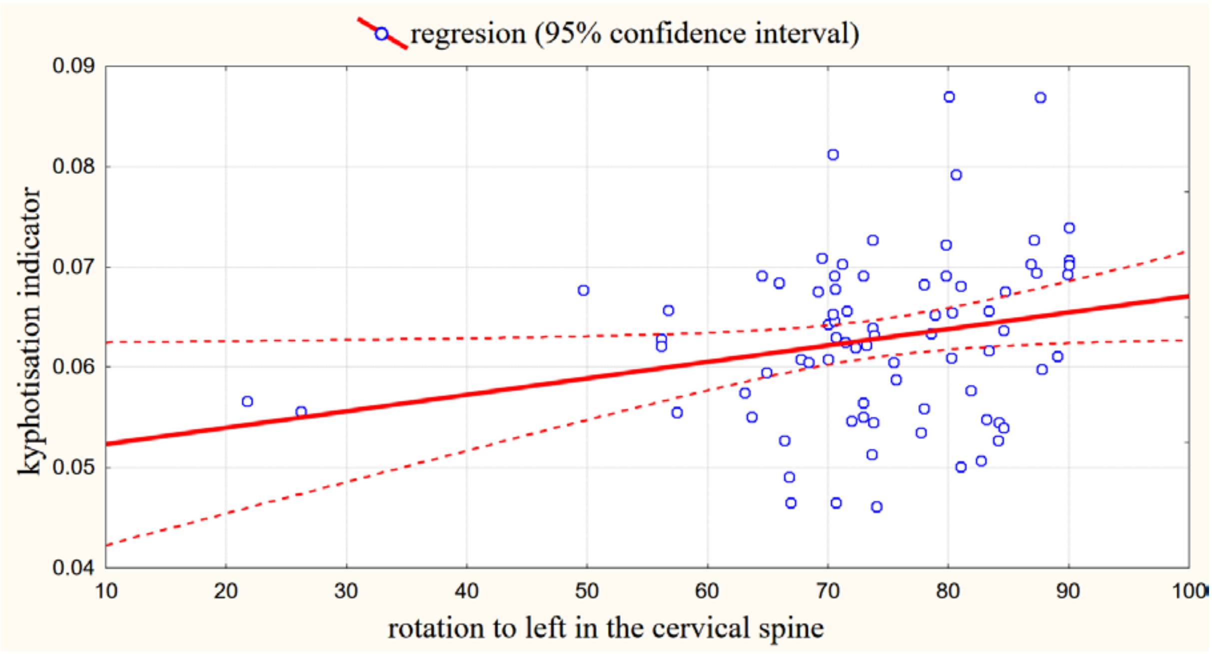


**Figure 4.** Effect of rotation to left in the cervical spine on kyphotisation in a sitting position with a foot resting on the knee

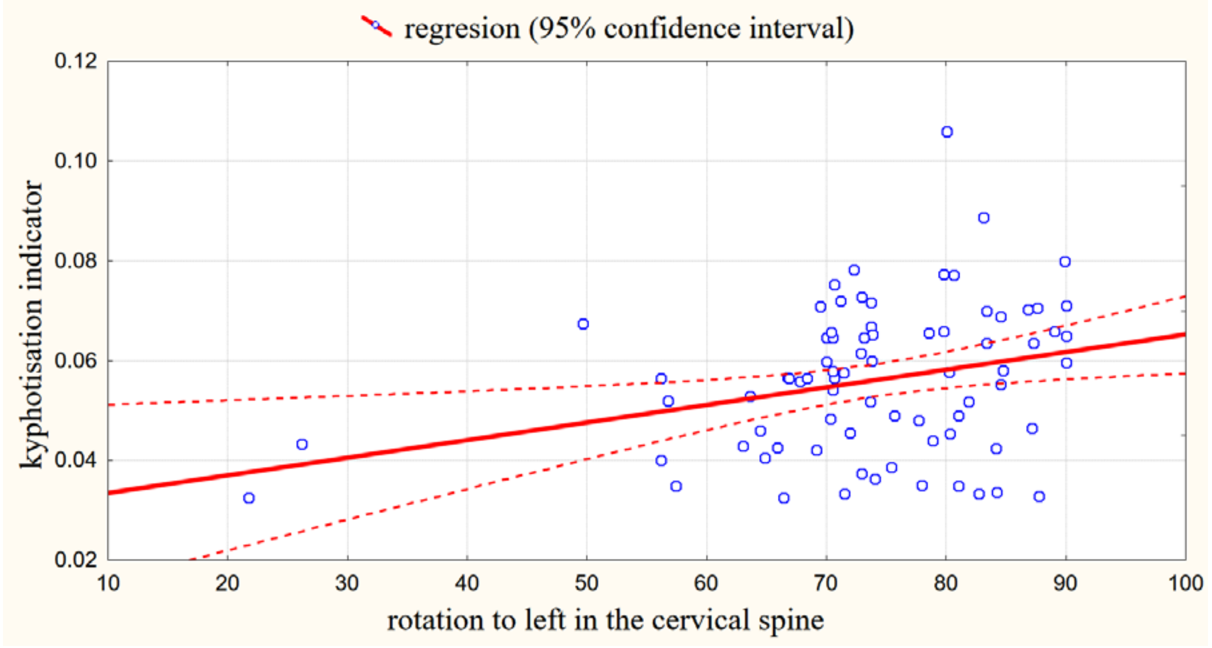


**Figure 5.** Effect of rotation to left in the cervical spine on kyphotisation in a favourite position

flexion and extension, while an increase in the angle of lumbar lordosis causes a decrease in the indicator of kyphotisation (Fig. 3). Factor analysis also included the ranges of motion in the cervical and lumbar sections of the spine to determine their impact on the components of the kyphotisation indicator. Seven factors with the highest factor loadings for the regression analysis were selected. Backstep analysis for the *kyphotisation indicator* in the standing position did not show the influence of any independent variable, i.e. the kyphotisation in this position does not depend on the range of cervical and lumbar spine motion. Only as for the *kyphotisation indicator* in the position with a foot resting on the knee of the opposite leg and the position of favourite sitting, rotation to left of the cervical spine has a positive effect, i.e. the higher rotation to left, the greater tendency to kyphotisation (Fig. 4 and 5).

## Discussion

The sitting posture is shaped by sensorimotor education and belongs to an individual repertoire of postural and movement patterns of a person. The morphological and functional base for the sitting posture is the bone-joint system and muscular-ligament system together with the controlling nervous system, whereas the functional balance between these three systems allows correct stabilization of the spine according to Panjabi.[7] Anatomical-kinematic links between individual segments of the human body while sitting display enormous complexity. The problem of stabilization of the human body, especially the torso, was solved in the phylogenetic process by s-shaped setting of the spinal column in the sagittal plane with greater muscle strength of the extensors in relation to the flexors so that they can effectively counteract the rotational force of gravity and by appropriate pelvic tilt, which results from the balance of muscle strength. However, due to lack of physical activity and muscular effort, deactivation of the locomotor system and functional disorders of the spine stabilizing systems take place, thus the sitting posture. It has been indicated in the research. It turned out that most respondents do not cope with the spatial arrangement of the body in the sitting posture and they automatically take (from the three described types of sitting) a frontal sitting position with the *kyphotic* spinal position. According to Snijders, a frontal sitting position is the most beneficial in the sense of functional expenditure, while a back sitting position is very demanding in terms of energy usage, and an intermediate sitting with the centre of gravity over the ischial tuberosities is unstable.[10] While sitting, quick fatigue occurs as well as failure of muscle stabilizers and shift of stabilization towards fascial-ligamentous structures susceptible to nociception. This leads to the loss of optimal (sigmoidal) spinal position and changes in its statodynamic parameters. This is done through the click-clap phenomenon with counter-nutation of the sacrum and a posterior pelvic tilt and a simultaneous compensatory change in the spinal position. It is obvious that these maladaptive changes have hidden costs in the form of increased static loading and mechanical stress of the intervertebral discs, which may lead to discomfort of sitting. Therefore, researched persons take 2 types of habitual sitting. The first of them (with a higher rate of *kyphotisation)* can be defined as a forced sitting, whereas the second one (with a lower rate of kyphotisation) may be named an antalgic sitting. Probably because of discomfort, the respondents are subconsciously looking for the optimal sitting posture.[11] The *kyphotic* spinal position in both types of sitting is most influenced by angles of the *thoracocervical* and thoracolumbar transitions as well as the rotation of the pelvis controlling the angle of lumbar lordosis. At the position of the spine in a sitting posture with a foot resting on the knee (forced sitting), the angles of *thoracocervical* and thoracolumbar transitions have the biggest influence, as well as a posterior pelvic tilt, while the spine position in a favourite sitting (antalgic sitting) is influenced by the angle of *thoracocervical* transitions and pelvic rotation. At the same time, it turns out that this postural habit is transferred by subjects from a favourite sitting position to a "standing" manner, because *kyphotisation* in a standing position is also determined by the angle of *thoracocervical* transition and pelvic rotation. On the other hand, the angle of lumbar lordosis and in a favourite sitting position remains inversely related to the *kyphotic* spinal position, which corresponds to the research of O'Sullivan and Callaghan. According to them the change in the pelvic-lumbar complex may lead to a change in the motor control of the torso muscles, i.e. the response of the torso muscles remains under the influence of the angle of lumbar lordosis.[12,13] The higher the value of lumbar lordosis is in a favourite sitting position, the smaller the spinal *kyphotisation* and the smaller stoop of the torso. Whereas, the smaller the angle of lumbar lordosis, the greater the spinal *kyphotisation* and the stoop of the torso. This is particularly evident in a sitting position with a foot resting on the knee, because the straightening of the lumbar lordosis results not only in increased *kyphotisation*, but also in the change of the angle size of the thoracolumbar transition. The setting of the spine, and therefore its kyphotisation indicator in both sitting postures also depend on back extensor muscles, which has a so-called weak point around the third thoracic vertebra, predestining to the phenomenon of flexion-relaxation in the course of sitting, i.e. myoelectric silence, which according to Callaghan already appears at the small angle of the lumbar spine flexion in the sagittal plane.[13] This is probably due to the small mass of the local "muscular" area around the third thoracic vertebra and the upper body stabilization, and especially the upper limb girdle joined only functionally to the trunk with the fascial-ligamentous system, which increases the bending moment of the thoracic spine in the upper section and thus increases the angle of *thoracocervical* transition in both types of sitting. In other words, the change in the size of the angle of the *thoracocervical* transition determines directly proportional *kyphotisation* of the spine in both types of habitual sitting. In turn, the pelvic rotation (flexion and extension movement) in the position of a favourite sitting position corresponds to the research conducted by Vergara et al., who consider pelvic postural changes during sitting (called macro movement) as a good indicator of discomfort in the back and especially of the lumbar spine.[14] Moreover, Callaghan and Mc Gill in their studies also observe a dynamic strategy of sitting associated with frequent changes in the pelvis and loins, which is explained by the mechanism of fatigue of muscle stabilizers.[15] Therefore, considering the conducted research it can be concluded that the habitual sitting posture is instinctively modified due to discomfort or back pain. Thus, the second sitting posture is not accidental, it only gives the possibility of migrating the loads between the muscular-ligamentous structures stabilizing the spine and allows for hydration of the intervertebral discs. The conducted analysis shows that subjects during the sitting dangerously use kinematic redundancy of the spine (61 °) and pelvis (15 °) by pelvic maladaptation and compensatory changes in the position of the spine in the sagittal plane. This results in a change in statodynamic conditions and at the same time it is a manifestation of pathological postural motility. Kinematic redundancy of the motion system is beneficial only in the case of pathology, because it gives the opportunity to adjust the lack or functional deficiency by controlled compensation during the rehabilitation treatment. Compensation is reserved for use in medical conditions as so-called "rehabilitation potential". Thus compensatory mechanisms should not appear in healthy people in the course of sitting as adaptation strategies resulting from poor physical efficiency and low "threshold" of peripheral fatigue, which is accompanied by central fatigue associated with the demand for relief and static position change. The studies also show that setting the spine in a habitual sitting posture is determined only by a change in the statodynamic parameters in the sagittal plane and does not depend essentially on the range of motion in the other planes. Only rotation to left in the cervical segment has a positive effect on the *kyphotic* spinal position while sitting, which is probably a kind of functional habit associated with the adjustment of the head to organize a work station, for example a computer monitor. The cervical segment rotation is a very beneficial form of adaptive activity from the point of view of energy costs while working in a sitting posture, due to the fact that it does not move the centre of gravity of the head in relation to its fulcrum. Thus, we can see that the surveyed persons use incorrectly the kinematic redundancy of their motor system while sitting by creating maladaptive postural-motor patterns, which will cause in time degenerative overload changes in the spine. To sum up, it should be stated that a modern "Homo sedentarius" should use various preventive and therapeutic strategies that will help maintain optimal spine stabilization while sitting. For this purpose, the most often used exercises are strengthening the muscles of the pelvis and loins complex, which, improving motor control, contribute to the reduction of spinal overload and pain problems. However, according to some authors, they are insufficient and sometimes even unnecessary.[16,17,18,19] It seems that people with a sedentary lifestyle should reach primarily for cognitive therapies, and among them especially for educational programs such as "explain pain" or strategies for counteracting spinal overload and pain problems.[20,21,22]

## Conclusions

1. Habitual sitting postures are determined by the size of angles of the *thoracocervical* and thoracolumbar transitions as well as the size of the amplitude of the pelvic movements.
2. The research has indicated worrying trends to misuse of kinematic redundancy in the spine while sitting in the sagittal plane.

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