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Application of Euclidean geometry in the assessment of body posture in a sitting position

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Abstract

Introduction: The analysis of the literature and the results of my research and experience showed the need to search for biomechanical criteria that will make it possible to describe the body shape, especially in a sitting position, and will facilitate the implementation of therapeutic measures.

Aim: Application of Euclidean geometry in the body posture assessment.

Material and methods: The study uses Euclidean geometry and the concept of common sense to define mutual relationship of the position of the body of the sternum, the sacrum, thoracic kyphosis and lumbar lordosis. The findings are the result of long-time population observations.

Results and discussion: The criteria found in the process of my clinical observations and studies allowed me to show close relationship of simultaneous movements and positions of individual parts of the body, i.e. the body of the sternum and the sacrum, as well as thoracic kyphosis and lumbar lordosis in relation to each other. On the basis of Euclidean geometry, this relationship was equated with the shape of a triangle, showing that common relationship between the specified body parts, the so-called 'common sense,' could be a method of assessing the body posture in a sitting position.

Conclusions: (1) The movement of the sternum and sacrum system as well as a thoracic and lumbar spine are biomechanically correlated with each other. (2) Positioning the sternum to the value of the angle α may be a tip on how to control the body posture.

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1. INTRODUCTION

Modern ways of individual behaviour, especially the use of smartphones and tablets, imply the necessity to consider what the population will look like in the next decades of social phenomena. In this context, it should be assumed that sitting is one of the main daily activities. This activity accompanies each person throughout their lives. The average time spent in a sitting position is 346.2 minutes per day and varies depending on age, education and a geographic region, and can reach the value of 1020 minutes per day in some communities.[1] In the light of these reports, the quality of posture while sitting is an important issue.

Proper sitting is characterized by free spine extension with moderate lumbar extension. The purpose of maintaining this position is to ensure, among other things, reduced load on the intercellular joints compared to the positioning of spine sections in the final range of motion.[2,3] This position is recommended, i.a. for the following reasons: improving the function of the respiratory system[4–6] or regular compression load of the fibrous ring and maintaining shock-absorbing properties of the spine.[7–9] The opposite of the correct sitting position is the passive flexion position – slump position.

Spinal flexion increases pressure inside the spinal cord, which results in disturbances in blood flow and perfusion, leading to disturbances in oxidative metabolism in mitochondria of spinal cord neurons,[10] thus affecting axonal transport and nerve conduction disorders.[11] Remaining in flexion positions disturbs, i.a. the respiratory cycle, resulting in the reduction of respiratory capacity and minute capacity of lung ventilation,[4] problems with intestinal peristalsis,[12] or passage of intestinal gases.[13] The presented findings on clinical complications of incorrect sitting call for the search for the parameters that would assess the quality of the sitting position.

It should be emphasised that contrary to the common view that correct posture is the result of the sum of strength of muscles and muscle groups, it is primarily conditioned by the integration of visual, vestibular and somatosensory stimuli.[14–17]

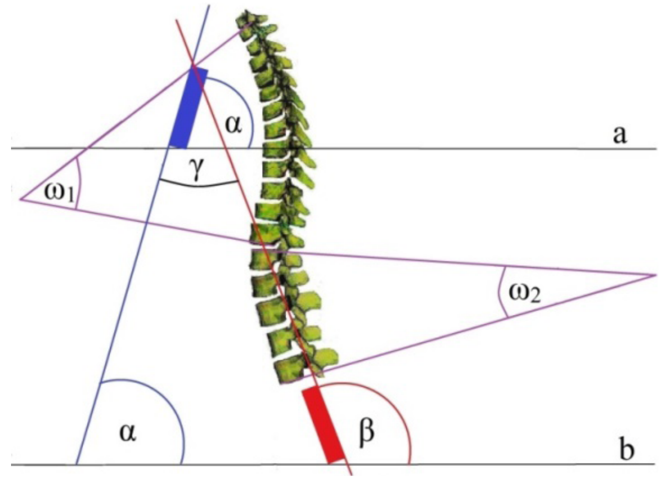

Figure 1. The common system of the position of the sternal body and the sacrum in relation to thoracic kyphosis and lumbar lordosis.[20]

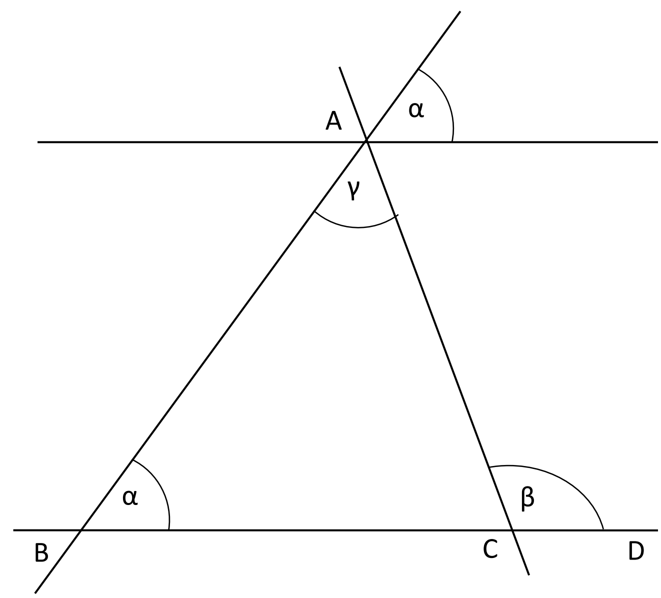

Figure 2. The system of the line of the sternal body AB and the line of the sacrum AC in the triangle.[20]

2. AIM

Application of Euclidean geometry in the assessment of body posture.

3. MATERIAL AND METHODS

The analysis of the literature on the discussed issues and the findings of my research[18,19] showed the need to search for such biomechanical parameters which will allow to describe the body posture in a sitting position. Therefore, correlations found in the process of my long-time clinical observations and studies[20] allow me to show close correlation of simultaneous movements of individual body parts, i.e. the body of sternum and the sacrum, as well as thoracic kyphosis and lumbar lordosis against each other. Euclidean geometry[21–23] helped to solve the set tasks. On its basis, common relations between mentioned above body parts, the so-called 'common sense,' were shown.[24,25] The fact that the lines of the body of the sternum (blue section) and the sacrum (red section) can be 'inscribed' in a triangle, and the movement of one part of this system causes the movement of its other parts is an important element in this concept. The sternal body forms the angle α in relation to the horizontal line, the sagittal axis of the body a, and the sacrum forms the angle β in relation to the horizontal line of the sagittal axis of the body b. The angle γ is the common sense for the sternal body angle α and the sacrum angle β (Figure 1).

For clinical purposes, the Saunders inclinometer can be used to determine the angular values. In the α-angle test, the Saunders inclinometer is placed against the anterior surface of the body of the sternum, and in the β-angle test, one foot of the inclinometer is placed against the surface of the sacrum joint and the other foot against the surface of the medial sacral crest.

The effect on the changes in spine curvature of the thoracic segment ω1 and the lumbar segment ω2 is the consequence of common relation of the movements of the sternal body against the sacrum (Figure 1).

In this perspective, the position of the pelvis is the key element for the body posture. If the pelvis positions itself in anterior tilt, the forward tilt of the sacrum and lower lumbar spine increases, which, through active behaviour, induces deepening of lumbar lordosis and desirable head retraction. This correlation proves the occurrence of mutual relations of individual body sections against each other.[26–28]

4. RESULTS

Analytical search for the common sense relationship for the angles is discussed below: the sternal body, the sacrum, thoracic kyphosis, lumbar lordosis.

4.1. Analytical search for the common sense for the angles of the sternal body and the sacrum

The angles were marked as follows: α is the angle ABC for the position of the sternal body and β is the angle ACD for the position of the sacrum. Both these angles were marked in relation to the horizontal line, the sagittal axis of the body (Figure 2).

The straight lines *a* and *b* are the lines parallel to the horizontal line. The ABC triangle was obtained by running the straight line AC as the extension of the sacrum line to the intersection with the line AB as the extension of the sternal body line, making the angle BAC, i.e. angle γ. The

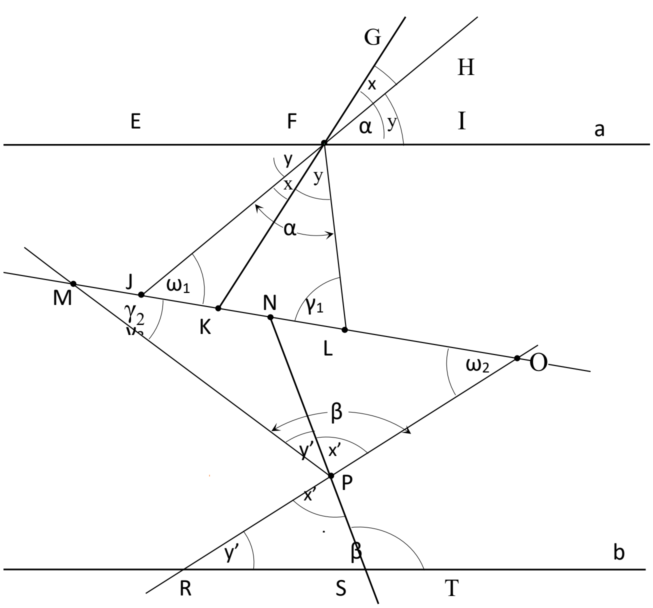

Figure 3. The system of the line of the sternal body FK and the line of the sacrum NS in relation to the angles of thoracic kyphosis ω1 and lumbar lordosis ω2.[20]

horizontal line makes the base of the triangle. The angle ACD, i.e. β, is the exterior angle of the triangle ABC. On the basis of the Euclidian geometry theorem, the exterior angle of a given triangle is equal to the sum of its interior angles non-adjacent to it, thus we get the following: $\beta = \alpha + \gamma$, hence $\gamma = \beta - \alpha$ (Figure 2), where γ is the common sense for the angle of the sternum and the angle of the sacrum β as the difference between the position of the angles β and α. It follows from the above that the angle γ has connotations with both the angle α and the angle β, showing common relations, the so-called common sense.

4.2. Analytical search for the common sense for the angles of the sternal body and thoracic kyphosis

The sternal angle retains the symbol α and the thoracic kyphosis angle FJL is marked by the symbol ω1 (Figure 3).

The straight line a is the parallel line to the horizontal line, the sagittal axis of the body.

It was found that the angle GFI, i.e. the angle α as the vertex angle is equal to the angle EFK, hence both these angles are equal to the angle α; with the angle $\alpha = x + y$. It was also found that the angle HFI as the vertex angle equals the angle EFJ, so both these angles are equal to the angle *y*, and the angle GFH as the vertex angle equals the angle JFK, so both these angles are equal to the angle *x*.

In order to show the common sense of the thoracic kyphosis angle ω1 and the sternum angle α, on the arm FK of the angle JFK the angle EFJ was set equal to the angle KFL, which is equal to the angle *y*; therefore, the resulting angle JFL is equal to the angle α which is the sum of the angles *x* and *y*, so, $\alpha = x + y$. The triangle FJL was obtained whose interior angles are the kyphosis angle ω1, the sternum angle α and the angle γ1 as the third vertex of the triangle.

The angle γ1 is the common sense for the kyphosis angle ω1 and the sternum α. This is proved by the following justification: in Euclid's geometry, the sum of the angles in any triangle is 180°, therefore: $\alpha + \omega 1 + \gamma 1 = 180°$.

Hence, γ1 is the common sense as the difference of the sum of the angles of the triangle FLJ and the sum of the kyphosis angle ω1 and the sternum α, so

$$\gamma 1 = 180° - (\alpha + \omega 1) \text{ (Figure 3).}$$

4.3. Analytical search for the common sense for the angles of the sacrum and lumbar lordosis

The sacrum angle retains symbol β and the lumbar lordosis angle NOP was marked by the symbol ω2 (Fig. 3).

The straight line b is parallel to the horizontal line, the sagittal axis of the body.

The triangle PRS is constructed as follows: point S is the vertex of the sacrum angle PST, i.e. the angle β, point P is made as a result of the intersection of the lower arm of the lumbar lordosis angle ω2 with the line NS, i.e. the extension of the arm of the sacrum angle, point R comes from the intersection of the lower arm of the lordosis angle ω2 with the straight line *b* to form the angle PRS which is equal to the angle *y′*.

Point N is formed as a result of the intersection of the upper arm of the lordosis angle ω2 and the extension of the arm of the sacrum angle; the resulting angle NOP is equal to the angle ω2.

It was found that the angle of the sacrum NST, i.e. β, is the exterior angle of the triangle RSP and is not adjacent to the y' and x angles. By the theorem of Euclidean geometry that the exterior angle of a triangle is equal to the sum of its interior angles not adjacent to it, it was found:

$$\beta = x' + y'.$$

It was also found that the angles NPO and RPS are vertex angles and, being equal, both have the value of angle x'.

In order to show the common sense of the lordosis angle ω2 and the sacrum angle β, the angle PRS equal to the angle y' was set on the arm NP of the angle NPO, and the angle NPM was obtained, which is equal to the angle y'. The angle OPM is the sum of the angles x', and y', i.e., $x' + y' = \beta$. The triangle OMP was obtained, whose interior angles are the lordosis angle ω2, the sacrum angle β and the angle γ2 as the third vertex of the triangle.

The angle γ2 is the common sense for the sacrum angle β and lordosis angle ω2. This is proved by the following justification: the sum of the angles in any triangle in Euclidean geometry is 180°, therefore:

$$\beta + \omega 2 + \gamma 2 = 180°.$$

Hence, γ2 is the common sense as the difference of the sum of the angles of the triangle OPM and the sum of the angles of the sacrum β and lordosis ω2, that is:

$$\gamma 2 = 180° - (\beta + \omega 2) \text{ (Figure 3).}$$

5. DISCUSSION

In accordance with the properties of Euclidean geometry and the relation of 'common sense,' the lines of the sternal body and the sacrum can be 'inscribed' in the shape of a triangle, documenting correlation of their position in relation to the spine in the sagittal plane. This fact is especially important due to the relationship between the position of the spine in the sagittal plane and the development of scoliosis in the developmental age.[29]

The results of the conducted study[20] and daily clinical observations confirm the usefulness of the application of the presented theoretical structure in monitoring the simultaneity of movements of the sternum and sacrum system as well as of the thoracic and lumbar spine. This observation is confirmed by the results of other authors' works.[30–32] During the conducted observations, it was found that the angle α of the sternum body position is easily controlled and easy to measure for the examined person. Reaching its value of approximately 65° makes it possible to achieve physiological parameters of thoracic kyphosis and lumbar lordosis.[20] Considering this observation and taking into account the simultaneity of the movements of the aforementioned system, positioning the sternum to the value of the angle α should be a tip for the method of body posture control. It is recommended that changes of adopted posture should take place in the time span not exceeding 5 minutes.[33] However, the presented model needs further verification based on clinical observations. This is especially important in the case of significant spine deformities.[34] The use of the described measurement method does not require meeting the laboratory requirements. The angle of the sternum and sacrum refers to the sagittal plane of the body axis. The solution presented in the paper can be used in all conditions of everyday human activity.

6. CONCLUSIONS

(1) The movement of the sternum and the sacrum system as well as the thoracic and lumbar spine are biomechanically correlated with each other.
(2) Positioning the sternum to the value of the angle α may be the tip of how to control the body posture.

Conflict of interest

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