Genij Ortopedii. 2022. Vol. 28, no. 3. P. 400-409.

Original article

https://doi.org/10.18019/1028-4427-2022-28-3-400-409

Measurement of damaged segment deformity in the thoracic and lumbar spine with spiral computed tomography to calculate the required correction

Vladimir D. Usikov[1], Vladimir S. Kuftov[2]✉, Dmitry N. Monashenko[3]

[1] MTF " Sintez", Penza, Russian Federation
[2] City hospital No. 1, Bryansk, Russian Federation
[3] City hospital No. 26, Saint Petersburg, Russian Federation

Corresponding author: Vladimir S. Kuftov, kuftov@mail.ru

Abstract

Introduction The more accurate is the measurement of the parameters for correcting the deformity of damaged spinal segments the more accurate will be the restoration of the sagittal profile and original anatomy of the spine. **Purpose** Substantiation of calculated indicators for deformity correction in one or two damaged spinal motion segments in the thoracic and lumbar spine according to spiral computed tomography. **Material and methods** The material for the study was the results of spiral computed tomography (SCT) of an anatomically unchanged thoracic and lumbar spine in 25 patients (12 women and 13 men aged 18 to 60 years). The study model consisted of three vertebral bodies and four adjacent discs from T4 to L4. Anterior and posterior dimensions of the vertebral bodies, intervertebral discs, and segmental deformity angle α (formed by the lower endplate of the overlying vertebra and the upper endplate of the underlying vertebra) were measured using RadiAnt computer software in the midsagittal projection. Damage to the body of the middle vertebra with adjacent discs was modeled, the dimensions of which were calculated from the adjacent vertebral bodies and adjacent discs. Statistical processing of the material was carried out using the computer software SPSS Statistics. **Results** The measurement error of the anterior interbody spaces was 1.4 ± 0.4 mm, the posterior interbody spaces were 1.3 ± 0.5 mm, the error in calculating the segmental deformation angle α was 2.5 ± 0.6 degrees, what indicates the high accuracy of the proposed method. Discussion The use of absolute deformity values as a standard for surgical intervention in the treatment of vertebral fractures is complicated by varieties of normal anatomy. **Conclusion** The proposed calculations for the restoration of the anterior and posterior interbody distances, as well as the angle of segmental deformity α after a spinal cord injury of the thoracic and lumbar spine provide an approach to the target individualized anatomical dimensions.

Keywords: spine morphometry, modeling, anatomical dimensions, vertebral bodies, intervertebral discs, segmental deformity

For citation: Usikov V.D., Kuftov V.S., Monashenko D.N. Measurement of damaged segment deformity in the thoracic and lumbar spine with spiral computed tomography to calculate the required correction. *Genij Ortopedii*, 2022, vol. 28, no 3, pp. 400-409. https://doi.org/10.18019/1028-4427-2022-28-3-400-409

INTRODUCTION

A good knowledge of the anatomy, morphology and biomechanics of the spine is a must in the treatment of vertebral fractures. An important step in the surgical treatment of post-traumatic deformities in the thoracic and lumbar spine is accurate reduction and deformity correction, what is emphasized by many authors [1–3].

Before surgery, in the postoperative period and at follow-ups, a number of parameters are used to evaluate radiological results, such as anterior and posterior vertebral body height, local sagittal angle, regional sagittal angle, disc angle, and some others. [4–7]. The emphasis is elimination of angular deformity after surgery or the loss of deformity correction if individual anatomy is not considered. What parameters we should strive for when eliminating segmental deformity is helped by the knowledge of the morphology of the vertebrae and intervertebral discs [8–10]. Insufficient attention is paid to restoring the height of the interbody space in eliminating segmental deformity, while the restoration of the posterior dimensions of the body of the damaged vertebra is taken as the basis and an indicator of the effectiveness of intraoperative distraction, without considering the dimensions of adjacent discs [11].

The literature data show that a good long-term outcome with minimal complications can be achieved only if the biomechanical principles for restoring the sagittal profile of the spine are observed [12-16]. Excessive or insufficient correction of spinal deformity contributes to the development of the adjacent level syndrome [17].

The question of what dimensions should one be guided by and what dimensions should one be aimed at in the process of spinal reduction remains controversial. Accuracy of reduction of the spine is determined "by eye", "according to the degree of tension of the capsules of the vertebral joints" or when "extension reaches the limits of physiological extension". The set of angles of kyphotic spinal deformity proposed for measurement confuses the assessment of research results, and the calculations of deformity correction angles proposed by the authors are approximate, based on a large individual diversity [18, 19]. It is possible to calculate the exact dimensions of the sagittal profile of the injured spine before surgery only after spondylography of the spine with the pelvis, taken the day before the operation in a standing position, and using a variety of spinal and pelvic parameters, which is difficult to perform in patients with spinal cord injury [20].

In the standing position, relative to the supine position, lumbar lordosis decreases, pelvic parameters change towards an increase in the pelvic tilt and a decrease in the tilt of the sacrum [21]. The radiographic examination in the supine position does not reflect the true sagittal profile of the patient, as in the standing position [22]. Unlike degenerative deformities of the spine, post-traumatic deformities are a local segmental problem [23]. The use of absolute deformity values as a standard for surgical intervention in the treatment of fractures is complicated by a wide variety of normal spinal anatomy [24]. The more accurate is the measurement of the parameters for correcting the deformity of the damaged segment of the spine, the more accurate will be the restoration of the sagittal profile and the original anatomy of the spine.

Aim of the study is substantiation of calculated indicators for the correction of deformity of one or two damaged spinal motion segments in the thoracic and lumbar regions according to the data of spiral computed tomography.

MATERIALS AND METHODS

The material for the study was the results of spiral computed tomography (SCT) in 25 patients (12 women and 13 men, aged 18 to 60 years). SCT was performed in patients with suspected trauma to the thoracic or lumbar spine. The selection criteria for our study were patients without congenital anomalies of the spine; lack of indications of trauma and surgical intervention in the studied section of the spine; without deformity of the spinal motion segments due to spondylosis, scoliosis, spondylolisthesis; without signs of damage to the studied spine area according to CT data; provided that the studied segment was two or more vertebrae away from the injury site. The study model consisted of three vertebrae with adjacent intervertebral discs (Fig. 1). Measurements were made using the computer software RadiAnt after multiplanar reconstruction in the DICOM format in the midsagittal projection. The extreme points of the vertebral bodies under assessment were taken for measurement (Fig. 1, 2).

In modeling the injury to the body of the L1 vertebra (Fig. 1), measurements were from the T11–T12 disc to the L2–L3 disc (distance from A to L along the anterior surface and from A1 to L1 along the posterior surface of the spine). To study the angle of segmental deformity (Fig. 2), we used the line |X–I1| that is parallel to the lower endplate of the overlying vertebra |C1| and the intersection with the projection line of the upper endplate of the underlying vertebra |I-I1|. Forty-four models from T4 to L4 vertebrae were measured. To reduce the measurement error, the image of the specific segment of the spine was enlarged to the size of the screen. The measurement error was 0.15 ± 0.07 mm. The anterior and posterior dimensions of the vertebral bodies and intervertebral discs, the dimensions of the vertebral bodies with adjacent discs, and the segmental deformity angle formed by the lower endplate of the overlying vertebra and the upper endplate of the underlying vertebra were measured. The measurement error was calculated by the formula: $X = \Delta x \pm t \times m$, where Δx is the average measurement difference, t is a tabular value (for a confidence level of 95% at p = .05, the t-criterion is 2), m is standard error of the mean. Statistical processing of the material was carried out with the SPSS Statistics using descriptive statistics, comparison of average values with a 95% confidence interval, determination of the t-test for pairwise comparisons, Pearson's correlation coefficient.

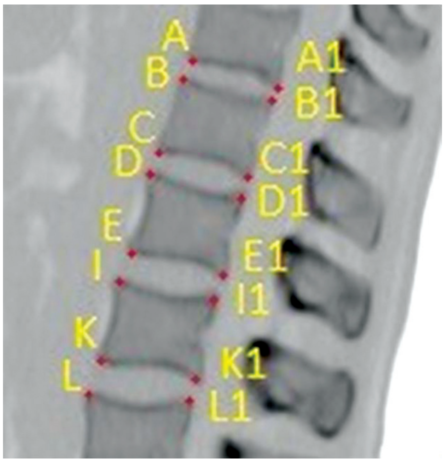

Fig. 1 Points for measuring the anterior and posterior dimensions of the vertebral bodies and intervertebral discs according to the median sagittal projection after multiplanar reconstruction of the studied spine

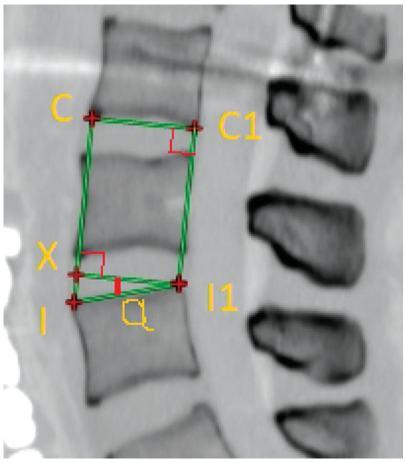

Fig. 2 Diagram for measurement of the angle of segmental deformity α

RESULTS

I. At the first stage, the measured and calculated anterior and posterior dimensions of the vertebral bodies were compared, for which 2 groups were formed: Group I are actual measurements of the anterior |D-E| and posterior |D1-E1|surfaces of 44 vertebrae from T4 to L4 (average of 4 measurements per vertebra) in 25 patients (12 women and 13 men aged 18 to 60 years); Group II are calculated dimensions of the anterior, as half the sum of the size of the anterior surface of the superior and underlying vertebrae – (|B-C| + |I-K|)/2, and the posterior, as the half-sum of the dimensions of the posterior surface of the superior and underlying vertebrae – (|B1-C1| + |I1-K1|)/2 in the same patients. The average dimensions of the anterior surface in group I were 25.65 mm with a standard error of 0.62 mm, in the second group 25.58 mm and 0.60 mm, respectively. When statistical calculations were rounded to tenths, an acceptable error in the calculations of the anterior surface of the vertebra was obtained at a 95% confidence interval: 0.7 ± 0.2 mm. After comparing two groups, Student's t-test was 0.403, p = 689. A strong correlation was found between the groups. The Pearson correlation coefficient is r = 0.973 (Fig. 3).

The acceptable error in the calculations of the posterior surface of the vertebra was 0.7 ± 0.2 mm, Student's t-test was 1.534 at p = 0.132. The correlation coefficient r was 0.959. The calculated anterior and posterior dimensions of the vertebral bodies were close to the anatomical dimensions.

II. To compare the anterior and posterior sizes of the intervertebral discs, 3 groups were formed.

Group I – the actual size of 44 discs from T4–T5 to L4–L5 in 25 patients (12 women and 13 men aged 18 to 60 years).

Group II – the size of the discs was half the sum of the sizes of two adjacent discs in the same patients;

Group III – disc sizes taken from table data (J.G. Fletcher [25] for the thoracic and K. Bach [26] for the lumbar), matching by sex and age.

We formed group III in order to compare how individual sizes of intervertebral discs differ from the average sizes of discs of the chosen location and specified sex and age.

The average size of the disk anteriorly in group I was 6.08 mm with a standard error of 0.52 mm; in the second group, the average size of the disk anteriorly was 6.02 mm, the standard error was 0.48 mm; in the third group – 5.88 mm and 0.27 mm, respectively (Fig. 4, a). Pearson's correlation coefficient between groups I and II – 0.982; between groups I and III – 0.87. The average difference in modulus in calculations in groups I and II is 0.7 mm, in groups I and III – 1.6 mm. The error in calculations by comparing groups I and II is 0.7 ± 0.2 mm, groups I and III is 1.6 ± 0.36 mm.

The average dimensions of the disc from posterior: in group I – 4.07 mm, standard error – 0.32 mm; in the second group, the average disk size was 3.9 mm, the standard error was 0.28 mm; in the third group – 4.29 mm and 0.25 mm, respectively (Fig. 4, b). The Pearson correlation coefficient between groups I and II is 0.939; between groups I and III – 0.73. The average difference in the size of the back of the disk between groups I and II is – 0.1 mm (modulo 0.6 mm); between groups I and III, the average difference was 0.2 mm (modulo 1.2 mm). The error in calculations by comparing groups I and II is 0.6 ± 0.2 mm, groups I and III is 1.2 ± 0.3 mm.

III. Calculations for modeling the sizes of the vertebral body with the overlying disc. Three groups were formed (Table 1).

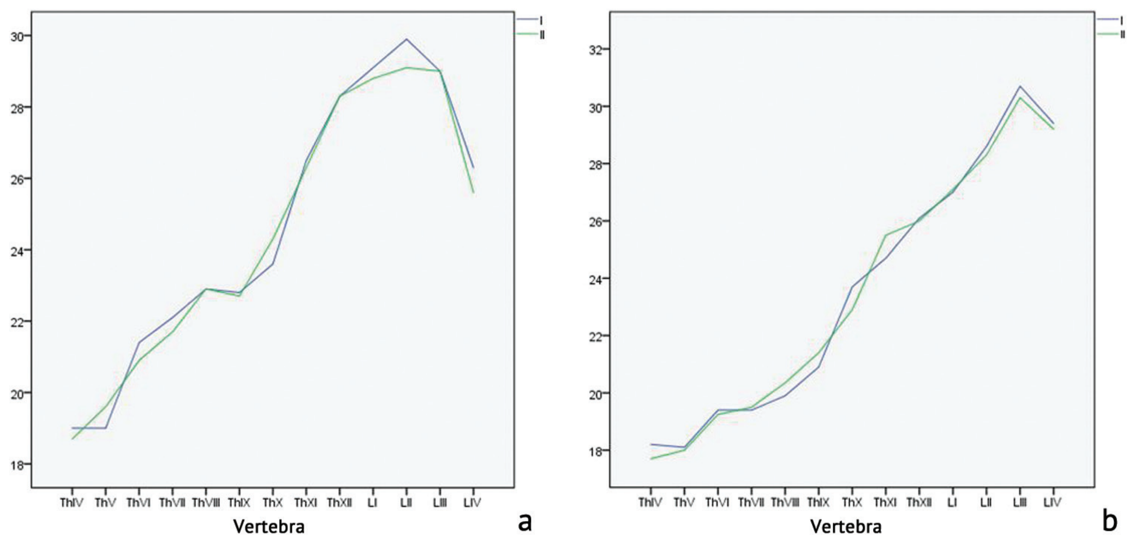

Fig. 3 Average dimensions of the anterior (a) and posterior (b) surfaces of vertebral bodies in two groups by location

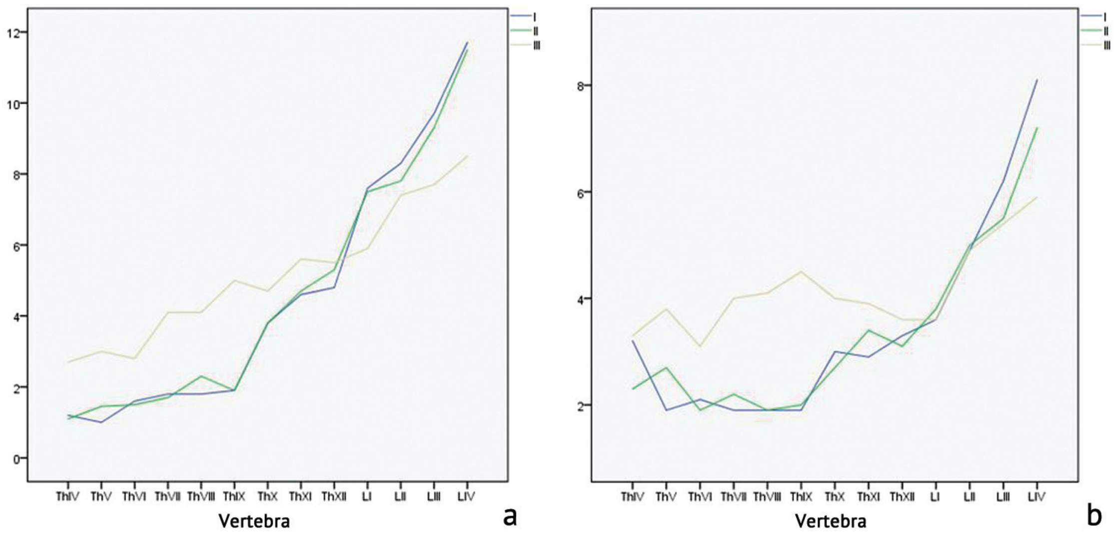

Fig. 4 Anterior (a) and posterior (b) sizes of discs in three groups by location

Table 1

Groups for calculating the size of the vertebral body with the overlying disc

Group I	Actual 44 measurements of anterior |C-E| and posterior |C1-E1| vertebral body surface with overlying disc from T4 to L4 in 25 patients (12 women and 13 men, aged 18 to 60 years)
Group II	Calculated 44 sizes of anterior (|B-C| + |I-K|)/2 + (|A-B| + |E-I|/2) and posterior (|B1-C1| + |I1-K1|)/2 + (|A1-B1 |+|E1-I1|/2) vertebral surfaces with overlying disc in the same patients. Moreover, the dimensions of the anterior and posterior surfaces of the vertebral bodies were half the sum of the dimensions of the adjacent vertebral bodies, and the anterior and posterior dimensions of the overlying disc were half the sum of the dimensions of the adjacent discs
Group III	Calculated 44 sizes of anterior ((|B-C| + |I-K|)/2 + |C-D| – from tables) and posterior ((|B1-C1| + |I1-K1|)/2 + |C1-D1| – from tables) surface of the vertebrae with the overlying disc in the same patients. Moreover, the dimensions of the anterior and posterior surfaces of the vertebral bodies were half the sum of the sizes of adjacent vertebral bodies, and the size of the overlying disc was from table data (J.G. Fletcher – for the thoracic [25] and K. Bach – for the lumbar spine[26])

Average dimensions |C-E| in group I were 31.9 mm, standard error of the mean value was 1.4 mm; in group II, the average sizes |C-I| – 31.7 mm, standard error of the mean value – 1.5 mm; in group III – 31.3 mm with a standard error of the mean value of 1.3 mm. The Pearson correlation between groups I and II is 0.984; between groups I and III – 0.947. The average difference between the compared sizes in groups I and II is 0.3 mm; in groups I and III – 0.6 mm. The average difference in modulus in calculations in groups I and II is 1.0 mm, in groups I and III – 1.8 mm. The error in calculations when comparing groups I and II is 1.0 ± 0.4 mm, groups I and III is 1.8 ± 0.5 mm.

Average sizes |C1-E1| in group I – 30.4 mm, standard error of the mean value – 0.8 mm; in group II, the average sizes |C1-E1| – 30.6 mm, standard error of the mean value – 0.7 mm; in group III – average sizes |C1-E1| – 30.1 mm and standard error of the mean – 0.7 mm. Pearson correlation between groups I and II – 0.956, between groups I and III – 0.874. The average difference between the compared sizes in groups I and II is 0.9 mm; in groups I and III – 0.5 mm. The average difference of measurements by module in groups I and II is 1.2 mm, the standard error of the mean value is 0.21 mm; in groups I and III – the average difference of measurements in modulus – 1.8 mm and the standard error of the mean value – 0.27 mm. The error in calculations between groups I and II was 1.2 ± 0.5 mm, and between groups I and III – 1.7 ± 0.5 mm.

IV. At the next stage of the study, injury to the vertebral body with adjacent discs was modeled. The grouping is the same (Table 2).

Average dimensions |C-I| in group I were 38.9 mm, standard error of the mean value was 1.6 mm; in group II, the average dimensions were 38.7 mm, the standard error of the mean was 1.5 mm; in group III – 38.3 mm with a standard error of the mean value of 1.3 mm. T-test of paired samples in groups I and II – 0.697, P = 0.49; in groups I and III: t = 1.026; P = 0.311. The Pearson correlation between groups I and II is 0.986; between groups I and III – 0.957. The average difference between the compared sizes in groups I and II is 0.2 mm; in groups I and III – 0.6 mm. The average difference in modulus in the calculations in groups I and II was 1.37 mm, the standard error of the mean value was 0.17 mm; in groups I and III, the mean difference was 3.17 mm, the standard error of the mean was 0.39 mm. The error in calculations when comparing groups I and II is 1.4 ± 0.4 mm, groups I and III is 3.2 ± 0.8 mm.

Table 2

Groups for calculating the vertebral body sizes with adjacent discs и

Group I	Actual 44 measurements of the anterior |C-I| and posterior |C1-I1| surfaces of vertebral bodies with adjacent discs from T4 to L4 in 25 patients (12 women and 13 men, aged 18 to 60 years)
Group II	Calculated 44 sizes of anterior (|B-C| + |I-K|)/2 + (|A-B| + |K-L|) and posterior (|B1-C1| + |I1-K1|)/2 + (|A1-B1| + |K1-L1|) surfaces of the vertebrae with adjacent discs. Moreover, the dimensions of the anterior and posterior surfaces of the vertebral bodies were half the sum of the dimensions of the adjacent vertebral bodies, and the dimensions of the adjacent discs were the anterior and posterior dimensions of the discs a level above and below the injured ones
Group Ш	Calculated 44 sizes of anterior ((|B-C| + |I-K|)/2 + (|C-D| + |E-I|) – from tables) and posterior ((|B1-C1| + |I1-K1|)/2 + (|C1-D1| +| E1-I1|) – from tables) vertebral surfaces with adjacent discs in the same patients. Moreover, the dimensions of the anterior and posterior surfaces of the vertebral bodies were half the sum of the sizes of adjacent vertebral bodies, and the dimensions of adjacent discs were taken from table data (J.G. Fletcher – for the thoracic [25] and K. Bach - for the lumbar spine [26])

Average dimensions |C1-I1| in group I were 35.4 mm, standard error of the mean value was 0.9 mm; in group II, the average dimensions were 34.9 mm, the standard error of the mean was 0.8 mm; in group III, the average dimensions were 35.1 mm and the standard error of the mean was 0.7 mm. Pearson's correlation between groups I and II is 0.953, between groups I and III is 0.864. The average difference of measurements by module in groups I and II is 1.29 mm, the standard error of the mean value is 0.25 mm; in groups I and III – the average difference of measurements by modulus – 2.7 mm and the standard error of the mean value – 0.27 mm. The error in calculations between groups I and II was 1.3 ± 0.5 mm, and between groups I and III, 2.7 ± 0.5 mm.

V. Modeling of segmental deformation angle α. The angle was formed between the lower endplate of the overlying vertebral body and the upper endplate of the vertebral body underlying the injured body (Fig. 2). The studies were carried out in 3 groups, the principle of group formation is given Table 3.

Table 3

Groups for calculation of segmental deformity angle α

Group I	The actual angle α between the cortical plates |C-C1| and |I-I1|
Group II	Calculated angle α according to the formula: sin-1 x (|C-I| – |C1-I1|)/|I-I1| , where the dimensions |C-I| and |C1-I1| were taken from Table 2, group II and actual sizes |I-I1|
Group III	Calculated angle α according to the formula: sin-1 x (|C-I| – |C1-I1|)/|I-I1|, where |C-I| and |C1-I1| taken from Table 2, group III and actual dimensions |I-I1|

To measure the angle α in group I, a line parallel to C-C1 was drawn until it intersected with the line I-I1 (Fig. 2). In groups II and III, the angle α was calculated by the formula: sin-1 x (|C-I| – |C1-I1|)/|I-I1|. This formula was used because the lines connecting the interbody spaces |C-I| and |C1-I1|, as a rule, are perpendicular to the line drawn along the lower endplate of the overlying vertebra |C-C1|. Therefore, the triangle X-I1-I is close to a right triangle with a hypotenuse |I-I1|, which allows using trigonometric functions in angle calculations.

The mean angle difference α between groups I and II by the module was 2.48 degrees, the standard error of the mean value was 0.31 degrees; between groups I and III, the mean angle difference α was 3.62 degrees, the standard error of the mean was 0.56 degrees. Pearson correlation for groups I and II – 0.95, at $p < 0.01$; for groups I and III – 0.83, at $p < 0.01$. The error in the calculation of the angle α between groups I and II was 2.5 ± 0.6 degrees, and between groups I and III – 3.6 ± 1.1 degrees.

All stages of the measurements are shown in Figure 5, which includes the bodies of L2, L3, L4 vertebrae with adjacent discs, as an example of measuring the indicators described above.

Fig. 5 Measurement of interbody spaces and angle α

The calculated anterior interbody distance was 48.2 mm; the calculated posterior interbody distance was 40.7 mm. The actual dimensions of the anterior and posterior interbody spaces were 48.4 mm and 40.9 mm. The calculated angle α was 14.3 degrees, the measured one was 13.9 degrees. In this example, our calculations on the dimensions of the interbody gap differ from the actual ones by 0.2 mm, and the calculated angle by 0.4 degrees. The calculations obtained are close to the actual dimensions, what indicates the high accuracy of the proposed method.

DISCUSSION

The height of the vertebrae is not only race-specific, but also depends on gender and region of residence [27]. The height of the vertebrae gradually increases from T4 to L3, but then decreases at the level of L4 and L5. In both sexes, the ratio of vertebral sizes was the same, but male vertebrae were statistically bigger than those of females (Fig. 6).

The anterior and posterior sizes of the vertebral bodies are shown on diagrams for inhabitants of the United States, mainland China and Hong Kong, according to L. Ning et al., 2017 [27], and Turkey, according to B. Abuzayed et al., 2010 [28] (Fig. 7).

The vertebra size of the mainland Chinese population was smaller than that of the US population, but was surprisingly bigger than that of the Hong Kong Chinese, despite being of the same race. In Turkey nationals, the smaller anatomical dimensions of the vertebral bodies can be explained by the fact that the measurements were carried out not in radiographs, but according to computed tomography. Though, the results of measurements according to X-rays and computed tomography can be quite comparable [29]. Data from different racial populations showed similar size ratios across all vertebrae. The sizes of the thoracic vertebral bodies showed a tendency to increase from T1 to T12, with the posterior height of the vertebral body always being 1–2 mm bigger [30], and the sizes of the thoracic vertebrae are always smaller than those of the lumbar ones [31]. The ratios obtained by us for the sizes of the vertebral bodies coincide with the literature data.

Calculating the anterior and posterior dimensions of the vertebral body, it is assumed that their dimensions are the average of the dimensions of neighboring vertebrae [32]. A statistically significant correlation was obtained between the anterior height of the vertebral body and human age [33]. Thus, the anterior and posterior height of the vertebral body is almost the same for all lumbar vertebrae in newborns, then the anterior height continuously increases in childhood, adolescence and adulthood and decreases slightly in the elderly due to osteopenia.

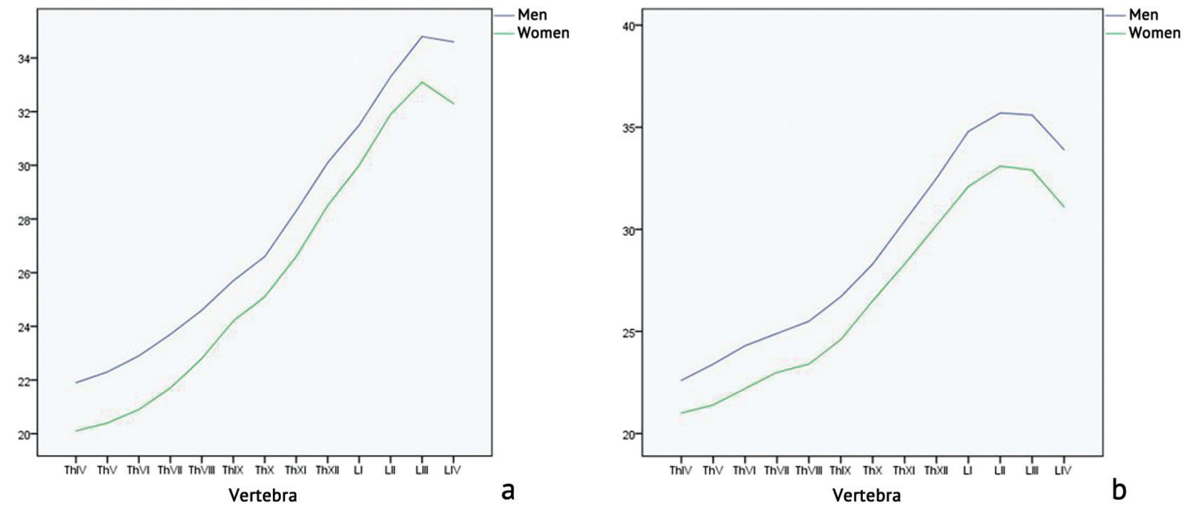

Fig. 6 Anterior (a) and posterior (b) dimensions of the vertebral bodies in men and women (L. Ning et al., 2017 [27])

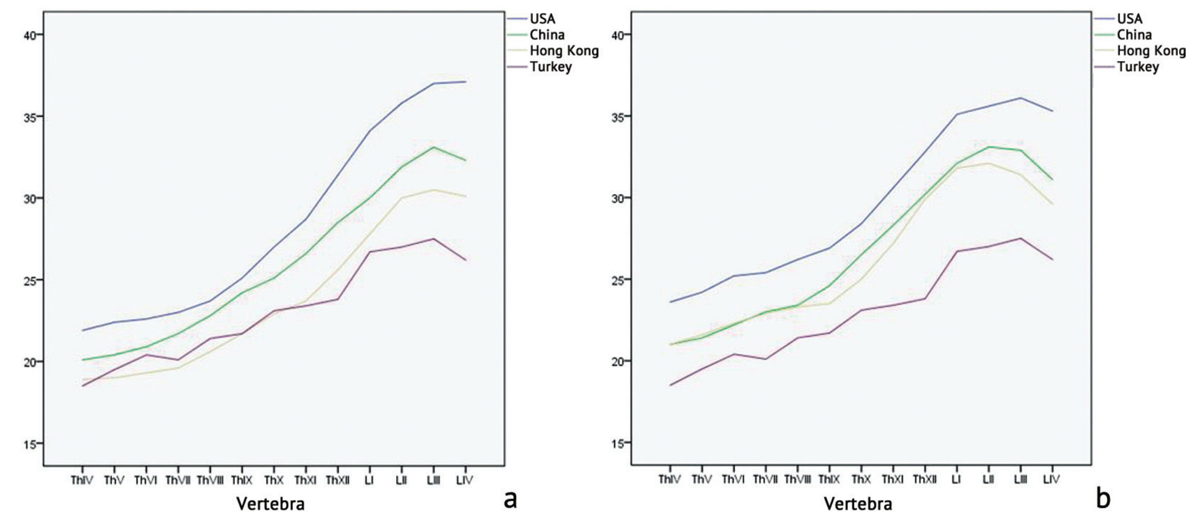

Fig. 7 Anterior (a) and posterior (b) dimensions of the vertebral bodies in individuals of different nationalities (USA, mainland China and Hong Kong – according to L. Ning et al., 2017 [27]; Turkey – according to B. Abuzayed et al. , 2010 [28])

The anatomical anterior and posterior dimensions of the discs in the thoracic and lumbar regions vary depending on the level of the disc, sex, and age [34, 35]. The disc height at the level of T4–T5 vertebrae is considered to be the lowest [36], then the dimensions increase caudally towards the L4–L5 segment in all subjects [37]. To calculate the disk space, a new approach has been introduced, and is called the expression of its adjacent segment. Calculations of the disc height based on the height of adjacent vertebral bodies have been proposed [38]. A disc height index was derived, which takes into account 3 sizes of the intervertebral disc and neighboring vertebral bodies, along with a fixed percentage coefficient α [39]. For each segment of the lumbar spine, the authors calculated the disc-vertebral index [40]. Correlation coefficients were derived to calculate the disc height depending on gender and age [41]. Knowing the obtained morphometric results on the size of the intervertebral discs, we confirmed in our calculations that the total size of the adjacent discs is close to the total size of the discs per segment above and below the damaged vertebra. Moreover, the individual sizes of the disks in the calculations are more accurate than the average sizes of the disks of a given location for the corresponding sex and age.

Due to the difference between the anterior and posterior disc heights, a disc or intervertebral angle is formed. Similar to disc sizes, disc angles in asymptomatic patients have been well studied by numerous investigations [42–44]. The different distribution of physiological angles in the thoracic and lumbar spine in accordance with 4 types of posture was theoretically confirmed [45, 46].

To analyze segmental deformity of the spine, various authors suggest the vertebral wedging angle or the local sagittal angle [47]; sagittal index and Gardner's deformity [48]; local segmental angle and segmental lordosis [49]. All this makes it difficult to compare the listed criteria. Thus, segmental kyphosis, according to some authors, is the angle between the lower endplate of the overlying vertebral body and the upper endplate of the vertebral body located caudally from the injured vertebra [50]; according to other data, it is an angle bounded by the lines parallel to the superior endplate of the overlying vertebral body and the inferior endplate of the underlying vertebral body [51].

The segmental angles of the spine change evenly by movements. Thus, the segmental range of motion in the thoracic region in flexion-extension ranges from 1.9 to 3.8 degrees [52], and it is minimal in the T4–T5 segment. The total range of motion in the thoracic region, composed of segmental angles, was 31.7 ± 11.3 degrees [53]. During inhalation and exhalation, the total range of motion in the thoracic spine is 15.9 ± 4.6 degrees [54].

In the course of spinal deformity correction, according to L.Y. Dai [55], the impact is exhibited on the vertebral body, not on the discs. According to A.B. Tomilova et al, the vertebral body and adjacent discs are affected after sustaining injuries [56]. According to our observations, both the dimensions of the damaged vertebral body and the angles of adjacent discs change by spinal reduction. It indicates the need to consider them by correcting the deformity. Since the physiological shape of the spine is subject to fluctuations, an individual approach is required to correct post-traumatic deformity, and knowledge of the normal values of segmental angles in the sagittal plane is especially important by reduction of a spinal fracture. Based on the analysis of a large amount of radiographs and computed tomography images, the authors present reference values of segmental angles in the thoracolumbar junction, which vary greatly (Table 4) [57].

Table 4

Reference values of segmental angles according to the authors

Spinal segment	Kwon S.M. et al. [57]	Verheyden A.P. et al. [22]
T9–T11		-5
T10–T12	6.5 ± 3.9	-2
T11–L1	5.5 ± 4.1	2
T12–L2	2.2 ± 4.7	7
L1–L3	3.3 ± 5.3	10
L2–L4		15
L3I–L5		25
L4–S1		40

In this situation, the angle was measured from the superior cortical plate of the overlying vertebra to the inferior cortical plate of the body of the underlying injured vertebra. This angle (Cobb's angle) was recognized as the most reliable by measuring deformities due to a vertebral fracture [58]. The segmental angle from the lower endplate of the overlying vertebral body to the upper endplate of the underlying vertebral body was chosen by us due to the convenience of calculation and measurement: at the planning stage, during surgery and at follow-ups. Both the Cobb's angle and the angle we chose are bisegmental angles that involve the injured vertebra and two adjacent discs.

The authors propose the calculation of the sagittal index in fractures of the thoracolumbar spine, and namely, the measurement of kyphotic deformity of the spinal segment (the angle between the lower endplate of the overlying vertebral body and the lower endplate of the body of the injured vertebra), corrected for the normal sagittal contour at the level of the deformed segment [59]. Given that the angle is monosegmental, and therefore big errors in the calculations are obtained due to a large individual variety of segmental angles, depending on the types of posture according to Rossoully.

Uncorrected spinal deformity can lead to incorrect position of the neighboring segments, changes in the general statics of the spine, and chronic pain [60, 61].

The method proposed by us for calculating target indicators for the restoration of an individual sagittal profile allows us to reduce the error in assessing the sagittal contour by averaged target values. In modeling the dimensions of the interbody spaces and the angle of segmental deformity, the parameters calculated using our models are close to the actual anatomical dimensions. For assessing post-traumatic deformity in the thoracic and lumbar spine, the calculated anterior and posterior dimensions of the interbody spaces should be taken as 100%, and the calculated segmental angle as 0 degrees. This will allow you to assess the corrected deformity of the injured segment of the spine.

CONCLUSIONS

1. In modeling injuries to one or two spinal motion segments in the thoracic and lumbar spine, it is necessary to calculate the size of the interbody spaces of the ventral and dorsal surfaces and the segmental deformity angle α along the midsagittal section of spiral computed tomography after multiplanar reconstruction.

2. The proposed calculations for the restoration of the anterior and posterior interbody distances, as well as the angle of segmental deformity α after a spinal cord injury in the thoracic and lumbar spine, enable to approach the target individualized anatomical dimensions. The measurement error of the anterior interbody spaces was 1.4 ± 0.4 mm, the posterior interbody spaces was 1.3 ± 0.5 mm. The error in calculating the segmental deformity angle α was 2.5 ± 0.6 degrees, and indicates the high accuracy of the proposed method.

REFERENCES

1. Afaunov A.A., Poliukhovich E.M., Afaunov A.I., Mishagin A.V., Vasilchenko P.P. Khirurgicheskoe lechenie posttravmaticheskikh deformatsii grudnogo i poiasnichnogo otdelov pozvonochnika [Surgical treatment of post-traumatic deformities of the thoracic and lumbar spine]. *Khirurgiia Pozvonochnika*, 2007, no. 3, pp. 8-15. (in Russian)
2. Rerikh V.V., Borzykh K.O. Posttravmaticheskie deformatsii grudnogo i poiasnichnogo otdelov pozvonochnika u patsientov v pozdnem periode pozvonochno-spinnomozgovoi travmy posle ranee provedennykh operativnykh vmeshatelstv [Post-traumatic deformities of the thoracic and lumbar spine in patients in the late period of spinal-spinal cord injury after previous surgical interventions]. *Mezhdunarodnyi Zhurnal Prikladnykh i Fundamentalnykh Issledovanii*, 2015, no. 12-4, pp. 657-660. (in Russian) Available from: https://applied-research.ru/ru/article/view?id=7998 (accessed 18.01.2021).
3. Olivares O.B., Carrasco M.V., Pinto G.I., Tonda F.N., Riera Martínez J.A., González A.S. Preoperative and Postoperative Sagittal Alignment and Compensatory Mechanisms in Patients with Posttraumatic Thoracolumbar Deformities who Undergo Corrective Surgeries. *Int. J. Spine Surg*., 2021, vol. 15, no. 3, pp. 585-590. DOI: 10.14444/8079.
4. De Gendt E.E.A., Vercoulen T.F.G., Joaquim A.F., Guo W., Vialle E.N., Schroeder G.D., Schnake K.S., Vaccaro A.R., Benneker L.M., Muijs S.P.J., Oner F.C. The Current Status of Spinal Posttraumatic Deformity: A Systematic Review. *Global Spine J*., 2021, vol. 11, no. 8, pp. 1266-1280. DOI: 10.1177/2192568220969153.
5. Rava A., Fusini F., Cinnella P., Massè A., Girardo M. Is cast an option in the treatment of thoracolumbar vertebral fractures? *J. Craniovertebr. Junction Spine*, 2019, vol. 10, no. 1, pp. 51-56. DOI: 10.4103/jcvjs.JCVJS_8_19.
6. Ullrich B.W., Ottich M., Lawson McLean A., Mendel T., Hofmann G.O., Schenk P. Lokales Wirbelsäulenprofil nach operativer Behandlung thorakolumbaler und lumbaler fraktures: Einfluss von Repositionstechnik und Knochenqualitätlmpakt of reduction technique and bone quality [Local spinal profile following operative treatment of thoracolumbar and lumbar fractures : Impact of reduction technique and bone quality]. *Unfallchirurg*, 2022, vol. 125, no. 4, pp. 295-304. (in German) DOI: 10.1007/s00113-021-01013-7.
7. Weiß T., Hauck S., Bühren V., Gonschorek O. Repositionsmöglichkeiten mittels perkutaner dorsaler Instrumentierung. Bei Berstungsfrakturen des thorakolumbalen Übergangs [Repositioning options with percutaneous dorsal stabilization. For burst fractures of the thoracolumbar junction]. *Unfallchirurg*, 2014, vol. 117, no. 5, pp. 428-436. (in German) DOI: 10.1007/s00113-013-2364-7.
8. Allaire B.T., DePaolis Kaluza M.C., Bruno A.G., Samelson E.J., Kiel D.P., Anderson D.E., Bouxsein M.L. Evaluation of a new approach to compute intervertebral disc height measurements from lateral radiographic views of the spine. *Eur. Spine J*., 2017, vol. 26, no. 1, pp. 167-172. DOI: 10.1007/s00586-016-4817-5.
9. Kunkel M.E., Schmidt H., Wilke H.J. Prediction equations for human thoracic and lumbar vertebral morphometry. *J. Anat*., 2010, vol. 216, no. 3, pp. 320-328. DOI: 10. 1111/j.1469-7580.2009.01187.x.
10. Oei L., Ly F., El Saddy S., Makurthou A.A., Hofman A., van Rooij F.J., Uitterlinden A.G., Zillikens M.C., Rivadeneira F., Oei E.H. Multi-functionality of computer-aided quantitative vertebral fracture morphometry analyses. *Quant. Imaging Med. Surg*., 2013, vol. 3, no. 5, pp. 249-255. DOI: 10.3978/j.issn.2223-4292.2013.09.03.
11. Rerikh V.V., Borzykh K.O., Rakhmatillaev Sh.N. Khirurgicheskoe lechenie vzryvnykh perelomov grudnykh i poiasnichnykh pozvonkov, soprovozhdaiushchikhsia suzheniem pozvonochnogo kanala [Surgical treatment of burst fractures of the thoracic and lumbar vertebrae, accompanied by narrowing of the spinal canal]. *Khirurgiia Pozvonochnika*, 2007, no. 2, pp. 8-15. (in Russian)
12. Hempfing A., Zenner J., Ferraris L., Meier O., Koller H. Wiederherstellung der sagittalen Balance bei der Versorgung thorakaler und lumbaler Wirbelkörperfrakturen [Restoration of sagittal balance in treatment of thoracic and lumbar vertebral fractures]. *Orthopade*, 2011, vol. 40, no. 8. (in German) DOI: 10.1007/s00132-011-1796-4.
13. Mayer M., Ortmaier R., Koller H., Koller J., Hitzl W., Auffarth A., Resch H., von Keudell A. Impact of Sagittal Balance on Clinical Outcomes in Surgically Treated T12 and L1 Burst Fractures: Analysis of Long-Term Outcomes after Posterior-Only and Combined Posteroanterior Treatment. Biomed. *Res. Int*., 2017, vol. 2017, 1568258. DOI: 10.1155/2017/1568258.
14. Burtsev A.V., Ryabykh S.O., Kotelnikov A.O., Gubin A.V. Clinical issues of the sagittal balance in adults. *Genij Ortopedii*, 2017, vol. 23, no. 2, pp. 228-235. (in Russian) DOI: 10.18019/1028-4427-2017-23-2-228-235.
15. Hosseini P., Mundis G.M. Jr., Eastlack R.K., Bagheri R., Vargas E., Tran S., Akbarnia B.A. Preliminary results of anterior lumbar interbody fusion, anterior column realignment for the treatment of sagittal malalignment. *Neurosurg. Focus*, 2017, vol. 43, no. 6, pp. E6. DOI: 10.3171/2017.8.FOCUS17423.
16. Le Huec J.C., Thompson W., Mohsinaly Y., Barrey C., Faundez A. Sagittal balance of the spine. *Eur. Spine J*., 2019, vol. 28, no. 9, pp. 1889-1905. DOI: 10.1007/s00586-019-06083-1.
17. Lee J.C., Choi S.W. Adjacent Segment Pathology after Lumbar Spinal Fusion. *Asian Spine J*., 2015, vol. 9, no. 5, pp. 807-817. DOI: 10.4184/asj.2015.9.5.807.
18. Aoui M., Sahnoun N., Abid M., Maatoug M., Hsairi M., Hentati Y., Keskes H. Posterior short segment pedicle screw fixation for the treatment of thoracolumbar fracture. *Pan Afr. Med. J*., 2020, vol. 35, pp. 102. DOI: 10.11604/pamj.2020.35.102.21540.

19. Hou G.J., Zhou F., Tian Y., Ji H.Q., Zhang Z.S., Guo Y., Lv Y., Yang Z.W., Zhang Y.W. [Risk factors of recurrent kyphosis in thoracolumbar burst fracture patients treated by short segmental pedicle screw fixation]. *Beijing Da Xue Xue Bao Yi Xue Ban*, 2020, vol. 53, no. 1, pp. 167-174. (in Chinese) DOI: 10.19723/j.issn.1671-167X.2021.01.025.
20. Koller H., Acosta F., Hempfing A., Rohrmüller D., Tauber M., Lederer S., Resch H., Zenner J., Klampfer H., Schwaiger R., Bogner R., Hitzl W. Long-term investigation of nonsurgical treatment for thoracolumbar and lumbar burst fractures: an outcome analysis in sight of spinopelvic balance. *Eur. Spine J*., 2008, vol. 17, no. 8, pp. 1073-1095. DOI: 10.1007/s00586-008-0700-3.
21. Hasegawa K., Okamoto M., Hatsushikano S., Caseiro G., Watanabe K. Difference in whole spinal alignment between supine and standing positions in patients with adult spinal deformity using a new comparison method with slot-scanning three-dimensional X-ray imager and computed tomography through digital reconstructed radiography. *BMC Musculoskelet. Disord*., 2018, vol. 19, no. 1, pp. 437. DOI: 10.1186/s12891-018-2355-5.
22. Verheyden A.P., Hölzl A., Ekkerlein H., Gercek E., Hauck S., Josten C., Kandziora F., Katscher S., Knop C., Lehmann W., Meffert R., Müller C.W., Partenheimer A., Schinkel C., Schleicher P., Schnake K.J., Scholz M., Ulrich C. Therapieempfehlungen zur Versorgung von Verletzungen der Brust- und Lendenwirbelsäule [Recommendations for the treatment of thoracolumbar and lumbar spine injuries]. *Unfallchirurg*, 2011, vol. 114, no. 1, pp. 9-16. (in German) DOI: 10.1007/s00113-010-1934-1.
23. Olivares O.B., Carrasco M.V., Pinto G.I., Tonda F.N., Riera Martínez J.A., González A.S. Preoperative and Postoperative Sagittal Alignment and Compensatory Mechanisms in Patients with Posttraumatic Thoracolumbar Deformities who Undergo Corrective Surgeries. *Int. J. Spine Surg*., 2021, vol. 15, no. 3, pp. 585-590. DOI: 10.14444/8079.
24. Zappalá M., Lightbourne S., Heneghan N.R. The relationship between thoracic kyphosis and age, and normative values across age groups: a systematic review of healthy adults. *J. Orthop. Surg. Res*., 2021, vol. 16, no. 1, pp. 447. DOI: 10.1186/s13018-021-02592-2.
25. Fletcher J.G., Stringer M.D., Briggs C.A., Davies T.M., Woodley S.J. CT morphometry of adult thoracic intervertebral discs. *Eur. Spine J*., 2015, vol. 24, no. 10, pp. 2321-2329. DOI: 10.1007/s00586-015-3925-y.
26. Bach K., Ford J., Foley R., Januszewski J., Murtagh R., Decker S., Uribe J.S. Morphometric Analysis of Lumbar Intervertebral Disc Height: An Imaging Study. *World Neurosurg*., 2018, S1878-8750(18)32836-5. DOI: 10.1016/j.wneu.2018.12.014.
27. Ning L., Song L.J., Fan S.W., Zhao X., Chen Y.L., Li Z.Z., Hu Z.A. Vertebral heights and ratios are not only race-specific, but also gender- and region-specific: establishment of reference values for mainland Chinese. *Arch. Osteoporos*., 2017, vol. 12, no. 1, pp. 88. DOI: 10.1007/s11657-017-0383-7.
28. Abuzayed B., Tutunculer B., Kucukyuruk B., Tuzgen S. Anatomic basis of anterior and posterior instrumentation of the spine: morphometric study. *Surg. Radiol. Anat*., 2010, vol. 32, no. 1, pp. 75-85. DOI: 10.1007/s00276-009-0545-4.
29. Abdel M.P., Bodemer W.S., Anderson P.A. Supine thoracolumbar sagittal spine alignment: comparing computerized tomography and plain radiographs. *Spine* (Phila Pa 1976), 2012, vol. 37, no. 4, pp. 340-345. DOI: 10.1097/BRS.0b013e31821946d1.
30. Kaur K., Singh R., Prasath V., Magu S., Tanwar M. Computed tomographic-based morphometric study of thoracic spine and its relevance to anaesthetic and spinal surgical procedures. *J. Clin. Orthop. Trauma*, 2016, vol. 7, no. 2, pp. 101-108. DOI: 10.1016/j.jcot.2015.12.002.
31. Waxenbaum J.A., Reddy V., Futterman B. *Anatomy, Back, Thoracic Vertebrae*. StatPearls [Internet]. Treasure Island (FL), StatPearls Publishing, 2022. Available from: https://www.ncbi.nlm.nih.gov/books/NBK459153/
32. Guglielmi G., Diacinti D., van Kuijk C., Aparisi F., Krestan C., Adams J.E., Link T.M. Vertebral morphometry: current methods and recent advances. *Eur. Radiol*., 2008, vol. 18, no. 7, pp. 1484-1496. DOI: 10.1007/s00330-008-0899-8.
33. Mavrych V., Bolgova O., Ganguly P., Kashchenko S. Age-Related Changes of Lumbar Vertebral Body Morphometry. *Austin. J. Anat*., 2014, vol. 1, no. 3, pp. 1014.
34. Wáng J.Q., Káplár Z., Deng M., Griffith J.F., Leung J.C.S., Kwok A.W.L., Kwok T., Leung P.C., Wáng Y.X.J. Thoracolumbar Intervertebral Disc Area Morphometry in Elderly Chinese Men and Women: Radiographic Quantifications at Baseline and Changes at Year-4 Follow-up. *Spine* (Phila Pa 1976), 2018, vol. 43, no. 10, pp. E607-E614. DOI: 10.1097/BRS.0000000000002482.
35. Okada E., Daimon K., Fujiwara H., Nishiwaki Y., Nojiri K., Watanabe M., Katoh H., Ishihama H., Fujita N., Tsuji T., Nakamura M., Matsumoto M., Watanabe K. Ten-year Longitudinal Follow-up MRI Study of Age-related Changes in Thoracic Intervertebral Discs in Asymptomatic Subjects. *Spine* (Phila Pa 1976), 2019, vol. 44, no. 22, pp. E1317-E1324. DOI: 10.1097/BRS.0000000000003145.
36. Volkov A.A., Beloselskii N.N., Pribytkov Iu.N. Rentgenovskaia morfometriia mezhpozvonkovykh prostranstv pozvonochnogo stolba v norme i pri distroficheskikh izmeneniiakh mezhpozvonkovykh diskov [X-ray morphometry of the intervertebral spaces of the spinal column in the norm and with degenerative changes in the intervertebral discs]. *Vestnik Rentgenologii i Radiologii*, 2015, no. 3, pp. 23-30. (in Russian) Available from: https://doi.org/10.20862/0042-4676-2015-0-3-23-30 (accessed 14.02.2021).
37. Machino M., Nakashima H., Ito K., Katayama Y., Matsumoto T., Tsushima M., Ando K., Kobayashi K., Imagama S. Age-related degenerative changes and sex-specific differences in osseous anatomy and intervertebral disc height of the thoracolumbar spine. *J. Clin. Neurosci*., 2021, vol. 90, pp. 317-324. DOI: 10.1016/j.jocn.2021.06.020.
38. Kunkel M.E., Herkommer A., Reinehr M., Böckers T.M., Wilke H.J. Morphometric analysis of the relationships between intervertebral disc and vertebral body heights: an anatomical and radiographic study of the human thoracic spine. *J. Anat*., 2011, vol. 219, no. 3, pp. 375-387. DOI: 10.1111/j.1469-7580.2011.01397.x.
39. Fyllos A.H., Arvanitis D.L., Karantanas A.H., Varitimidis S.E., Hantes M., Zibis A.H. Magnetic resonance morphometry of the adult normal lumbar intervertebral space. *Surg. Radiol. Anat*., 2018, vol. 40, no. 9, pp. 1055-1061. DOI: 10.1007/s00276-018-2048-7.
40. Iliescu D., Bordei P., Ionescu E.V., Albina S., Oprea C., Obada B., Lupu A.A., Hangan T.L., Iliescu M.G. Anatomic-Imaging Correlations of Lumbar Disk-Vertebral Morphometric Indices. *Int. J. Morphol*., 2017, vol. 35, no. 4, pp. 1553-1559. DOI: 10.4067/S0717-95022017000401553.
41. Lavecchia C.E., Espino D.M., Moerman K.M., Tse K.M., Robinson D., Lee P.V.S., Shepherd D.E.T. Lumbar model generator: a tool for the automated generation of a parametric scalable model of the lumbar spine. *J. R. Soc. Interface*, 2018, vol. 15, no. 138, 20170829. DOI: 10.1098/rsif.2017.0829.
42. Zhang F., Zhang K., Tian H.J., Wu A.M., Cheng X.F., Zhou T.J., Zhao J. Correlation between lumbar intervertebral disc height and lumbar spine sagittal alignment among asymptomatic Asian young adults. *J. Orthop. Surg. Res*., 2018, vol. 13, no. 1, pp. 34. DOI: 10.1186/s13018-018-0737-x.
43. Chung N.S., Lee H.D., Jeon C.H. Differences in lumbar segment angle among Roussouly types of global sagittal alignment in asymptomatic adult subjects. *Spine Deform*., 2020, vol. 8, no. 2, pp. 227-232. DOI: 10.1007/s43390-019-00010-6.
44. Ito K., Ando K., Kobayashi K., Nakashima H., Hasegawa Y., Imagama S. A Longitudinal Study of Lumbar Sagittal Change in Middle-Aged Healthy Volunteers. *Spine Surg. Relat. Res*., 2020, vol. 5, no. 3, pp. 160-164. DOI: 10.22603/ssrr.2020-0123.
45. Roussouly P., Gollogly S., Berthonnaud E., Dimnet J. Classification of the normal variation in the sagittal alignment of the human lumbar spine and pelvis in the standing position. *Spine* (Phila Pa 1976), 2005, vol. 30, no. 3, pp. 346-353. DOI: 10.1097/01.brs.0000152379.54463.65.
46. Celestre P.C., Dimar J.R. 2nd, Glassman S.D. Spinopelvic Parameters: Lumbar Lordosis, Pelvic Incidence, Pelvic Tilt, and Sacral Slope: What Does a Spine Surgeon Need to Know to Plan a Lumbar Deformity Correction? *Neurosurg. Clin. N. Am*., 2018, vol. 29, no. 3, pp. 323-329. DOI: 10.1016/j.nec.2018.03.003.
47. Vialle R., Levassor N., Rillardon L., Templier A., Skalli W., Guigui P. Radiographic analysis of the sagittal alignment and balance of the spine in asymptomatic subjects. *J. Bone Joint Surg. Am*., 2005, vol. 87, no. 2, pp. 260-267. DOI: 10.2106/JBJS.D.02043.
48. Ulmar B., Brunner A., Gühring M., Schmälzle T., Weise K., Badke A. Inter- and intraobserver reliability of the vertebral, local and segmental kyphosis in 120 traumatic lumbar and thoracic burst fractures: evaluation in lateral X-rays and sagittal computed tomographies. *Eur. Spine J*., 2010, vol. 19, no. 4, pp. 558-566. DOI: 10.1007/s00586-009-1231-2.
49. Park K.H., Baek S., Kang E.K., Park H.W., Kim G., Kim S.H. The Association between Sagittal Plane Alignment and Disc Space Narrowing of Lumbar Spine in Farmers. *Ann. Rehabil. Med*., 2021, vol. 45, no. 4, pp. 294-303. DOI: 10.5535/arm.21037.

50. De Iure F., Lofrese G., De Bonis P., Cultrera F., Cappuccio M., Battisti S. Vertebral body spread in thoracolumbar burst fractures can predict posterior construct failure. *Spine J*., 2018, vol. 18, no. 6, pp. 1005-1013. DOI: 10.1016/j.spinee.2017.10.064.
51. Formica M., Cavagnaro L., Basso M., Zanirato A., Felli L., Formica C., Di Martino A. Which patients risk segmental kyphosis after short segment thoracolumbar fracture fixation with intermediate screws? *Injury*, 2016, vol. 47, no. Suppl. 4, pp. S29-S34. DOI: 10.1016/j.injury.2016.07.048.
52. Borkowski S.L., Tamrazian E., Bowen R.E., Scaduto A.A., Ebramzadeh E., Sangiorgio S.N. Challenging the Conventional Standard for Thoracic Spine Range of Motion: A Systematic Review. *JBJS Rev*., 2016, vol. 4, no. 4, pp. e51-e511. DOI: 10.2106/JBJS.RVW.O.00048.
53. Morita D., Yukawa Y., Nakashima H., Ito K., Yoshida G., Machino M., Kanbara S., Iwase T., Kato F. Range of motion of thoracic spine in sagittal plane. *Eur. Spine J*., 2014, vol. 23, no. 3, pp. 673-678. DOI: 10.1007/s00586-013-3088-7.
54. Burgos J., Barrios C., Mariscal G., Lorente A., Lorente R. Non-uniform Segmental Range of Motion of the Thoracic Spine during Maximal Inspiration and Exhalation in Healthy Subjects. *Front. Med*. (Lausanne), 2021, vol. 8. 699357. DOI: 10.3389/fmed.2021.699357.
55. Dai L.Y., Jiang L.S., Jiang S.D. Conservative treatment of thoracolumbar burst fractures: a long-term follow-up results with special reference to the load sharing classification. *Spine* (Phila Pa 1976), 2008, vol. 33, no. 23, pp. 2536-2544. DOI: 10.1097/BRS.0b013e3181851bc2.
56. Tomilov A.B., Kuznetsova N.L. Orthopedic correction of posttraumatic spinal deformities. *Genij Ortopedii*, 2012, no. 1, pp. 60-63. (in Russian)
57. Kwon S.M., Chun H.J., Yi H.J., Kim Y.S., Kim K.D. Computed Tomographic Assessment of Sagittal Plane Alignment of the Thoracolumbar Junction in a Young Adult Korean Population. *World Neurosurg*., 2019, vol. 121, pp. e351-e357. DOI: 10.1016/j.wneu.2018.09.105.
58. Kuklo T.R., Polly D.W., Owens B.D., Zeidman S.M., Chang A.S., Klemme W.R. Measurement of thoracic and lumbar fracture kyphosis: evaluation of intraobserver, interobserver, and technique variability. *Spine* (Phila Pa 1976), 2001, vol. 26, no. 1, pp. 61-65; discussion 66. DOI: 10.1097/00007632-200101010-00012.
59. Farcy J.P., Weidenbaum M., Glassman S.D. Sagittal index in management of thoracolumbar burst fractures. *Spine* (Phila Pa 1976), 1990, vol. 15, no. 9, pp. 958-965. DOI: 10.1097/00007632-199009000-00022.
60. Mattei T.A., Hanovnikian J., Dinh D.H. Progressive kyphotic deformity in comminuted burst fractures treated non-operatively: the Achilles tendon of the Thoracolumbar Injury Classification and Severity Score (TLICS). *Eur. Spine J*., 2014, vol. 23, no. 11, pp. 2255-2262. DOI: 10.1007/s00586-014-3312-0.
61. Machino M., Yukawa Y., Ito K., Kanbara S., Kato F. The complement of the load-sharing classification for the thoracolumbar injury classification system in managing thoracolumbar burst fractures. *J. Orthop. Sci*., 2013, vol. 18, no. 1, pp. 81-86. DOI: 10.1007/s00776-012-0319-4.

The article was submitted 02.06.2021; approved after reviewing 03.12.2021; accepted for publication 28.03.2022.

Information about the authors:

1. Vladimir D. Usikov – Doctor of Medical Sciences, Professor, usikov@list.ru, ORCID: 0000-0001-7350-6772;
2. Vladimir S. Kuftov – Candidate of Medical Sciences, kuftov@mail.ru, ORCID: 0000-0002-0548-8944;
3. Dmitry N. Monashenko – Candidate of Medical Sciences, d.monashenko@yandex.ru, ORCID: 0000-0002-8571-144.