# THE NEW PROCESSING OF THE RESULTS OF EXAMINATIONS MADE WITH ZEBRIS WIN-SPINE SPINE-MEASURING METHOD AND ITS VALIDATION

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**Abstract**

Aim: The Zebris spine-examination system and the associated measurement control program determine the spatial coordinates of processus spinosuses. Our processing program calculates kyphosis, lordosis and scoliosis values from the measurement data similarly to Cobb method. The aim of our research is to clarify whether the angle values determined from the X-ray results of young schoolchildren suffering from scoliosis by Cobb method differ from the values calculated from the spatial coordinates of processus spinosuses.

Methods: In the case of 25 children suffering from scoliosis two-way full spine X-rays in standing position on 31 occasions were taken, in accordance with the professional standards. On the basis of the photographs the thoracic kyphosis, lumbar lordosis and scoliosis values were determined with Cobb method. While the children were in standing position, ultrasound-based spine examinations was performed with a WINSPINE measuring software developed specially for the Zebris CMS-HS measuring system.

From the spatial coordinates of processus spinosuses the same angle values with our self-developed Excel processing program according to the principles of Cobb method were calculated. The degree of scoliosis was evaluated in the dorsal and in the lumbar section separately. The relationship between the two measurements was indicated by the Pearson correlation.

Results: From the comparison of the results of the two different measurement methods it was concluded that the correlation was strong between the values of the dorsal kyphosis and the lumbar lordosis ($r_{kyphosis}$=0.80 $r_{lordosis}$=0.94) while the correlation between the scoliosis values of the dorsal and lumbar sections was moderate ($r_{thoracic\ scoliosis}$= 0.67 $r_{lumbar\ scoliosis}$= 0.73).

Conclusion: The sagittal curvatures calculated with our self-developed software from the spatial coordinates of processus spinosuses which were determined with the CMS-HS ultrasound-based motion analysing system, show a strong correlation with the values calculated from X-rays using Cobb technique. The accurate assessment of the degree of scoliosis can only be done with an X-ray. Values defined with motion analysing measurements without exposure to radiation in the terms between X-rays performed regularly as specified in the professional recommendations can give satisfactory information about the possible trend of changes.

**Keywords:** children, spine, posture, ultrasound-based motion analysing system, Zebris.

**Introduction**

A frequently asked question in paediatric orthopaedics is how can be evaluated the spinal curvatures quantitatively in children who suffer from postural disorders or scoliosis. To determine the shape and the curves of the spine an X-ray is required. It is a priority to protect the young, growing organism against X-ray radiation[1]. Many efforts have been made to use low radiation to follow the changes in the shape of the spine, such as the ultra-low dose 2D/3D digital X-ray system[2] or the 3D freehand ultrasound system[3] developed from the traditional ultrasound measuring system. The biggest disadvantage of the latter is that the examined subject is in a lying position so the examination does not provide information about the posture in a natural standing position. Vrtovec and his colleagues examined devices suitable for taking X-rays with exposure to low radiation and they discovered that their accuracy is not worse that the accuracy of the traditional devices[4]. To reduce or to completely avoid X-ray radiation, the use of various motion analysing systems is becoming more and more common. They are used to determine the curvatures of the spine and to monitor the effectiveness of the therapy. During the measurement procedures the processus sensors are placed on the skin above the processus spinosuses to determine their spatial position (Fastrack, CA6000)[5,6]. From these spatial coordinates the curvatures of the spine can be seen and also the mobility of each spine section can be calculated[7,8]. The advantage of these examination methods is that they can be used in motion, too. Their disadvantage, however, is that the sensors on the body also record the skin movements, the sensors can move away when the skin is sweaty and they can influence or alter the motion as well. Today sensoring systems which are not attached to the spine but scrolled over or touched to the processus spinosuses (Spinal Mouse, kyphometer, goniometer and inclinometer)[9,10,11,12,13,14,15] are also available. One of the disadvantages of these systems and of their softwares is that the curvatures of the spine are not calculated according to the radiological Cobb method used in routine medical practice. The Zebris CMS-HS system and the WINSPINE software which was specially developed for this system fall into this category. Scoliosis is one of the most complex spinal deformities, as it can cause pathological curvatures in all three planes (sagittal, frontal and horizontal). The treatment is mostly conservative therapy which includes long-term physiotherapy, Schroth exercises and the wearing of a corset. If the curvature is severe (over 45-50 Cobb degrees), corrective surgery with conservative therapy before and after the operation may be needed. Concerning spinal deformities the rapid growth period in puberty requires special attention. In females between the ages of 10-14 years and males between the ages of 12-16 years the progression of scoliosis may be expected[16]. When the bone growth is complete there is little chance for deterioration. To set up a diagnosis we use X-ray (Rissel sign). Besides a lateral X-ray, which is used nowadays to diagnose scoliosis, also antero-posterior X-ray photographs help to determine the Cobb degree of lordosis and kyphosis. For screening mild cases, however, X-ray can be used for very strong professional reasons only, but in case of bad posture where there is no frontal deformity it cannot be used at all. After the diagnosis of scoliosis, during the monitoring of the effectiveness of the therapy it is necessary to make an effort to use non-invasive devices. The aim of our study was to define how much the spinal curvatures – which were calculated with our self-developed software from the spatial coordinates of the processus spinosus measured with Zebris ultrasound-based motion analysing system – differ from the curvature values determined with the Cobb method on X-rays. In this research the correlation of dorsal kyphosis, lumbar lordosis and scoliosis determined in a standing position was calculated.

## Material and methods

### Subjects

In the Orthopaedic Department of MÁV Hospital, Szolnok several children suffering from spine deformities were examined but the ultrasound based and X-ray examinations were carried out only in 25 scoliosis cases at the same time. Comparative examinations were made after half a year and after one year in 6 further cases in the group. The patients' parents had always received detailed verbal and written information before they filled the consent form. The average age of the 12 male subjects was 9.2±1.4 years, the average height was 135.8±7.1 cm and the average weight was 30.1±4.2 kg. The average age of the 19 female subjects was 9.5±1.3 years, the average height was 140.1±8.5 cm and the average weight was 33.5±6.6 kg.

### Methods

1. X-ray examination

The traditional X-ray images were taken in a natural standing position. Antero-Posterior (A-P) and lateral radiographs were taken about the whole spine.

2. Zebris Ultrasound-based spinal examination

In the Biomechanics Laboratory of MÁV Hospital, Szolnok the shape of the spine in a natural standing position was measured with a Zebris CMS-HS ultrasound-based motion analysing system (Zebris Medizintechnik GmbH, Isny, Germany). The system consists of

- a head which emits ultrasound pulses from three transmitters,
- a triplet consisting of three ultrasound microphones to screen the movements of the spine
- a pointer stick with two ultrasound microphones

The three transmitters of the head send ultrasound pulses at regular intervals which are recorded by the microphones (the measurement frequency is 100 Hz). If the temperature is known, from the speed and running time of the ultrasound the distance from the microphones to the transmitters can be calculated. By triangulation the spatial coordinates of the microphones can be determined in every minute during the measurement from the spatial coordinates of the head's markers and from the distance between the markers and the microphones. This calculation can be performed for every microphone. The WINSPINE measuring software (Zebris Medizintechnik GmbH, Isny, Germany) records and stores the spatial coordinates of the microphones numerically and the spatial coordinates of the processus spinosuses are calculated from these coordinates.

The steps of the examination (*Figure 1*):

1. Placing the triplet consisting of three miniature ultrasound microphones on the patient's pelvis. Connecting the triplet and the pointer stick to the central unit with special cables (a).

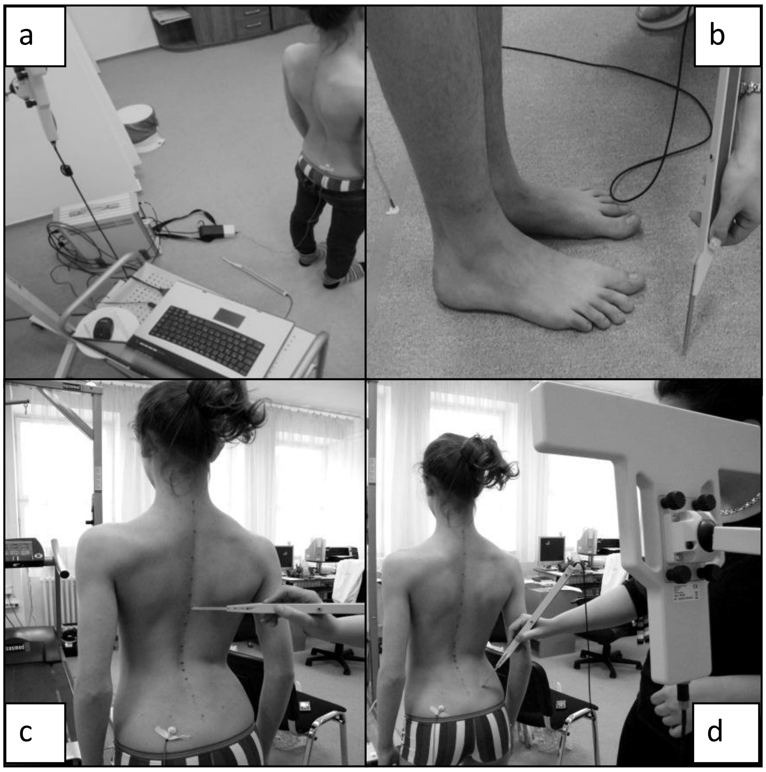


*Figure 1.* The steps of the examination

2. Placing the subject in front of the measuring head with his back towards the machine. It is necessary to pay special attention to the correct posture when children are the subjects: shoulders must be lowered, flat scapulas must be held close to each other.
3. Calibration: measuring of the global coordinate system with the pointer (b).
4. Marking of certain anatomic points on both sides of the body (acromion, angulus inferior scapulae, spina iliaca posterior superior) and the determination of the point between the thoracic XII. and the lumbar I. vertebrae.
5. Recording the shape of the spine: guiding the pointer over the processus spinosuses from the cervical VII. vertebrae to the sacral I. vertebrae.

**Characteristics and statistical analysis**

1. X-ray characteristics

Cobb method was used to evaluate the A-P and lateral curvatures. On the lateral radiographs the degree of the thoracic kyphosis was calculated as the supplementary angle of the perpendicular lines placed on the upper closing membrane of the thoracic I. and on the lower closing membrane of the thoracic XII. vertebrae. The lordosis between L1 and L5 was also determined using Cobb angles with the same method. On antero-posterior X-ray images the supplementary angles of the perpendicular lines placed on the two closing membranes of the vertebrae at the ends of the curvature which gave both the degree of the thoracic and that of the lumbar scoliosis was determined.

2. Data of Zebris ultrasound-based motion analysing system

The spatial position of the processus spinoususes was calculated with the Zebris CMS-HS ultrasound-based measuring system and its WINSPINE measurement control program. The further processing was made with the self-developed Excel-based processing program.

To determine the thoracic and lumbar curvature we used coordinates from the sagittal plane (x-z plane) (*Figure 2*):

- the angle of thoracic kyphosis in the sagittal plane is the differences between the angle formed by the straight line placed on the processus spinosus of the thoracic vertebrae I. and II. and the vertical line and the angle formed by the straight line placed on the processus spinosus of the thoracic vertebrae XI. and XII. and the vertical line.
- the angle of lumbar lordosis in the sagittal plane is the difference between the angle formed by the straight line placed on the processus spinosus of the lumbar vertebrae I. and II. and the vertical line and the angle formed by the straight line placed on the processus spinosus of the lumbar vertebrae IV. and V. and the vertical line

The angle of the scoliosis was determined in the frontal plane (y-z plane) and so we used only coordinates of this plane (*Figure 3*):

- The degree of thoracic scoliosis is the angle formed by the straight line placed on the processus spinosus of the thoracic vertebrae I. and II. and by the straight line placed on the processus spinosus of the thoracic vertebrae XI. and XII.
- The degree of lumbal scoliosis: the angle formed by the straight line placed on the processus spinosus of the lumbar vertebrae I. and II. and by the straight line placed on the processus spinosus of the lumbar vertebrae IV. and V.

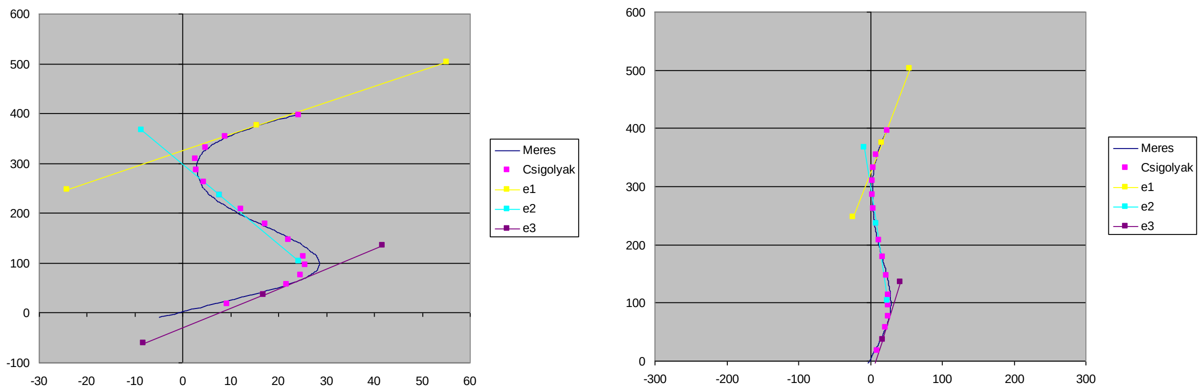


*Figure 2.* Spine posture in the sagittal plane non-scaled (left) and scaled (right)

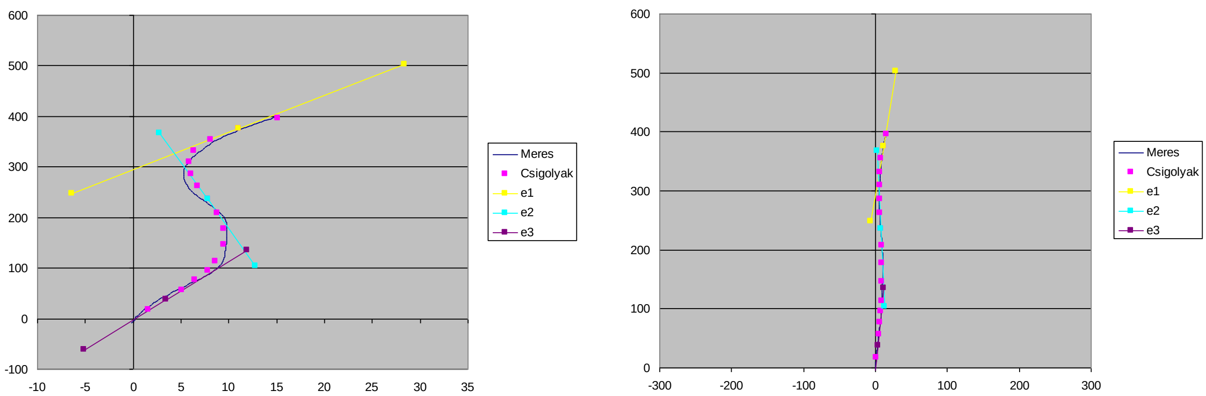


*Figure 3.* Spine posture in the frontal plane non-scaled (left) and scaled (right)

**Statistical analysis**

In the case of every subject the thoracic kyphosis, lumbar lordosis, thoracic and lumbar scoliosis were determined by both methods. From the results the means, standard deviations (SD) and the maximum and minimum values of the groups were calculated. From the calculated data the Pearson correlation coefficient (r), the gradient of the regression line (m) were determined with linear regression and the significance level was calculated by one-sample t-test . The statistical analysis was made with Microsoft Excel 2003.

**Results**

From the spatial coordinates of the subjects' processus spinosus which were measured on the radiographs and were determined with the WINSPINE with Excel processing software we calculated the angles' means, standard deviations, minimum and maximum values as it is shown in *Table 1*. The results of the statistical analysis are shown in *Table 2*.

| | | **mean±SD** | **minimum** | **Maximum** |
|---|---|---|---|---|
| **Thoracic kyphosis** | X-ray Cobb degree | 34.58±6.76 | 20.0 | 50.0 |
| | Excel | 33.48±5.45 | 21.9 | 42.9 |
| **Lumbar lordosis** | X-ray Cobb degree | 32.84±10.17 | 10.0 | 50.0 |
| | Excel | 27.75±8.95 | 12.2 | 45.5 |
| **Scoliosis Thoracic** | X-ray Cobb degree | 6.55±4.41 | 0.0 | 15.0 |
| | Excel | 5.35±3.88 | 0.1 | 16.1 |
| **Scoliosis Lumbar** | X-ray Cobb degree | 7.81±4.87 | 0.0 | 20.0 |
| | Excel | 7.43±5.28 | 0.5 | 22.0 |

*Table 1.* The mean±standard deviation (SD), minimum and maximum values where calculated with the two different methods in sagittal (thoracic kyphosis, lumbar lordosis) and in frontal plane (scoliosis thoracic, scoliosis lumbar)

| | **Thoracic Kyphosis (Cobb degree-Excel)** | **Lumbar Lordosis (Cobb degree-Excel)** | **Scoliosis deformation (Thoracic) (Cobb degree-Excel)** | **Scoliosis deformation (Lumbar) (Cobb degree-Excel)** |
|---|---|---|---|---|
| **r** | 0.80 | 0.94 | 0.67 | 0.73 |
| **m** | 1.00 | 1.07 | 0.77 | 0.67 |
| **p** | 0.07 | 0.00 | 0.03 | 0.29 |

*Table 2.* The values of the correlation coefficient (r), the gradient of the regression line (m) and the significance level (p) at kyphosis, lordosis, thoracic scoliosis and lumbar scoliosis, calculated with the two measuring methods

By comparing the results of the two measuring methods the conclusion is that the correlations between the thoracic kyphosis and the lumbar lordosis values are good ($r_{kyphosis}$=0.80; $r_{lordosis}$=0.94) which is confirmed by the gradients of the regression lines ($m_{kyphosis}$=1.00; $m_{lordosis}$=1.07). The correlations between thoracic scoliosis and lumbar scoliosis values are medium ($r_{thoracic\ scoliosis}$= 0.67; $r_{lumbar\ scoliosis}$= 0.73) (*Table 1.* and *2.*), which is confirmed by the gradients of the regression lines ($m_{kyphosis}$=1.00; $m_{lordosis}$=1.07).

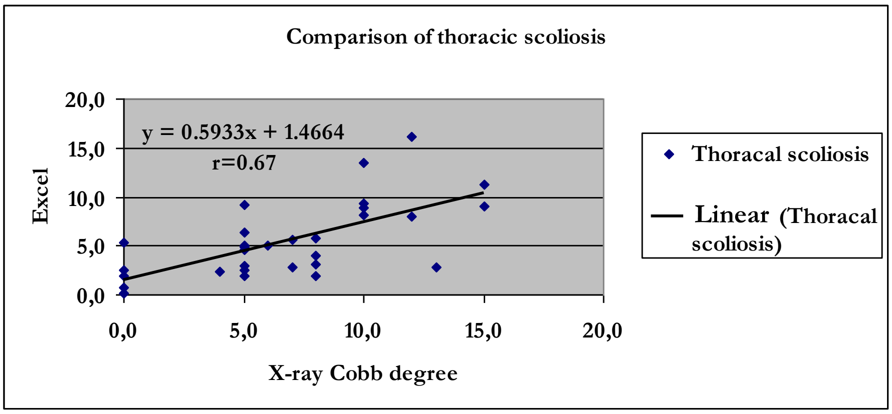


*Figure 4.* Comparing the thoracic scoliosis values of the two methods

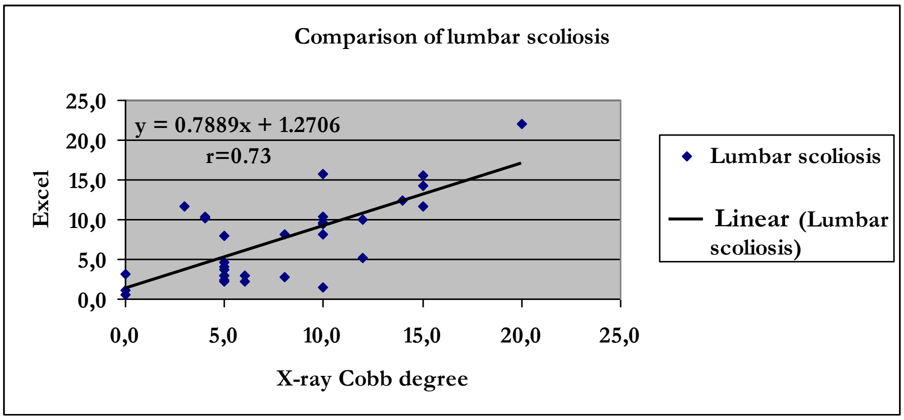


*Figure 5.* Comparing the lumbar scoliosis values of the two methods

## Discussion

Viola and his colleagues[18] concluded from an examination of 25 girls suffering from AIS (Adolescent Idiopathic Scoliosis) that the Cobb degree for measuring the degree of scoliosis and the angle formed by the processus spinosus and defined by Zebris WIN-SPINE show a strong correlation in the frontal plane both in the thoracic and at the lumbar sections. When they evaluated the results, however, they did not mention the sagittal curvatures[18]. In our study we were able to assess the degree of thoracic kyphosis and lumbar lordosis on lateral radiographs of children suffering from scoliosis. in our study the angles set by the Cobb method on radiographs with the angles determined with the self-developed Excel software from the processus spinosus defined with Zebris WINSPINE were compared. The results of the two measurement methods are close to identical in the sagittal plane in kyphosis and lordosis because the correlation is strong and the gradient of the regression line is around 0.7 (*Figure 4 and 5*). The comparison of X-ray images was only possible in patients suffering from scoliosis. The results showed that scoliosis induces deformities of the spine in all three dimensions but still the curvatures measured in the different dimensions are almost identical when we compare the results of the two methods.

Therefore, we assumed that in daily orthopaedic practice the Zebris motion analyzing system and our self-developed Excel processing software together are useful for the follow-up of the effectiveness of conservative therapy in children with bad posture and in children suffering from deformities in the sagittal plane caused by Scheuermann's disease. Because of the medium correlation found in frontal curvatures the diagnosis of scoliosis and the annual health check must be based on X-ray in the future too,, in accordance with the recommendations of the Orthopaedic Advisory Board, but in the intervals the Zebris motion analysing system with the self-developed Excel processing software can be used to estimate the degree of scoliosis.

## REFERENCES


1. Doody MM, Lonstein JE, Stovall M, Hacker DG, Luckyanov N, Land CE. Breast cancer mortality after diagnostic radiography: findings from the U.S. Scoliosis Cohort Study. Spine 2000;25(16):2052-63.
2. Somoskeöy S, Tunyogi-Csapó M, Bogyó C, Illés T. Accuracy and reliability of coronal and sagittal spinal curvature data based on patient-specific three-dimensional models created by the EOS 2D/3D imaging system. Spine J. 2012;12(11):1052-9.
3. Purnama KE, Wilkinson MH, Veldhuizen AG, van Ooijen PM, Lubbers J, Burgerhof JG, Sardjono TA, Verkerke GJ. A framework for human spine imaging using a freehand 3D ultrasound system. Technol Health Care 2010;18(1):1-17.
4. Vrtovec T, Pernus F, Likar B. A review of methods for quantitative evaluation of spinal curvature. Eur Spine J. 2009;18(5):593-607.
5. Mannion A, Troke M. A comparison of two motion analysis devices used in the measurement of lumbar spinal mobility. Clin Biomech 1999;14(9):612-9.
6. Petersen CM, Johnson RD, Schuit D, Hayes KW. Intraobserver and interobserver reliability of asymptomatic subjects' thoracolumbar range of motion using the OSI CA 6000 Spine Motion Analyzer. J Orthop Sports Phys Ther. 1994;20(4):207-12.
7. Schuit D, Petersen C, Johnson R, Levine P, Knecht H, Goldberg D. Validity and reliability of measures obtained from the OSI CA-6000 Spine Motion Analyzer for lumbar spinal motion. Man Ther. 1997;2(4):206-215.
8. Troke M, Moore AP, Maillardet FJ, Hough A, Cheek E. A new, comprehensive normative database of lumbar spine ranges of motion. Clin Rehabil. 2001;15(4):371-9.
9. Mannion AF, Knecht K, Balaban G, Dvorak J, Grob D. A new skin-surface device for measuring the curvature and global and segmental ranges of motion of the spine: reliability of measurements and comparison with data reviewed from the literature. Eur Spine J. 2004;13(2):122-36.
10. Ripani M, Di Cesare A, Giombini A, Agnello L, Fagnani F, Pigozzi F. Spinal curvature: comparison of frontal measurements with the Spinal Mouse and radiographic assessment. J Sports Med Phys Fitness. 2008;48(4):488-94.
11. Van Herp G, Rowe P, Salter P, Paul JP. Three-dimensional lumbar spinal kinematics: a study of range of movement in 100 healthy subjects aged 20 to 60+ years. Rheumatology (Oxford). 2000;39(12):1337-40.
12. Salisbury PJ, Porter RW. Measurement of lumbar sagittal mobility. A comparison of methods. Spine 1987;12(2):190-3.

13. Stokes IA, Bevins TM, Lunn RA. Back surface curvature and measurement of lumbar spinal motion. Spine 1987;12(4):355-61.
14. Tillotson KM, Burton AK. Noninvasive measurement of lumbar sagittal mobility. An assessment of the flexicurve technique. Spine 1991;16(1):29-33.
15. Zuberbier OA, Kozlowski AJ, Hunt DG, Berkowitz J, Schultz IZ, Crook JM, Milner RA. Analysis of the convergent and discriminant validity of published lumbar flexion, extension, and lateral flexion scores. Spine 2001;26(20):E472-8.
16. Busscher I, Wapstra FH, Veldhuizen AG. Predicting growth and curve progression in the individual patient with adolescent idiopathic scoliosis: design of a prospective longitudinal cohort study. BMC Musculoskelet Disord. 2010;11:93.
17. Tanure MC, Pinheiro AP, Oliveira AS. Reliability assessment of Cobb angle measurements using manual and digital methods. Spine J. 2010;10(9):769-74.
18. Viola S, Szoke G, Kocsis L, Körmendi Z, Zsidai A. Kinesiological examination in AIS. Orv Hetil. 2007;148(6):259-63.

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