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Original Research Article

Analysis of the sagittal plane in standing and sitting position in girls with left lumbar idiopathic scoliosis

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ABSTRACT

Introduction: Current development of civilization and technology makes a sitting position dominant in everyday life. This applies also to patients with spinal deformities.
Aim: The aim of this study was to analyze the size of physiological spinal curvatures in standing and sitting posture in girls with left lumbar scoliosis and evaluate usefulness of Zebris CMS-10 System in the assessment of physiological curvatures in both positions.
Material and methods: A group of 30 girls aged 11–17 years with left lumbar idiopathic scoliosis, with a Cobb angle in the range of 10°–21°, was examined. Control group consisted of 30 healthy girls aged 10–17 years. Studies were conducted with the use of ZEBRIS CMS-10 System (Zebris Medical, Germany) in a standardized standing (P1) and sitting (P2) position. Mean kyphosis and lordosis angle and differences between kyphosis and lordosis angle dependent upon positional changes were analyzed in each of the groups.
Results and discussion: Mean kyphosis angle in both positions showed no statistically significant differences between the study group and control group. Mean lordosis angle in P1 position in the study group was statistically significantly higher than in control group. Differences between mean kyphosis angle in P1 and P2 position in the study group in comparison with control group were not statistically significant. Differences between mean lordosis angle in P1 and P2 position in comparison with control group showed a statistical significance.
Conclusions: The presence of low degree lumbar scoliosis can result in deepening of lumbar lordosis in the standing posture, but it does not significantly affect kyphosis angle measured in standing and sitting position. Zebris CMS 10 System is a useful tool for the assessment of physiological spinal curvatures in standing and sitting position.

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1. Introduction

Idiopathic scoliosis (IS) is defined as multi-dimensional deformity of the spine, where buckling of the spine in frontal plane is accompanied by abnormal curvature of the sagittal and transverse alignment of the spine.[1,2,4,5,8,10]

2. Aim

Analysis of physiological curvatures in standing and sitting posture in girls with left lumbar IS and evaluation of usefulness of Zebris CMS-10 in the assessment of physiological curvatures in standing and sitting position.

3. Material and methods

The studies were conducted in the Department of Rehabilitation, Faculty of Medical Sciences of the University of Warmia and Mazury in Olsztyn in 2011–2013. Guardians of participants of the study provided a written informed consent for the conduct of the tests.

In total, 284 subjects, including 146 girls and 138 boys, were examined in a relaxed standing position. A group of 30 girls aged 11–17 years with left lumbar IS, with a Cobb angle of 10°–21°, not treated with orthoses, was separated from the study population. Measurements of the scoliotic curve were performed on radiographs in accordance with Cobb methodology (Table 1).[13]

Control group consisted of 30 girls without scoliosis, with an acceptable trunk asymmetry and the value of the angle of trunk rotation (ATR) up to 5°, measured with Bunnel scoliometer (Table 2).[9,12]

The study was conducted in standing (P1) and sitting position (P2).[5,15,19]

3.1. *Basic standing position (anthropometric)– P1*

Examined patients were standing upright with their heads slightly elevated, in Frankfort horizontal plane (*planum horizontale frankfurtensis*), i.e. tangent to the lower border of the orbit and upper margin of the external auditory meatus was parallel to the floor, with shoulders straight and relaxed, no tension of back muscles, upper limbs hanging by the sides with the palms facing (but not pressed against) the thigh, lower limbs straight (no hyperextension of the knee joints) with feet resting parallel to each other on the selected test square.[6,16]

3.2. *Sitting position (anthropometric)– P2*

Examined patients sat on a stool with their entire lower buttocks, with ischial tuberosities and back of the thighs leaned on the surface of the stool. The head, trunk and shoulders were positioned as in the basic standing position. Arms hanging vertically in line with the trunk with the palms facing the stool. Thighs set horizontally to achieve a 90° angle between the shank and the thigh, feet parallel to each other.[16] In the study, a square-shaped flat top stool was used. Its height was adjustable and matched the popliteal height.[6,16]

In the main study analysis of trunk postures of the IS girls in the sagittal plane was performed. The test was conducted in two positions with the use of Zebris CMS-10 Measuring System.[11,17,19]

The Zebris CMS-10 Posture Measuring System (Zebris Medical GmbH) uses the WinSpine software that runs under Microsoft Windows XP operating system.[17,19] This software contains a database of information on the projects, patients and individual measurements. The second component of the measuring system was a measuring device, ultrasonic marker and reference marker. Measuring device was fixed on the floor stand with the adjustable height. Pointer stick, which is directly touched to the bony landmarks, has two ultrasonic markers, center of which is in line with the tip of the sensor. The program precisely calculates position of the tip of the sensor. A reference marker in the form of a belt is fastened laterally below the posterior superior iliac spine and anterior superior iliac spine, not to cover measuring points. It is used to eliminate position changes during the conduct of the study. Prior to each test, the device was calibrated in relation to the ground. Average duration of the test in standing and

Table 2 – Characteristics of control group.

Values	Characteristics of control group ($n=30$)	
	Age	Height
Mean	13.90	161.90
SD	1.92	9.05
Minimum	10	140
Maximum	17	176
Median	14	164

Table 1 – Characteristics of patients with left lumbar scoliosis.

Values	Characteristics of study group ($n=30$)		
	Age	Height	Angle of curvature, according to Cobb, deg
Mean	14.0	162.3	14.0
SD	1.7	7.1	2.9
Minimum	11	146	10
Maximum	17	177	21
Median	14	163	14

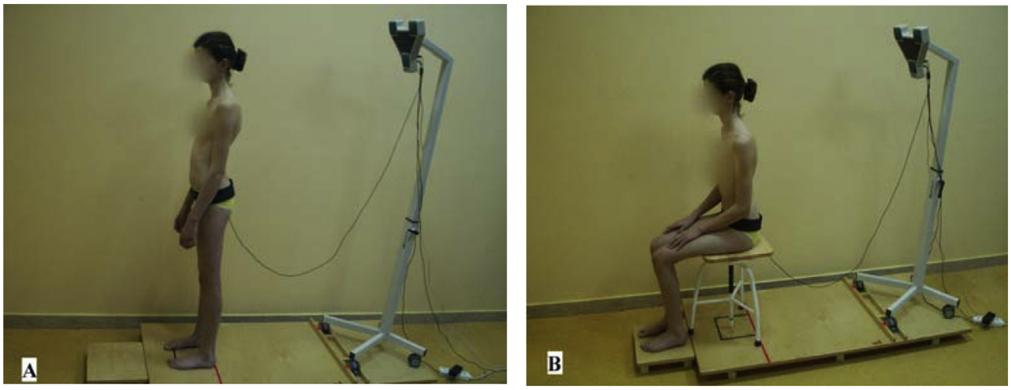

Fig. 1 – Study in a standing position P1 (A) and sitting position P2 (B) using Zebris CMS 10 system (own patients).

sitting position was 5–10 minutes. Measurement accuracy of the apparatus in respect to the calculated parameters is stated by the manufacturer in medical description, that is 2.2 mm or 1.96°. Each measurement of the spine was performed three times. Measuring unit consisted of a platform integrated with the sensors of Zebris CMS-10 Measuring System and computer with Microsoft Windows XP software. Measuring platform was divided into sections. In one third of platform length a transverse lock was mounted in order to immobilize Zebris CMS-10 device. It enabled placing the device in a fixed location and reduced unintentional movements associated with the use of the device. At a distance of 80 cm from the transverse lock a permanent transverse red line was drawn. It was the base of a square measuring 25 × 25 cm, outlined by a black line. Sides of the square determined foot position of subjects during the standing measurement. Red transverse line also determined a point in front of which heels of a subject were placed (Fig. 1).

Prior to the conduct of the posture measurement, anatomical bony landmarks were marked. Bony landmarks were marked in accordance with the principles of palpable anatomy, with an accuracy of 1 cm, including skin mobility (Fig. 2).[16,18]

In the first part of the study the patient was positioned in P1 position with feet placed on the drawn square and heels touching the red line. The investigated subject was standing back to the measuring device, always at the same distance from the apparatus. Second part of the study was conducted in P2 position. The stool was placed on the platform at a distance of 80 cm from the measuring device, near the red transverse line. The whole study procedure was performed identically in both P1 and P2 position, in accordance with the user manual. A floor stand of the measuring device was adjusted to patient's occiput height. In both measurements anatomical bony landmarks were marked with the ultrasonic pointer. First left and right acromion (*acromion*) were marked, and then bony landmarks of the pelvis, i.e. left and right posterior superior iliac spine (*spina iliaca posterior superior*), left and right anterior superior iliac spine (*spina iliaca anterior superior*) and the highest point of the left and right iliac crest (*crista iliaca*). Afterward, a thoracolumbar junction (*processus transversus Th12/L1*) was marked. In the next step, left and right inferior angle of the scapula (*angulus inferior scapulae*)

Fig. 2 – Zebris CMS 10 system – marking of bony landmarks (own patients).

and spinous processes (*processus spinosi*) of C7–S3 were entered to the system. Location of the spinous processes was introduced three times. WinSpine software calculated the average of the values entered. Through the spinous processes virtual planes were passing, which created a surface of projection of the calculated angles along the line of spinous processes. Report from the described studies showed a line of spinous processes in the sagittal, frontal and transverse plane. This is a line of spinous processes automatically divided by the number of anatomical vertebrae.

For a detailed analysis of results in P1 and P2 positions, several parameters reflecting the analysis of trunk position in the sagittal plane, including local kyphosis and lordosis angles, were chosen.[19]

In the descriptive statistics of the studied quantitative variables, means, standard deviations, medians and quartiles were used. While comparison of average quantitative variables in both groups was based on Student's *t*-test and permutation test.

4. Results

In a group of girls with left lumbar scoliosis, at a significance level of $p \leq .05$, the mean values of kyphosis angles were higher than in control group in both evaluated positions, but the differences were not statistically significant (Table 3). Values of lordosis angles in P1 position in the study group were

Table 3 – Mean values and standard deviations of kyphosis and lordosis angles in P1 and P2 positions and differences of kyphosis and lordosis angles in P1 and P2 positions.

Studied variables	Study group (n=30)	Control group (n=30)	P value
Kyphosis in P1 position	38.6±14.5	34.9±11.1	.265
Kyphosis in P2 position	27.7±13.4	24.7±10.2	.340
Lordosis in P1 position	35.10 (29.9, 40.2)*	27.90 (20.0, 38.2)*	.042
Lordosis in P2 position	11.2±9.1	12.1±7.2	.704
Difference of kyphosis angles in positions P1 and P2	11.0±15.7	10.1±11.4	.823
Difference of lordosis angles in positions P1 and P2	26.9 (14.1, 34.0)*	14.1 (9.5, 25.6)*	.046

Comments: P1 – standing position; P2 – sitting position; * – results given as median (25th percentile, 75th percentile).

Table 4 – Comparison of mean kyphosis and lordosis values in P1 and P2 positions among individual groups.

Studied variables	P1 position	P2 position	P value
Kyphosis in study group	38.60±14.50	27.70±13.40	<.01
Kyphosis in control group	34.90±11.10	24.70±10.20	<.01
Lordosis in study group	34.60±8.80	11.20±9.10	<.01
Lordosis in control group	29.50±10.90	12.10±7.20	<.01

Comments: P1 – standing position; P2 – sitting position.

statistically significantly higher than in the control group (Table 3). Lordosis angles in P2 position did not differ significantly between both groups. Differences between kyphosis angles in P1 position and in P2 position were also measured. The same differences were determined for lordosis angles. Determined differences in case of lordosis were higher in the study group than in control group (Table 3).

Comparison of mean values of kyphosis and lordosis angles in different positions P1 and P2 within the same group showed statistically significant differences (Table 4).

5. Discussion

Evaluation of spinal curvatures in sagittal plane in a clinical examination without the use of additional diagnostic tools involves a high level of subjectivity and does not allow monitoring of curvature changes over time. The advantage of examination performed by a clinician interacting with a patient is the ability to dynamically evaluate postural changes and response of spinal curvatures to correction/self-correction, as well as during certain clinical tests and changes of position, in which the assessment is conducted. Researchers and clinicians are still looking for simple, yet reliable tools to support the assessment and monitoring of individual components of body posture parameters.[3,7,20,21,22,24]

Sitting position seems to be currently underestimated in posture analysis, even though this is the position in which people are spending increasingly more time, both in the developmental age and in adulthood. Influence of correct and incorrect prolonged sitting position on body posture and secondary changes in the locomotor system should thus be obvious.[5,23,25]

Assessment of spinal curvatures with the use of Zebris CMS-10 – in this case thoracic kyphosis and lumbar lordosis – beside the evaluation of buckling of the spine in frontal plane, allows a three-dimensional analysis of the position of the trunk.[14]

The authors have extended the study in classical standing position with the assessment in sitting position, in accordance with methodology presented above. Similar position was used by Chowańska in the assessment of back topography in children with IS; however, this was a seated forward bend position.[5]

Comparison of kyphosis angle in standing and sitting position shows statistically significant differences regardless of whether it concerns control group or girls with lumbar scoliosis. Presence of lumbar scoliosis does not however significantly affect differences between kyphosis measured in P1 and P2 position.

The results of lordosis angle (statistically significantly higher in scoliosis group in P1 position), and particularly differences between measurements in P1 and P2 position (also statistically higher in scoliosis group) allow to presume to be associated with lumbar scoliosis. The study shows that in sitting position physiological thoracic and lumbar curvatures are significantly reduced. On the other hand, it seems that other factors, such as age, body weight, height, did not have any significant influence on the distribution of the evaluated parameters.

Further studies and analysis of other parameters that may affect spinal curvatures in sagittal plane in children with lumbar scoliosis, e.g. spinal mobility, coincidence of other spinal deformities (such as Scheuermann's disease), pain and presence of contractures of pelvic girdle muscles are required.[3,10,15]

6. Conclusions

1. Presence of low-grade lumbar scoliosis deepens lumbar lordosis in standing position.
2. Presence of low-grade lumbar scoliosis does not significantly affect kyphosis angle measured in standing and sitting position.

3. Zebris CMS-10 System is a useful tool for the assessment of spinal curvatures in sagittal plane in standing and sitting position.

Conflict of interest

None declared.

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REFERENCES

[1] Bruyneell AV, Chavet P, Bollini G, Allard P, Mesure S. The influence of adolescent idiopathic scoliosis on the dynamic adaptive behavior. *Neursci Lett*. 2008;447(2–3):158–163.
[2] Boos N, Aebi M, eds. *Spinal Disorders: Fundamentals of Diagnosis and Treatment*. Berlin: Springer; 2008.
[3] Chaise FO, Candotti CT, Torre ML, Furlanetto TS, Pelinson PP, Loss JF. Validation, repeatability and reproducibility of a noninvasive instrument for measuring thoracic and lumbar curvature of the spine in the sagittal plane. *Rev Bras Fisioter*. 2011;15(6):511–517.
[4] Chockalingam N, Bandi S, Rahmatalla A, Dangerfield HP, Ahmed el-N. Assessment of the centre of pressure pattern and moments about S2 in scoliotic subjects during normal walking. *Scoliosis*. 2008;3(10):1–6.
[5] Chowańska J. *Zasadność stosowania różnych pozycji przy badaniu metodą topografii powierzchniowej dla oceny zniekształcenia tułowia u dzieci ze skoliozą idiopatyczną [Validity of the Use of Various Positions in Surface Topography for the Assessment of Trunk Deformity in Children with Idiopathic Scoliosis]* [Master's thesis]. Poznań: Faculty of Health Sciences, Poznan University ⟨http://www.cq.com.pl/publikacje/Zasadnosc_pozycji.pdf⟩;2007. Accessed: 20.02.2013 [in Polish].
[6] Gedliczka A. Atlas miar człowieka. Dane do projektowania i oceny ergonomicznej [Atlas of Human Body Measures]. 2001. Warszawa: CIOP; 5 [in Polish].
[7] Greendale GA, Nili NS, Huang MH, Seeger L, Karlamangla AS. The reliability and validity of three non-radiological measures of thoracic kyphosis and their relations to the standing radiological Cobb angle. *Osteoporos Int*. 2011;22(6):1897–1905.
[8] Górecki A, Kiwerski J, Kowalski IM, Marczyński W, Nowotny J, Rybicka M, et al. Profilaktyka wad postawy u dzieci i młodzieży w środowisku nauczania i wychowania – rekomendacje ekspertów [Prophylactics of postural deformities in children and youth carried out within the teaching environment – experts recommendations]. *Pol Ann Med*. 2009;16(1):168–177 [in Polish].
[9] Kotwicki T, Negrini S, Grivas TB, Rigo M, Maruyma T, Durmala J, et al. Methodology of evaluation of morphology of the spine and trunk in idiopathic scoliosis and Rother spinal deformities – 6th SOSORT consensus paper. *Scoliosis*. 2009;4(26):1–16.
[10] Kowalski IM, Protasiewicz-Fałdowska H, Jóźwiak-Grabysa D, Kiebzak W, Zarzycki D, Lewandowski R, et al. Environmental factors predisposing to pain syndromes among adolescent girls with diagnosed idiopathic scoliosis. *J Elementol*. 2010;15(3):517–530.
[11] Küster M. Dreidimensionale Ultraschalltopometrie der wirbelsäle und Maximalkraftmessung der Rumpfmuskulatur bei Jugendlichen [3-D-ultrasound topometry of the spine and assessment of the maximum trunk muscle strength in adolescents]. *Deutshe Z Sportmedizin*. 2003;54(12):352–354.
[12] Kuźdżał A, Szczygieł A, Ćwirklej A. Porównanie parametrów krzywizn kręgosłupa w płaszczyźnie strzałkowej mierzonych metodą antropostereometryczną i inklinometryczną [Comparison of spinal curvature parameters in sagittal plane measured with anthropostereometry and inclinometry]. *Post Rehab*. 2004;18(4):11–14 [in Polish].
[13] Lam GC, Hill DL, Le LH, Raso JV, Lou EH. Vertebral rotation measurement: a summary and comparison of common radiographic and CT methods. *Scoliosis*. 2008;3(16):1–10.
[14] 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):122–136.
[15] Neuhous T, Sulam NL. Is there consistency between asymmetrical weight bearing in standing compare to sitting, in IS patients; and PT implementation? *Scoliosis*. 2010;5(suppl 1):60. http://dx.doi.org/10.1186/1748-7161-5-S1-O60.
[16] Nowak E. *Atlas antropometryczny populacji polskiej – dane do projektowania. The Antropetric Atlas of the Polish Population*. Warszawa: IWP; 21–26 [in Polish and English].
[17] Petrovitch A, Will T. Vergleich von 3D-Bewegungsanalysen und Röntgenfunktionsaufnahmen bei Patienten mit Verdacht auf segmentale Instabilität der Lendenwirbelsäule. *Phys Med Rehab Kuror*. 2001;11:151–152 [in German].
[18] Protasiewicz-Fałdowska H. *Przestrzenna analiza zmiany asymetrii tułowia w pozycji stojącej i pozycji siedzącej u dziewcząt ze skoliozą idiopatyczną [Spatial Analysis of Changes in Trunk Asymmetry in Standing and Sitting in Girls with Idiopathic Scoliosis]* [Ph.D. dissertation]. Olsztyn: Faculty of Medical Sciences, Univeristy of Warmia and Mazury; 2012 [in Polish].
[19] Roiha H. *Wirbelsäulenform und -beweglichkeit im Schulalter* [Dissertation]. München: Medizinische Fakultät der Ludwig-Maxililians-Universität. ⟨http://edoc.ub.uni-muenchen.de/2276/1/Roiha_Hanna.pdf⟩;2004. Accessed 20.02.2013 [in German].
[20] Smania N, Picelli A, Romano M, Negrini S. Neurophysiological basis of rehabilitation of adolescent idiopathic scoliosis. *Disabil Rehabil*. 2008;30(100):763–771.
[21] Śliwiński Z. Porównanie wyników ocen postawy ciała u dzieci szkolnych uzyskanych metodą fotogramometrii i badaniem statyki miednicy [Comparison of posture assessment in school-aged children by photogrammetry and static pelvic examination]. *Med Man*. 1997;1:17–22.
[22] Taft E, Francis R. Evaluation and management of scoliosis. *J Pediatr Health Care*. 2003;17(1):42–44.
[23] Tyrakowski M, Kotwicki T, Szulc A. Zasadność stosowania pozycji siedzącej do badania dzieci ze skoliozą metodą topografii powierzchniowej [Validity of using sitting position to the examination of children with scoliosis by surface topography]. *Ortop Traumatol Rehab*. 2004;6(suppl 1):48 [in Polish].
[24] Veldhuizen AG, Wever DJ, Webb PJ. The aetiology of idiopathic scoliosis: biomechanical and neuromuscular factors. *Eur Spine J*. 2000;9(3):178–184.
[25] Walicka-Cupryś K, Puszczałowska-Lizis E, Maziarz K. The forming of anterior-posterior spinal curvatures in young people from junior high schools and grammar schools. *Rehab Med*. 2008;12(4):28–36.