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The Analysis of Selected Posturogram Parameters in Children with Scoliotic Changes

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Abstract

The aim of the research was to analyze selected posturogram parameters in children with scoliotic changes. 28 girls aged 7-18 years old were involved in the study. Children attended to the Interschool Centre of Corrective Exercises in Starachowice. The research was conducted in June 2011. Spine research was made by ***Exhibeon digital radiography.*** Based on the size of the angle of spinal curvature there were identified scoliotic posture: 1-9° and scoliosis: ≥10°. There were 21 (75%) children with scoliotic posture, and 7 (25%) with idiopathic scoliosis. The frequency and type of defect ***didn't depended on age.*** Postural reactions were examined by static-dynamic Tecnobody's ST 310 Plus Stability System platform. Perimeter was from 539,46 with opened eyes (OE) to 759,04 with closed eyes (CE). The difference in Romberg's Test was 219,58. Ellipse area was from 447,46 with opened eyes (OE) to 850,32 with closed eyes (CE). The difference in Romberg's Test was 402,86. Perimeter ratio was 146,68, and Area ratio was 213,89. Analysis of variance showed a significant effect of study options which clearly differentiates Permeter (p=0,000008) and Ellipse Area (p=0,029882) in the research with opened and closed eyes. In a study with closed eyes it has been observed a significant increase of posturogram variables. Analysis of variance for Area ratio didn't show any significant effects (p= 0,376899) similarly for Perimeter ratio (p=0,523086). Posturogram variables generally decreased with age, however the analysis of variance didn't show any statistically significant effects. The analysis of the Spearman rank correlation of posturogram variables with age of examined persons also didn't show any significant associations.

Keywords: posturogram parameters, scoliotic changes, Tecnobody's Stability System platform

1. Introduction

The record which shows the way of the centre of feet pressure (COP) in a two-dimensional supporting plane is called posturogram or statokinesiogram. Most often assessed sway parameters are those, which are easiest to measure (Błaszczyk, 2016). The directions in this plane are determined by the letters x and y, wherein x (or AP) means sways in the sagittal plane, and y (or ML) lateral deflections in the frontal plane (Aroeira et al., 2016). The most frequently analyzed and probably the most valuable parameter of posturogram is the path length of posturogram. The road traveled by the center of gravity during the test, depends on the imposed time of registration and the speed movement of the COG (or COP) during the study (Michoński et al., 2016). Usually impaired balance control of standing posture is manifested by prolongation of this road (Nishida et al., 2016). Because the chaotic movements of the center of gravity are two-dimensional, additional informations about postural stability can be obtained, by analyzing the individual components of the way of statokinesiogram, separately sways in the sagittal plane, and separately in the frontal plane (Wilczyński & Ślężyński, 2016). Separate analysis of each component of posturogram allows to find, in which plane the instability intensifies. More information about the balance control provides the analysis of the entire envelope of posturogram, not just selected directions (Huec et al., 2016). If we

will connect the extreme points of statokinesiogram with the lines, we will get an irregularly shaped polygon. The area of a figure calculated by the computer, depends on the range of sways in all directions and it is the another characteristic parameter of posturogram (Park et al., 2016). More often, somewhat to simplify the problem of analysis, researchers fits the sway points into a circle or ellipse (Bogie et al., 2014). The geometrical dimensions of these figures, for example the radius of a described circle or length rays and tilt axis of the ellipse, are another important indicators of the quality of balance control (Tam et al., 2014; Pialasse et al., 2016). The posture of a man standing in a standard two-legged support is characterized by a greater sways in the sagittal plane (Pialasse & Simoneau, 2015; Yen et al., 2016). Movements of COG in the frontal plane are much smaller, and the increase of instability in this plane is usually effectively compensated by wider spaced feet (Khanal et al. 2016; Pialasse & Simoneau, 2014). The range of observed sways in the sagittal plane is usually two or three times greater than in frontal plane, and that's why the ellipse more accurately covers the measurement points of statokinesiogram (Park et al. 2013; Paolucci et al., 2013; de Santiago et al., 2013; Talić et al., 2016). In addition to the surface of the ellipse, an important indicator of the quality of balance control is the slope of a longer axis of the ellipse (corresponding to the sways in the sagittal plane) relative to coordinate system (Berdishevsky et al., 2016; Gomez, Hresko & Glotzbecker, 2016). Balance disorder, caused by scoliotic changes, in addition to the range increase of uncontrolled movements of the center of gravity of the body also causes characteristic changes seen in posturogram, for example the slope of axis of the ellipse (Yang et al., 2016; Seifert, Thielemann & Bernstein, 2016). The aim of the research was to analyze selected posturogram parameters in children with scoliotic changes on Tecnobody's ST 310 Plus Stability System platform.

2. Method

2.1 Participant (Subject) Characteristics

The study included 28 girls aged 7-18 years old with scoliotic posture and idiopathic scoliosis. All respondents were selected intentionally. All research procedures were carried out in accordance with the 1964 Declaration of Helsinki and with the consent of the University Bioethic Board for Scientific Research affairs at Jan Kochanowski University in Kielce (Poland). Children attended to the Interschool Centre of Corrective Exercises in Starachowice (Poland). The research was conducted in June 2011.

2.2 Research design

Spine research was made by ***Exhibeon digital radiography.*** Pixel Technology's Exhibeon digital radiology is a valuable diagnostic tool, which replace a traditional X-ray film. Exhibeon runs on Linux and Microsoft Windows operating systems. With a browser, we can describe changes in bone structure, and ***soft tissues.*** Exhibeon currently supports 84 graphic image formats, compatible with DICOM, including animation formats presented in CINE mode. Exhibeon is able to cooperate simultaneously with multiple image archives - PACS servers. The program supports the format DICOMDIR, and allows to search the images inside catalog. It allows printing on DICOM printers, and their configuration, through the base device, is simple. Exhibeon digital radiology allows, among others, to outline the central sacral vertical line, visible on X-ray of the spine on the computer screen, measure of the angle of axial circle rotation and to determine the Cobb angle. Radiographs have been taken of a free-standing position, anterior-posterior projection and lateral. With a browser, we could describe changes in bone structure, and ***soft tissues.*** X-ray included lumbar, thoracic and cervical spine, chest, and pelvis with hip joints. The Cobb angle has been marked on X-ray of the spine, which is visible on the computer screen. For the study of posturogram, the computerized posturography has been used. Posturogram variables were examined by static-dynamic Tecnobody's ST 310 Plus Stability System platform.

2.3 Measures and Covariates

The research based on continuous observation of the centre of feet pressure (COP). By recording the horizontal deflection of the body (postural sway) as a function of time, the detailed information concerning the postural system has been obtained. The COP displacements reflected the movements of center of body mass (COM) in the frontal and sagittal plane. The frequency of signal was 20 Hz. Change of the maximum pressure on the soles of the feet during the deviations of the body was perceived by mechanical-electronic transducer consisting of three sensors installed inside the platform. Recorded signal was processed from the analog information into digital, and then elaborated by computer program. The appropriate software created the possibility to calculate the resultant ground reaction force, which is the sum of the moments of the forces acting on the platform in three points of measurement. Vector addition of force moments allowed to designate the resultant ground reaction force at the moment, which is graphically presented as a dot on statokinesiogram. There was performed a standard stability rating test in a free-standing position (Romberg's Test). ***The test consisted of two successive samples*** lasting 30 seconds each: first with opened eyes (OE – *open eys*), second with closed eyes (CE– *close eys*). ***Measurements***

were taken in the morning. The tested person was carefully instructed about the test sequence. The ***silence has been assured*** during examination, because auditory stimuli acting on man ***in terms of attention*** can significantly impair the postural reflexes. The examined person has been ensured about the total harmlessness of the performed test. During the study, the investigator was behind the tested person all the time, not passing any messages. During the measurements with opened eyes (OE), the examined person has been asked to focus his sight on a point of reference located on the computer screen. The center of vision speckle was located at a distance of 1 meter from examined person. Before starting the test with closed eyes (CE), researcher made sure that the tested person is able to maintain an upright posture without visual control. The examined person stood on a platform barefoot, because shoes could interfere his posture. The feet were set with careful precision: heels 2 cm from each other, feet apart at the angle of 30 °, so that the center of gravity of a polygon base was in the sagittal axis of the platform at a distance of 3 cm from its center. To facilitate the correct positioning of the tested person, the platform was equipped with a pattern to keep the feet apart. The examined person took a habitual position with arms lowered along the torso and head straight. Test started at the time when investigated person took a posture, and on the screen the way of centre of feet pressure deviation was displayed. It has been analyzed the selected posturogram parameters, which records the centre of feet pressure deviations (COP):

- Perimeter. It is the total length of the path traveled by the COP in both planes during the oscillation (mm).
- Ellipse area. It is the total area which circled the COP in both planes during the oscillation (mm^2).
- Perimeter ratio. It is the ratio of circumference (perimeter) with eyes closed (CE) to the circumference with eyes opened (OE) in Romberg's Test.
- Area ratio. It is the ratio of ellipse area with eyes closed (CE) to the area with eyes opened (OE) in Romberg's Test.

Depending on the compatibility of variable distributions with normal distribution, and the value of skewness and kurtosis, parametric or non-parametric tests have been used. Variables were verified in terms of normal distribution by Shapiro-Wilk test. Variability of quantitative traits in terms of categorial features (age group, study options) were verified by analysis of variance with single and double classification. The level of significance was $p < 0,05$.

3. Results and Discussion

Based on the size of the angle of spinal curvature there were identified scoliotic posture (1-9°) and scoliosis (≥10°). There were 21 (75%) children with scoliotic posture, and with idiopathic scoliosis 7 (25%). The frequency and type of defect ***didn't depended on age.*** Perimeter was from 539,46 with opened eyes (OE) to 759,04 with eyes closed (CE). The difference in Romberg's Test was 219,58. Ellipse area was from 447,46 with opened eyes (OE) to 850,32 with closed eyes (CE). The difference in Romberg's Test was 402,86. Perimeter ratio was 146,68 and Area ratio was 213,89 (Tab. 1).

Table 1. Posturogram parameters with eyes opened (OE) and closed (CE)

Postural reactions	n	Average	Med	Min	Max	Range	Standard deviation	Skewn	Kurtos
Perimeter (OE)	28	539,46	493	248	1079	831	195,80	1,272	1,825
Ellipse Area (OE)	28	447,46	438,5	102	1660	1558	314,37	2,260	**7,616**
Perimeter (CE)	28	759,04	723	449	1330	881	232,50	0,714	-0,106
Ellipse Area (CE)	28	850,32	647	144	3776	3632	781,18	2,525	**7,165**
Perimeter ratio	28	146,68	140,5	71	226	155	36,45	0,271	-0,338
Area ratio	28	213,89	187,5	31	719	688	149,03	1,691	3,896

Perimeter in the age group of 7-11 was from 659,00 with opened eyes (OE) to 830,00 with closed eyes (CE). The difference in Romberg's Test was 171. In the age group of 12-14 was from 483,53 with opened eyes (OE) to 756,61 with closed eyes (CE). The difference in Romberg's Test was 273,08. In the age group of 15-18 was from 506,71 with opened eyes (OE) to 682,42 with closed eyes (CE). The difference in Romberg's Test was 175,71 (Tab. 2).

Table 2. Perimeter and Ellipse Area in age groups

Independent variables	(OE-CE)	Dependent variable				n
		Average	Standard error	-95,00%	95,00%	

7-11 years old (1)	Perimeter (OE)	659,00	66,05	522,96	795,04	8
7-11 years old (2)	Perimeter (CE)	830,00	83,00	659,04	1000,95	8
12-14 years old (3)	Perimeter (OE)	483,53	51,81	376,82	590,25	13
12-14 years old (4)	Perimeter (CE)	756,61	65,11	622,50	890,72	13
15-18 years old (5)	Perimeter (OE)	506,71	70,61	361,28	652,14	7
15-18 years old (6)	Perimeter (CE)	682,42	88,73	499,67	865,18	7
Independent variables	(OE-CE)	Dependent variable				n
		Average	Standard error	-95,00%	95,00%	
7-11 years old (1)	Ellipse Area (OE)	681,87	101,24	473,36	890,38	8
7-11 years old (2)	Ellipse Area (CE)	892,87	281,12	313,89	1471,85	8
12-14 years old (3)	Ellipse Area (OE)	362,84	79,41	199,27	526,41	13
12-14 years old (4)	Ellipse Area (CE)	965,61	220,53	511,42	1419,80	13
15-18 years old (5)	Ellipse Area (OE)	336,71	108,23	113,81	559,61	7
15-18 years old (6)	Ellipse Area (CE)	587,57	300,53	-31,38	1206,52	7

Ellipse area in the age group of 7-11 was 681,87 with opened eyes (OE) to 892,87 with closed eyes (CE). The difference in Romberg's Test was 211. In the age group of 12-14 was from 362,84 with opened eyes (OE) to 965,61 with closed eyes (CE). The difference in Romberg's Test was 602,77. In the age group of 15-18 was from 336,71 with opened eyes (OE) to 587,57 with closed eyes (CE). The difference in Romberg's Test was 250,86 (Tab. 3).

Table 3. Perimeter Ratio and Area Ratio in age groups

Independent variables	Perimeter Ratio Average	Confidence -95,00%	Confidence 95,00%	Perimeter Ratio n	Standard deviation	Min.	Max.
7-11 years old (1)	134,87	105,36	164,38	8	35,30	71	181
12-14 years old (2)	156,92	133,43	180,41	13	38,87	108	226
15-18 years old (3)	141,14	111,13	171,15	7	32,44	102	183
Total	146,68	132,54	160,81	28	36,44	71	226
Independent variables	Area ratio Average	Confidence -95,00%	Confidence 95,00%	Area ratio n	s	Min.	Max.
7-11 years old (1)	174,87	83,64	266,10	8	109,12	31	337
12-14 years old (2)	248,38	133,10	363,66	13	190,76	63	719
15-18 years old (3)	194,42	110,55	278,30	7	90,69	92	326
Total	213,89	156,10	271,68	28	149,03	31	719

Total Perimeter ratio was 146,68. In the age group of 7–11 was 134,87, in the age group of 12–14 was 156,92, and in the age group of 15–18 was 141,14. Total Area ratio was 213,89. In the age group of 7-11 it was 174,87. In the age group of 12–14 it was 248,38, and in the age group of 15–18 was 194,42. The analysis of variance with the single classification showed a significant effect of study options in Romberg's Test (OE/CE) both for Perimeter (p=0,000008) as well as Ellipse area (p=0,029882) (Tab. 4). Posturogram variables generally decreased with age, but this decrease wasn't statistically significant (Tab. 4). The analysis of variance with the single classification for Perimeter ratio and Area ratio showed no significant effects (Tab. 4). Also the correlation analysis of posturogram variables with opened and closed eyes and age showed no significant associations (Tab. 4).

Table 4. The analysis of variance for repeated measures (Note 1)

Perimeter					
Independent variables	SS	DF	MS	F	p

Free term	22264980	1	22264980	308,81	0
Age groups	209145	2	104573	1,45	0,25
Error	1802446	25	72098		
OE-CE	557081	1	557081	31,0743	**0,000008**
OE-CE - Age groups	34777	2	17389	0,96	0,39
Error	448185	25	17927		
Ellipse Area					
Independent variables	SS	DF DF	MS	F	p
Free term	21245034	1	21245034	52,54	0
Age groups	801211	2	400606	0,99	0,38
Error	10107697	25	404308		
OE-CE	1643698	1	1643698	5,30357	**0,029882**
OE-CE – Age groups	487872	2	243936	0,78	0,46
Error	7748081	25	309923		
Perimeter Ratio					
SS Effect	df Effect	MS Effect	SS Error	df Error	 Error
2693,45	2	1346,73	33174,7	25	1326,99
Area ratio					
SS Effect	df Effect	MS Effect	SS Error	 Error	df Error
30297,01	2	15148,51	569407,7	25	22776,31

The analysis of correlation of posturogram variables with opened and closed eyes and age

Posturogram variables	Age (OE)	Age (CE
Perimeter	R=-0,29; p=0,13	R= -0,31; p=0,10
Ellipse Area	R=-0,32; p=0,087	R= -0,25; p= 0,18
Perimeter Ratio	R= -0,04; p=0,81	
Area ratio	R= -0,10; p=0,58	

Within the meaning of ***etiopathogenesis***, scoliosis is only a symptom, an external expression of unrecognized pathology, which can occur in any segment of the spine and in ***children*** of ***different ages.*** In the present state of knowledge it is reasonable to talk more about the etiological factors, not about the theory (genetical, metabolic etc.) of scoliosis formation. Currently the concept which has got the most supporters is a multifactorial, including genetical (CHD7 gene) conditioned pathology of central nervous system, which causes changes in postural system (Tam et al. 2014). Scoliotic posture means a tendency to deflect the axis of the spine from a straight line, associated rather with the wrong habit of keeping the individual body segments. At the beginning each spontaneously growing scoliosis is a ***gradual low curvature – scoliotic posture (Myers, 2016).*** After time it reveals the actual development trends (Byun & Han, 2016; Kim & Hwang, 2016). In a ***pathobiomechanical*** term***, scoliosis*** is compensated when the original deflection (a) goes smoothly into compensatory, proximal and distal deflection (Porte et al. 2016). Then the compensatory deflections are enough developed, and they equilibrate the original deflection. The sum of their angle values corresponds approximately to the angle value of original deflection. Scoliosis is the result of original imbalance of vertically poised spine. Posturogram variables are the elements of body balance (van Herwijnen et al. 2016). Overall assessment of efficiency of the balance system provides the posturography test. This is possible because of the reactions analysis and postural strategies, which forms the basis of mechanisms that promote the body in balance (Saifi, Kang & Lehman, 2016). Balance is a certain state of postural system, which is characterized by the vertical orientation of the body achieved due to aligning the forces acting on a body and their moments (Nikolova et al. 2015). The balance is provided by the nervous system through the reflex tension of respective muscle groups called anti-gravity muscles (Romano et al. 2008). Some informations about the body balance gives the analysis of individual posturogram variables. Scoliosis is a disease associated with disorders of the central stabilization of the body caused by postural hypotonia. Disorders of posturogram variables that occurs in scoliosis affects on pathoetiology of scoliosis and reversal movements of individual body segments ***increase the amplitudes*** of these variables. Stabilization disorders associated with dysfunction of CNS, and postural hypotonia seen in the increased posturogram variables, are probably primary and they precede scoliotic changes (Wilczyński et al., 2018).

4. Conclusions

The analysis of variance showed a significant effect of study options which clearly differentiates Perimeter and Ellipse Area in Romberg's Test. In a study with eyes closed a significant increase of these variables has been observed. Posturogram variables generally decreased with age, however, analysis of variance showed no statistically significant effects. The analysis of the Spearman rank correlation of posturogram variables with age of examined persons also showed no significant associations.

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Note

Note 1. In analysis of ariance the symbols mean: SS – sum of square, DF –degree of freedom, MS –mean of squares, F – ratio of MS effect to MS error, p – level of significance.