Monitoring changes in the shape of the spine in children with postural disorders

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Abstract

Background

Due to numerous complications of an abnormal shape of the spine, it is extremely important to systematically monitor its shape. Precise and routine method of measurement enables comparison of the scores obtained over time and possible early intervention in order to avoid complications.

The aim of the work is to present the pattern for monitoring changes in the shape of the spine in children with postural deformities.

Methods

The study group (n = 211) consisted of the patients with diagnosed shape of the spine deformity, who underwent a four-month therapy, supervised by a physiotherapist. The control group (n = 101) were the children with no shape of spine deformity.

The children in the study group underwent a three-dimensional computer analysis of the shape of the spine. The DIERS test was performed in both groups (study and control). In the study group it was performed four times. It involved the measurement of seven parameters enabling a complete assessment of body posture.

Results

Statistically significant scores of the Friedman test for imbalance, pelvic tilt, kyphosis angle, lordosis angle, and lateral deviation were observed. Therefore, a series of post-hoc analyzes were performed using Dunn-Bonferroni tests. It was observed that changes in individual parameters analyzed in the authors' study come up at a different pace.

Conclusions

Detailed monitoring of the parameters describing the position of the spine makes it possible to control the course of the treatment process of patients with disorders of the position of the spine. The dynamics of changes taking place within the spine position varies for the individual parameters analyzed.

Introduction

Gradual change in the shape of the spine is an adaptation mechanism to changing conditions and motor needs which accompany a person during their growth [1]. The shape of the spine is formed by many factors, both internal and external, it changes throughout life, under the influence of age, kind of performed work, but also emotional state and physical fatigue [2, 3]. It should be emphasized that disorders in the shape of the spine often occur as a result of bad habits [4]. The aforementioned habits may result in the adoption of a non-physiological body posture in everyday activities, influencing the shaping and preserving an abnormal body shape [4], which consequently negatively affects many body

systems [5–13]. Some of these disorders, despite apparent regression, reappear later in life, most often as weakening of manual skills and graphic functions, as well as disorders in the development of eye-hand coordination, visual analysis and synthesis [14]. All these factors may lie behind psychosocial problems [15]. Due to numerous complications of an abnormal shape of the spine, it is extremely important to systematically monitor its shape. The precise and routine method of measurement enables the comparison of the scores obtained over time and possible early intervention in order to avoid the complications described above.

There are many ways to categorize the shape of the spine, ranging from visual assessment methods [16, 17], through the use of simple instruments [18–20], to complex computer systems [21–29]. The most frequently used method of visual assessment does not meet the criteria of objectivity and repeatablity, therefore it is worth implementing more effective methods of conducting tests in children [30]. X-radiation continues to play an important role in diagnostics as it enables the observation of morphological changes in the vertebrae, as well as calculation of the angle of spine curvature acc. Cobb [31]. Performing radiological examination, however, is associated with the patient's exposure to ionizing radiation and therefore cannot be performed as preventive examination. With respect to preventive examination and systematic monitoring of treatment effects, it is better to use photogrammetric systems, which are non-invasive and do not need big financial outlays [32].

Aim

The aim of the work is to present a pattern for monitoring changes in the shape of the spine in children with posture disorders.

Material And Method Of Study

Participants Subjects

The children aged 8-12 were assessed. The study group consisted of the patients diagnosed with the shape of spine deformity. Children in the study group underwent a four-month therapy conducted under the supervision of a physiotherapist. The control group consisted of the children who did not have posture defect in preventive medical examination or physiotherapeutic assessment.

The study group consisted of 211 children, 53% girls, 46.92% boys. The mean age in the study group was 10.72 years (SD = 1.25), body height 1.4 meters (SD = 0.16), body weight 34.7 kg (SD = 11.84), BMI 20.15 (SD = 2.35).

The control group consisted of 101 children, 50% girls, 50% boys. The mean age in the control group 10.69 (SD = 1.44), body height 1.39 meters (SD = 0.13), body weight 38.69 (SD = 8.03), BMI 20.02 (SD = 2.52).

Inclusion criteria:

- age 8-12 years

- diagnosed defect of shape of the spine

- good general health (≤2 acc. the ECOG Scale)

- the legal guardian's consent to participate in the study.

Exclusion criteria:

- comorbidities that may affect the shape of the spine disorder

- interruption or non-compliance with the recommendations included in the therapeutic procedure

- BMI below the 10th and above the 90th percentile.

Participation in the research was voluntary, combined with ensuring anonymity. The legal guardians of the children participating in the study gave their informed consent.

Study project

The children in the study group were subjected to a three-dimensional computer analysis of shape of the spine and a physiotherapeutic functional assessment. Based on the obtained results, rehabilitation program was chosen, which assumed: 1. performing specific therapeutic activities by the child at home twice a day under parental control, 2. the use of a mirror in order to properly correct body posture. The examination was conducted and the choice of therapy was made by a physiotherapy specialist. The study protocol assumed 4 appointments at four-week intervals. During each appointment, the analyzed parameters were measured and a functional test was performed. Based on these, the therapy was chosen. The parents were thoroughly trained by the physiotherapist in the recommended techniques, which they would then perform with the children until the subsequent appointment.

In the control group, the measurement of the analyzed parameters as well as the functional test were performed once.

The study was approved by the Bioethics Committee at the Faculty of Medicine and Health Sciences, the Jan Kochanowski University in Kielce (Approval No. 1/2016, issued 15.01.2016). All methods were performed in accordance with the relevant guidelines and regulations.

Body posture assessment

The shape of the spine was assessed in static conditions in a standing habitual position, with the back to the camera, with eyes directed straight ahead. The DIERS Formetric 4D system was used to assess the posture. The system enables precise assessment of the shape of the spine [29]. The DIERS test was performed in both groups (study and control). In the study group it was performed four times (before the

first and after the second, third and fourth therapeutic sessions). It involved the measurement of seven parameters enabling a complete assessment of body posture [33].

Parameters assessed:

1. Trunk imbalance VP-DM [mm] - shows the deviation of the VP (spinous process of the 7th cervical vertebra) from the DM (the midline connecting the right and left dimples of Venus)
2. VP-DM [mm] lateral deviation - means the maximum deviation of the spine midline from the VP-DM line in the frontal plane (value at the top of the curve)
3. Pelvic tilt [mm] - means the difference in the height of lumbar dimples in relation to the horizontal plane (cross-section)
4. Pelvic torsion [º] - calculated from the mutual torsion of the planes at the points of lumbar dimples (vertical component)
5. Surface rotation [o] - maximum trunk rotation on the symmetry line
6. Kyphosis angle [º] - the angle measured between VP and the estimated position of Th12
7. Lordosis angle [º] - the angle measured between the estimated position of Th12 and DM

Intervention

In the rehabilitation program for children from the study group, global patterns chosen on the basis of functional and computer testing were used, based on two recognized therapeutic methods. The planned therapeutic program was realised by the treated children under their parents' supervision. The therapeutic session was about 20 minutes long and was based on elements of the PNF and Vojta methods [34-36].

Statistical methods used

Statistical analyzes were performed with IBM SPSS Statistics 23 package. The basic descriptive statistics were analyzed: the mean, the median, standard deviation, skewness, kurtosis, the smallest and the biggest distribution value.

The sample size necessary to draw conclusions about the entire population was estimated [37], based on available epidemiological studies [38].

In order to assess normality of the distribution of variables, the non-parametric Kolmogorov-Smirnow test was used [39].

Percentage differences between the measurements were calculated. In order to assess the significance of differences between the parameters in the study and control groups, the Mann-Whitney U test was used due to the fact that most of the analyzed variables adopted different from normal distribution [40].

The analysis of changes occurring between consecutive measurements in the study group was conducted using the Friedman test [41]. This test was used because it allows to determine the differences

between the four measurements simultaneously.

Statistically significant scores of the Friedman test underwent Post-Hoc tests using the Dunn-Bonferroni test to counteract the problem of multiple comparisons, consisting in reducing nominal significance level of each set of related tests [42].

Results

Basic descriptive statistics of tested quantitative variables were calculated together with the Kolmogorov-Smirnow test checking the normality of the distribution of these variables. The analyzes were performed separately for the study group and the control group. The vast majority of measurements adopted distributions different from the normal distribution. Hence, in order to maintain the consistency of the scores, in this work, statistical analyzes were performed using non-parametric tests.

The minimum value/number necessary to infer about the entire population of children aged 8-12 with spinal posture defect in Poland is 296, therefore, the study group of 312 meets the assumed criteria.

The scores related to posture rates of children from the study and control groups are presented in Table 1. Nine statistically significant differences were recorded: five for measurement I and four for measurement IV. The values of trunk imbalance, pelvic tilt, pelvic torsion, surface rotation, and lateral deviation were higher in the study group. The strength of observed effects was high in the case of trunk imbalance in both measurements, pelvic tilt in both measurements, pelvic torsion in measurement I and lateral deviation in both measurements, moderately high in measurement IVof pelvic torsion and measurement I of trunk imbalance, in other cases the effect size was low. Observing the value of the effect size index *r*, the difference between the control group and the study group decreased in measurement IV. The biggest drop was recorded for trunk imbalance, surface rotation, and lateral deviation. It should be emphasized that drop in the difference between the control group and the study group was also recorded in kyphosis and lordosis angles, where the difference between the groups was not statistically significant.

Table 1.Comparison of the study and control groups in terms of the level of body posture rates

measurement		Study group (n = 211)		Control group (n = 101)		U	Z	p	r
		M	SD	M	SD				
trunk imbalance [mm]	I	9.09	6.09	-0.39	4.83	2053.5	-11.550	**<0.001**	0.65
	IV	4.24	4.13	-0.39	4.83	4645.0	-8.094	**<0.001**	0.46
pelvic tilt [mm]	I	3.55	3.45	0.21	3.54	5059.0	-7.747	**<0.001**	0.44
	IV	2.80	2.74	0.21	3.54	5708.0	-6.893	**<0.001**	0.39
pelvic torsion [°]	I	2.51	1.84	0.70	2.54	5749.5	-6.580	**<0.001**	0.37
	IV	2.17	1.65	0.70	2.54	6479.5	-5.601	**<0.001**	0.32
kyphosis angle [°]	I	41.37	9.60	39.45	8.28	9695.0	-1.288	0.198	0.07
	IV	38.92	8.28	39.45	8.28	10135.0	-0.698	0.485	0.04
lordosis angle [°]	I	37.05	9.55	38.33	8.59	9593.0	-1.425	0.154	0.08
	IV	38.10	8.13	38.33	8.59	10352.5	-0.406	0.684	0.02
surface rotation [°]	I	4.56	2.18	3.66	1.99	7776.0	-3.862	**<0.001**	0.22
	IV	4.10	2.10	3.66	1.99	9265.0	-1.865	0.062	0.11
lateral deviation [mm]	I	4.51	2.91	2.10	0.71	3857.5	-9.118	**<0.001**	0.52
	IV	3.97	2.58	2.10	0.71	5100.5	-7.451	**<0.001**	0.42

M – mean; *SD* – standard deviation; *U* – Mann-Whitney U test score; *Z* – standardised value; *p* – statistical significance; *r* - effect size

Statistically significant scores of the Friedman test for trunk imbalance, pelvic tilt, kyphosis angle, lordosis angle and lateral deviation were recorded. Therefore, a series of *post-hoc* analyzes were performed using Dunn-Bonferroni tests. For trunk imbalance, differences between all measurements were recorded. The value of this index was decreasing constantly with subsequent measurements. Two statistically significant differences for pelvic tilt were recorded. The highest level of this index was recorded in measurements I and II and was significantly higher than the index in measurement IV. The level in measurement III did not differ from the others. For kyphosis angle, the lowest level was recorded in measurement IV and it was statistically significantly lower than in measurement I, II and III. For lordosis angle, the lowest level was recorded in measurement I. It was statistically significantly lower than the level in the subsequent three measurements, while there were no statistically significant differences between them. For lateral deviation and trunk imbalance, the lowest score was recorded in measurement IV and it was statistically significantly lower than in measurements I, II and III, while there were no statistically significant differences between these measurements. Additionally, the Friedman test was close to statistical significance for surface rotation index. However, such a score did not enable *a post-*

hoc analysis. No statistically significant score for pelvic torsion was achieved. Detailed data are presented in Table 2.

Table 2. Changes in the level of body posture rates during the therapy.Dunn-Bonferoni Test

measurement	M	M	SD	
trunk imbalance [mm]	1	9.09a	6.09	
	2	7.61b	5.99	$\chi^2(3) = 127.82$
	3	6.48c	5.11	$p < 0.001$
	4	4.24d	4.13	
pelvic tilt [mm]	1	3.55a	3.45	
	2	3.59a	3.43	$\chi^2(3) = 12.79$
	3	3.31ab	3.45	$p = 0.005$
	4	2.80b	2.74	
pelvic torsion [°]	1	2.51	1.84	
	2	2.40	1.72	$\chi^2(3) = 4.63$
	3	2.36	1.71	$p = 0.201$
	4	2.17	1.65	
kyphosis angle [°]	1	41.37a	9.60	
	2	40.12a	9.63	$\chi^2(3) = 17.34$
	3	40.42a	9.46	$p = 0.001$
	4	38.92b	8.28	
lordosis angle [°]	1	37.05a	9.55	
	2	37.97b	9.35	$\chi^2(3) = 18.34$
	3	38.28b	9.61	$p < 0.001$
	4	38.10b	8.13	
surface rotation [°]	1	4.56	2.18	
	2	4.41	2.40	$\chi^2(3) = 7.81$
	3	4.60	2.44	$p = 0.050$
	4	4.10	2.10	
lateral deviation [mm]	1	4.51a	2.91	
	2	4.48a	2.77	$\chi^2(3) = 15.38$

3	4.76a	3.03	$p = 0.002$
4	3.97b	2.58	

Discussion

The applied DIERS measurement system enables detection of even small changes in tested parameters describing the position of the spine in space. The analysis of the scores shows that the computer system makes it possible to observe differences of a few millimeters or degrees in size. Their clinical value may be of varying importance in long-term observation. Thus, regular monitoring of specific parameters in objective manner enables precise comparison of the criteria of the dysfunction image at each stage of its treatment. This is especially important due to the risk of progression of a dysfunction, which is a phenomenon considered typical in children with the shape of spine disorders [3, 43].

In our study of the treatment process, a change in most parameters was recorded: trunk imbalance was reduced by 4.85 mm (53%), pelvic tilt by 0.75 mm (21%), thoracic kyphosis angle by 2.45 degrees (6%) and reached physiological value, just like lordosis angle, which increased by 1.05 degrees (3%). The rotation angle decreased by 0.46 degrees (10%), imbalance was reduced by 1.54 mm (12%). Pelvic torsion was the only parameter describing the body posture that did not change significantly in our study - reduction by 0.36 degrees (14%) p = 0.201 (Tab. 1).

The shape of spine correction effect is also described by other researchers. Lee, who used the PNF technique, achieved a considerable reduction in the frontal curvature within 3 weeks [44]. Weiss, using the combination of PNF and Schrot techniques with postural re-education, describes the reduction of abnormal curvature in frontal plane and considerable improvement in thoracic kyphosis angle and spine rotation [42]. Reduction of lateral deviation, thoracic kyphosis angle, lumbar lordosis angle, rotation angle and trunk imbalance after 4 weeks of rehabilitation was shown [45]. Misiuk points out that the application of PNF-based therapy 3 times a week results in a significant reduction in pelvic tilt after 6 weeks [46]. Stępień, using the PNF technique, described positive effects of her actions in the area of lumbar lordosis angle, spine rotation and pelvic torsion after 6 months of treatment [34]. Steffan, combining the methods of Vojta and Schrot, also indicates the reduction of spine abnormal shape parameters [47]. In the authors' observations, an important advantage of the methods described is that they are easy to learn and perform in home conditions.

It should be emphasized that changes in individual parameters analyzed in our study appear at a different pace. It was found that parameters such as trunk imbalance and pelvic torsion improved systematically with each appointment. For pelvic tilt, improvement had not been not observed until the third examination. Kyphosis angle, surface rotation and lateral deviation make an interesting group of described parameters, where, during examination 2, visible improvement was observed, and during examination 3 - deterioration against the second, and examination 4 had the best result of all the measurements. Another observation implies that lordosis angle, which improved in examinations 2 and 3, slightly deteriorated in 4 compared to 3 (Table 2).

The fact that the authors describe the effects of therapy after the the treatment cycle has finished, without analyzing them during its course, should be critically assessed. The lack of publications describing changes in the parameters of the spine position during treatment does not allow to compare our observations with the results of other authors. During the examination, special attention should be drawn to the spinal curvature in the sagittal plane, i.e. kyphosis angle and lordosis angle, because, as our observations show [45, 48, 49] and other authors' reports, it is these parameters that imply a change in the shape of the spine in the other two planes [50-52].

The abovementioned irregular changes in the spine position parameters during long-term rehabilitation may be the consequence of various factors which may disturb observation process. Natural changes in the spine during the growth period may affect the pace of shaping its curves [1,3]. Adopting a specific body position in everyday activities also influences the shaping and preserving the figure [3,53]. In view of negative changes, sedentary lifestyle, which contributes to the loss of lumbar lordosis, is particularly unfavorable in the treatment of scoliosis [3]. Reducing physical activity and frequent exceeding of the body's energy demand is also indicated as the cause of the deterioration of body posture among children and adolescents [3,54].

Considering the variability of effects achieved in the treatment process and, described in the literature, a number of factors influencing the rehabilitation process of patients with shape of spine disorders the authors recognize the need for continuous and objective monitoring of the achieved effects. Reliable assessment of the effects of therapy needs suitable tools, the more so that most physiotherapists examine the patient only subjectively [54]. Raster stereography is such a tool. Due to the lack of radiation emission, it is a sensitive and safe tool for monitoring therapeutic effects [45,55]. The versatility and fidelity of the three-dimensional model generated by the DIERS system enables obtaining reliable information about the patient's morphology throughout the treatment process [45], enabling precise match of therapeutic activities to existing dysfunction. Our observations suggest that systematic and objective monitoring of the treatment process is a condition for an effective and personalized treatment process.

Limitations

The presented study did not include variables describing physical activity or the quality of nutrition of the subjects during the rehabilitation process, which should be considered in further analyzes.

Clinical implications

Ongoing assessment of changes in the parameters describing the position of the spine in space allows careful monitoring of the course of the treatment process and enables possible quick correction of conducted activities, which can significantly improve the effectiveness of the entire therapeutic process. Systematic assessment should include changes occurring in all planes, because as this study has shown, individual parameters change at different pace. A reliable evaluation process allows the forecasting the

results of the implemented measures, as well as conducting a long-term study on the improvement of therapeutic protocols.

Conclusions

1. Detailed monitoring of parameters describing the position of the spine makes it possible to control the course of the treatment process in patients with spine position disorders.
2. Photogrammetric systems are very sensitive in detecting changes, so they are a good tool for ongoing monitoring of the treatment process of patients with spine alignment disorders.
3. The dynamics of changes happening within the spine alignment is different for the individual parameters analyzed.

Declarations

Ethics approval and consent to participate: The study was approved by the Bioethics Committee at the Faculty of Medicine and Health Sciences, the Jan Kochanowski University in Kielce (Approval No. 1/2016, issued 15.01.2016). All methods were performed in accordance with the relevant guidelines and regulations. Participation in the research was voluntary, combined with ensuring anonymity. The legal guardians of the children participating in the study gave their informed consent.
Consent for publication: Not applicable

Availability of data and materials: The datasets supporting the conclusions of this article are included within the article and its additional files
Competing interests: I declare that the authors have no competing interests as defined by BMC, or other interests that might be perceived to influence the results and/or discussion reported in this paper.
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