Original paper

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

Monitorowanie zmian krzywizn kręgosłupa u dzieci z zaburzeniami postawy ciała

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Key words: physiotherapy, posture defects, photogrammetry, monitoring the treatment process.

Słowa kluczowe: fizjoterapia, wady postawy, fotogrametria, monitorowanie procesu leczenia.

Abstract

Introduction: Due to numerous complications of an abnormal shape of the spine, it is extremely important to systematically monitor its shape. A precise and routine method of measurement enables comparison of the scores obtained over time and possible early intervention to avoid complications.
Aim of the research: To present the pattern for monitoring changes in the shape of the spine in children with postural deformities.
Material and methods: The study group consisted of patients with diagnosed shape of the spine deformity, who underwent a 4-month therapy, supervised by a physiotherapist. The control group comprised children with no shape of spine deformity. The children in the study group underwent a 3-dimensional computer analysis of the shape of the spine. The DIERS test was performed in both groups. In the study group it was performed 4 times. It involved the measurement of 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 analyses were performed using Dunn-Bonferroni tests. It was observed that changes in individual parameters analysed in the authors' study arise at different speeds.
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 analysed.

Streszczenie

Wprowadzenie: Ze względu na liczne powikłania nieprawidłowego kształtu kręgosłupa niezwykle istotne jest systematyczne monitorowanie jego formy. Precyzyjny i powtarzalny sposób pomiaru pozwala na porównanie wyników uzyskanych w czasie i ewentualną wczesną interwencję w celu uniknięcia powikłań. Jest to niezwykle istotne dla skutecznego prowadzenia leczenia tych pacjentów.
Cel pracy: Przedstawienie schematu monitorowania zmian kształtu kręgosłupa u dzieci z zaburzeniami postawy.
Materiał i metody: Grupą badaną (n = 211) byli pacjenci ze zdiagnozowanym zaburzeniem kształtu kręgosłupa, którzy poddani zostali czteromiesięcznej terapii prowadzonej pod nadzorem fizjoterapeuty. Grupę kontrolną (n = 101) stanowiły dzieci, u których nie stwierdzono zaburzeń kształtu kręgosłupa. Dzieci w grupie badanej poddano trójwymiarowej analizie komputerowej oceniającej ukształtowanie kręgosłupa. Badanie DIERS wykonano w obydwu grupach (badanej i kontrolnej), w grupie badanej przeprowadzono je czterokrotnie w czterotygodniowych odstępach. Obejmowało ono pomiar siedmiu parametrów pozwalających na pełną ocenę postawy ciała.
Wyniki: Stwierdzono statystycznie istotne wyniki testu Friedmana w zakresie odchylenia od pionu, skośności miednicy, kąta kifozy, kąta lordozy oraz odchylenia bocznego. Wykonano serię analiz *post-hoc* przy użyciu testów Dunn-Bonferroniego. Dostrzeżono, że zmiany poszczególnych parametrów poddanych analizie w badaniach własnych pojawiają się w różnym tempie.
Wnioski: Szczegółowe monitorowanie parametrów opisujących ustawienie kręgosłupa umożliwia kontrolę przebiegu procesu leczenia pacjentów z zaburzeniami ustawienia kręgosłupa. Dynamika zmian zachodzących w obrębie ustawienia kręgosłupa jest różna dla poszczególnych parametrów poddanych analizie.

Introduction

Gradual change in the shape of the spine is an adaptation mechanism to the changing conditions and motor needs that 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 and the type of performed work, but also the 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. A precise and routine method of measurement enables the comparison of the scores obtained over time and possible early intervention 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 repeatability; therefore, it is worth implementing more effective methods of conducting tests in children [30]. X-ray radiation continues to play an important role in diagnostics because it enables the observation of morphological changes in the vertebrae, as well as calculation of the angle of spine curvature (according to Cobb [31]). Performing a radiological examination, however, is associated with the patient's exposure to ionizing radiation and therefore cannot be performed as a 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 require large financial outlays [32].

Aim of the research

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 methods

Participants subjects

Children aged 8–12 years were assessed. The study group consisted of patients diagnosed with spine shape deformity. The children in the study group underwent a 4-month therapy conducted under the supervision of a physiotherapist. The control group consisted of children who did not have any posture defect in preventive medical examination or physiotherapeutic assessment. The research was carried out at the Clinical Rehabilitation Centre of the Świętokrzyskie Centre of Paediatrics, Poland.

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

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

Inclusion criteria

- Age 8–12 years,
- Diagnosed defect of shape of the spine (applies only to the study group),
- Good general health (≤ 2 according to the ECOG scale),
- A 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 (applies only to the study group),
- Body mass index (BMI) below the 10^{th} and above the 90^{th} 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 3-dimensional computer analysis of shape of the spine and a physiotherapeutic functional assessment. Based on the obtained results, a rehabilitation program was chosen, which assumed: 1) the child performing specific therapeutic activities at home twice a day under parental control, and 2) the use of a mirror to properly correct body posture. The examination was conducted and the choice of therapy was made by a physiotherapy specialist. The patients were rehabilitated according to 2 systems. A combination of proprioceptive neuromuscular facilitation (PNF) and Vojta's techniques, with individual therapeutic sessions consisting of a combination of global patterns based on Vojta's method (reflex creeping and the first phase of reflex rolling), a combination of patterns for the limbs and the shoulder and pelvic girdles according to the PNF concept, and patient education regarding the need to assume an optimal body posture for the rehabilitation process. The study protocol assumed 4 appointments at 4-week intervals. During each appointment, the analysed 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 analysed parameters and 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 4 times (before the first and after the second, third, and fourth therapeutic sessions). It involved the measurement of 7 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 7^{th} 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 [°] – 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 [°] – the angle measured between VP and the estimated position of Th12.
7. Lordosis angle [°] – 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 2 recognized therapeutic methods. The planned therapeutic program was realised by the treated children under their parents' supervision. The therapeutic session was about 20 min long and was based on elements of the PNF and Vojta methods [34–36].

Ethical 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 ensured anonymity. The legal guardians of the children participating in the study gave their informed consent.

Statistical analysis

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

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

To assess normality of the distribution of variables, the non-parametric Kolmogorov-Smirnov test was used [39].

Percentage differences between the measurements were calculated. 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 analysed variables adopted non-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 us to determine the differences between the 4 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 of reducing the nominal significance level of each set of related tests [42].

Results

Basic descriptive statistics of tested quantitative variables were calculated together with the Kol-

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

Parameter	Measurement	Study group (*n* = 211)		Control group (*n* = 101)		*U*	*Z*	*P*-value	*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.

mogorov-Smirnov test to check the normality of the distribution of these variables. The analyses were performed separately for the study group and the control group. Most measurements adopted distributions different from the normal distribution. Hence, to maintain the consistency of the scores, in this work, statistical analyses were performed using non-parametric tests.

The minimum value/number necessary to infer about the entire population of children aged 8–12 years with spinal posture defect in Poland is 296; therefore, the study population 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: 5 for measurement I and 4 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 was high in both measurements, moderately high in measurement IV of 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 a 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.

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* analyses were performed using Dunn-Bonferroni tests. For trunk imbalance, differences between all measurements were recorded. The value of this index decreased 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 3 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

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

Parameter	Measurement	M	SD	Statistic
Trunk imbalance [mm]	1	9.09[a]	6.09	
	2	7.61[b]	5.99	$\chi^2(3) = 127.82$
	3	6.48[c]	5.11	$p < 0.001$
	4	4.24[d]	4.13	
Pelvic tilt [mm]	1	3.55[a]	3.45	
	2	3.59[a]	3.43	$\chi^2(3) = 12.79$
	3	3.31[ab]	3.45	$p = 0.005$
	4	2.80[b]	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	41.37[a]	9.60	
	2	40.12[a]	9.63	$\chi^2(3) = 17.34$
	3	40.42[a]	9.46	$p = 0.001$
	4	38.92[b]	8.28	
Lordosis angle [°]	1	37.05[a]	9.55	
	2	37.97[b]	9.35	$\chi^2(3) = 18.34$
	3	38.28[b]	9.61	$p < 0.001$
	4	38.10[b]	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	4.51[a]	2.91	
	2	4.48[a]	2.77	$\chi^2(3) = 15.38$
	3	4.76[a]	3.03	$p = 0.002$
	4	3.97[b]	2.58	

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.

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 millimetres 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 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%), and thoracic kyphosis angle by 2.45° (6%), which reached a physiological value, just like the lordosis angle, which increased by 1.05° (3%). The rotation angle decreased by 0.46° (10%), and imbalance was reduced by 1.54 mm (12%). Pelvic torsion was the only parameter describing body posture that did not change significantly in our study - reduction by 0.36° (14%) p = 0.201 (Table 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, described the reduction of abnormal curvature in the frontal plane and considerable improvement in thoracic kyphosis angle and spine rotation [43]. Reduction of lateral deviation, thoracic kyphosis angle, lumbar lordosis angle, rotation angle, and trunk imbalance after 4 weeks of rehabilitation was shown [45]. Misiuk *et al*. 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 *et al*., 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 analysed 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 was 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 treatment cycle had finished, without analysing 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 us 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 report, it is these parameters that imply a change in the shape of the spine in the other 2 planes [50–52].

The abovementioned irregular changes in the spine position parameters during long-term rehabilitation may be the consequence of various factors that can disturb the 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 of the figure [3, 53]. In view of negative changes, sedentary lifestyle, which contributes to the loss of lumbar lordosis, is particularly unfavourable in the treatment of scoliosis [3]. Reducing physical activity and frequently 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, as 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, especially because most physiotherapists examine the patient only subjectively [54]. Raster stereography is one such suitable 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 3-dimensional model generated by the DIERS system enables reliable information to be obtained about the patient's morphology throughout the treatment process [45], enabling a precise match of therapeutic activities to existing dysfunction. It is very important to be able to notice even discrete disturbances in the development of the antigravity system, perform qualitative analysis of postural and motor compensation patterns, and predict their consequences [56, 57]. 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 analyses.

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 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 paces. A reliable evaluation process allows the results of the implemented measures to be forecast and a long-term study on the improvement of therapeutic protocols to be conducted.

Conclusions

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. 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. The dynamics of changes happening within the spine alignment is different for the individual parameters analysed.

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Conflict of interest

The authors declare no conflict of interest.

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