J Musculoskelet Neuronal Interact 2024; 24(1):67-72

Journal of Musculoskeletal and Neuronal Interactions JMNI

Original Article

Association Between Two Methods of Spinal and Pelvic Analysis Among Children With Cerebral Palsy

Mostafa S. Ali[1,2], Mahmoud Usama[1]

[1]Department of Pediatric Physical Therapy, Faculty of Physical Therapy, Cairo University, Egypt;
[2]Department of Pediatric Physical Therapy, Faculty of Physical Therapy, October 6 University, Egypt

Abstract

Objectives: Children with cerebral palsy have weak muscles, which may impair postural adjustments. These postural adjustments are required for gait and dynamic balance during the daily living activities. The aim of this study was to investigate the association between Cobb's angle and Formetric 4D surface topography system in evaluating spinal and pelvic deformity in children with cerebral palsy. **Methods**: One hundred children with spastic diplegia (6 to 8 years old) diagnosed as cerebral palsy participated in this study and selected from the Outpatient Clinic of Faculty of Physical Therapy. Digital x- ray and formetric analysis were used to measure spinal deformities and pelvic deviation in children with cerebral palsy. **Results**: There were positive correlations between Cobb's angle and formetric parameters, including trunk imbalance, lateral deviation, and pelvic tilt. Also, Formetric parameters were significant predictors of Cobb's angle, including trunk imbalance (for a one-degree increase, Cobb's angle increases by 0.227, lateral deviation (for a one-degree increase, Cobb's angle increases by 0.665), and pelvic tilt (for a one-degree increase, Cobb's angle increases by 0.252). **Conclusion**: Formetric 4D surface topography system was effective in evaluating spinal and pelvic deformity in children with cerebral palsy when compared with Digital x-ray.

Keywords: Association, Cerebral palsy, Cobb's angle, Formetric analysis, Spinal analysis

Introduction

Cerebral palsy (CP) is used to refer to a variety of underlying brain abnormalities, that result in impairments occurring in early development of movement, posture, or muscle tone[1]. The main cause is non-progressive damage to the brain during the prenatal, perinatal, or postnatal periods[2].

Spastic diplegia is the most common type of CP, presenting with symmetric involvement of both lower limbs with prevalence of 35% of all CP cases[3]. Gait abnormalities and defects are common in children with spastic diplegia as a result of balance, motor control, and spasticity deficiencies[4]. Children with spastic diplegia have difficult to maintain balance while standing up straight[5]. They lose coordinated trunk flexor and extensor activation, which is necessary for a balanced posture due to trunk muscles stiffness and weakness[6]. The standing posture quality is also reduced by the presence of abnormal back geometry, poor postural reflexes, and poor alignment of the trunk that affects quality of life and daily living activities[7].

Although foot and knee postures in children with CP during standing are often examined[8], little is known about the alignment of other body segments such as the trunk, spine, and pelvis. Moreover, how the disorientation of body segments influences standing posture has not been described[9]. Spinal and pelvic malalignments are possible in children with CP. Since, the spine terminates at the pelvis, spinal malformations in children with CP are highly prevalent, as are deformities that affect the pelvis. Furthermore, because the pelvis is between the hips and the spine, pelvic malalignments may result from either supra- or infra-pelvic causes, or both[10].

Spinal deformity is the term used to describe morphological deviations from the spine's normal posture in its coronal, sagittal, or axial positions[11]. Treatment for this condition usually consists of observation and surveillance to look for

The authors have no conflict of interest.

Corresponding author: Mostafa S. Ali, Department of Pediatric Physical Therapy, Faculty of Physical Therapy, October 6 University, Egypt
E-mail: drmostafamalak@cu.edu.eg

Edited by: G. Lyritis
Accepted 18 December 2023

signs of curve progression when the deformity is minor, less than 20°. For bigger curves, greater than 20° and 40°, respectively, bracing and surgery are the recommended therapies; however, therapy in these individuals also entails screening for signs of a change in the deformity[12].

A routine examination will reveal spinal deformity, standing full-column radiographs of the spine continue to serve as the gold standard for diagnosis and subsequent curve surveillance. Medical practitioners can use radiographic pictures to measure the curvatures of the spine and determine the degree of the deformity in both the coronal and sagittal planes. However, the drawback of radiography is that repeated exposure to ionizing radiation significantly raises the likelihood of developing malignancies later in life, especially in young individuals[13]. For instance, the relative risk of breast cancer is roughly 4 times higher in these people[14]. While no patient can totally avoid x-rays, every effort should be made to limit radiation exposure[15].

The Formetric 4D system by Diers Medical Systems analyze surface asymmetry and recognize bone landmarks, a standing patient's back is projected with white raster lines, which are then photographed digitally. The clinician can apply external markers on landmarks they feel under the skin in obese individuals. The machine then uses a sophisticated algorithm to quickly recreate a three-dimensional representation of the patient's spine without subjecting them to radiation harm by comparing the observed surface topography to a database of thousands of radiographic and topographic measurements of patients with scoliosis[16]. Recent studies have demonstrated that using more advanced formulas and powerful computers has increased the accuracy of these mathematical models throughout time[17].

Thus, to overcome previous limitations, the current study aimed to investigate the association between Cobb's angle and Formetric 4D surface topography system in evaluating spinal and pelvic deformity in children with cerebral palsy.

Materials and methods

Study design

This study was designed to be a cross sectional study

Participants

This study was conducted between January and April 2023. Parents were asked to an informed consent forms and agree to participate in the study and evaluate their children. One hundred children were selected from the Outpatient Clinic of Faculty of Physical Therapy at Cairo University. The inclusion criteria were: a) Diagnosed as cerebral palsy with spastic diplegia, b) Aged from 6 to 8 years, c) Having grade 1 and 1+ spasticity according to the Modified Ashworth Scale, d) Height not less than one meter, e) Both genders participated, f) Children have normal flexibility of the lower back muscles as adequate flexibility with normal muscle length is essential for proper joint function and efficient movement. The exclusion criteria were: a) Congenital or acquired skeletal deformities or cardiopulmonary dysfunction, b) Had undergone previous orthopedic surgery in lower limbs, c) Had abnormal motor development or neurological disease that affect balance and gait, d) Had behavioral problems causing inability to cooperate during the study.

Procedures

Digital X-ray

The Cobb angle is the most popular tool to measure scoliosis and used to measure the severity of scolisis. Also, Cobb angle measurement is essential for the purpose of choosing a course of therapy, evaluating the efficacy of orthopedic and surgical operations, determining the severity of scoliosis and estimating the risk of progression[20]. To calculate the cobb angle, the upper and lower endplates of the upper and lower end vertebrae's respective tangents must be estimated.

When the Cobb angle is less than 10 degrees, the condition of a spine is related to the spinal curvature rather than scoliosis. Mild scoliosis is defined as a Cobb angle of 10 to 20 degrees or less. If the Cobb angle is between 20 and 40 degrees, the degree of scoliosis is considered to be moderate. Scoliosis with a severe Cobb angle is defined as one greater than 40 degrees[19].

Formetric instrumentation

Formetric instrumentation system is a three-dimensional scan and a spatial reconstruction of the spine that obtained by particular mathematical model to determine the spine geometry. Formetic system is valid and reliable based on the intra- and inter-rater reliability[2,21]. The formetric system consists from: a) Scan system (an optical column with base plate that contains a raster projector and a video camera mounted into a profile tube), b) Computer (a visual spine software that provides 3D-reconstruction of the spine based on measurement data of the system and allows individual image analysis of the carried-out examinations), c) Black background screen that allows light rays which fall away from the patient's body to be absorbed and prevents them from reflecting back to the recording camera, allowing for clear and accurate recording of the patient's back, d) Laser printer that provides high-quality printing. Before the testing session, each child received instructions regarding the evaluative procedures after signing a written consent form. This was done to ensure that all children understood the processes of the evaluation and were comfortable using the equipment, additionally all parents were informed of the study's procedures and objectives for their children without any risk. Finally, warm and quiet environment required to evaluate each child. First enter date of birth, name, sex, height, and weight of the child then each child was instructed to stand with their backs to the black background screen by about two meters away from the scanning apparatus, either on the ground or on blocks depending on their height. The child's back was fully bare, down to his or her buttocks to prevent altered image structures. Each child was instructed to stand normally with their chin tucked and keep both upper extremities as far apart from the body as possible to enhance the presentation of the spinal prominence. The right image is obtained when the optical column's height was adjusted prior to capture. Afterthought, the child was instructed to hold on breath for 40 milliseconds while being captured. Now three-dimensional analysis was recorded and reproduced, also, pelvic inclination angle, which indicated the mean torsion of the surface normal of the right and left lumbar dimples, was recorded using a single capture[23]. The outcomes of the shape analysis are graphically represented on the laser printer. The anatomical parameters in each graphic technique are derived from the anatomical landmarks which include VP (vertebra prominence), SP (sacrum point), DL (left dimple), DR (right dimple), and DM (midpoint between both dimples). Using a certain mathematical model, a spatial reconstruction of the spine is then created[22].

Statistical analysis

Data management and statistical analysis were done using SPSS version 28 (IBM, Armonk, New York, United States). Quantitative data were assessed for normality using the Kolmogorov–Smirnov test and direct data visualization methods. According to normality, quantitative data were summarized as means and standard deviations or medians and ranges. Categorical data were summarized as numbers and percentages. Correlations between Cobb's angle and formetric parameters were assessed using Spearman's correlation. Multivariate linear regression analysis was done to predict Cobb's angle from formetric parameters. The regression coefficients with their 95% confidence intervals were calculated. All statistical tests were two-sided. P values less than 0.05 were considered significant.

Results

Demographics

The mean age of the studied patients was 7.2 ±0.7 years. Approximately half of the patients were males (53.2%), and the other half were females (46.8%). The mean weight and height were 16 ±1 kg and 123 ±6 cm, respectively (Table 1).

Formetric parameters

The median trunk imbalance was 10 degrees, ranging from 0.4 to 33 degrees. The median lateral deviation was 8 degrees, ranging from 0 to 15 degrees. The median pelvic tilt was 9 degrees, ranging from 0 to 27 degrees. The mean Cobb's angle was 20 ±4 degrees (Table 2, Figure 1).

Correlation between formetric parameters and Cobb's angle

As shown in Figure 2, there were positive correlations between Cobb's angle and formetric parameters, including trunk imbalance (r = 0.430, P < 0.001), lateral deviation (r = 0.518, P < 0.001), and pelvic tilt (r = 0.422, P < 0.001).

Table 1. General characteristics of the studied patients.

General characteristics		
Age (years)	Mean ±SD	7.2 ±0.7
Gender		
Males	n (%)	41 (53.2)
Females	n (%)	36 (46.8)
Weight (kg)	Mean ±SD	16 ±1
Height (cm)	Mean ±SD	123 ±6

Table 2. Formetric scan parameters of the studied patients.

Formetric parameters		
Trunk Imbalance	Median (range)	10 (0.4 - 33)
Lateral Deviation	Median (range)	8 (0 - 15)
Pelvic tilt	Median (range)	9 (0 - 27)
Cobb's angle	Mean ±SD	20 ±4

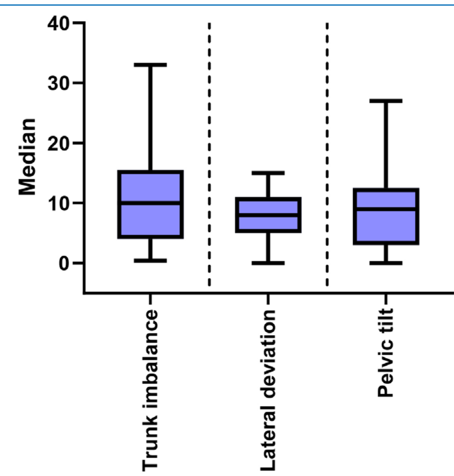

Figure 1. Formetric scan parameters of the studied patients.

Prediction of Cobb's angle

Multivariate linear regression analysis was done to predict Cobb's angle from formetric parameters. Each formetric parameter was evaluated separately to avoid potential multicollinearity, controlling for age, gender, weight, and height. Results revealed that formetric parameters were significant predictors of Cobb's angle, including trunk imbalance (for a one-degree increase, Cobb's angle increases by 0.227, B = 0.227, 95% CI = 0.13 – 0.324, P < 0.001),

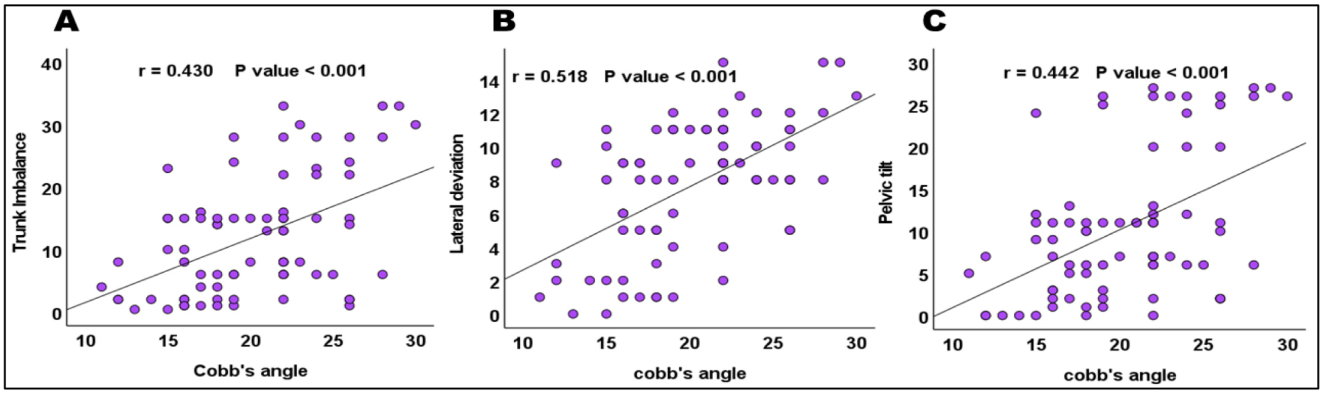

Figure 2. Correlation between Cobb's angle of the studied patients and a) Trunck imbalance; b) Lateral deviation; c) Pelvic tilt.

Table 3. Multivariate linear regression analysis to predict Cobb's angle from formetric scan parameters.

	B (95% CI) †	P-value
Trunk Imbalance	0.227 (0.13 - 0.324)	<0.001*
Lateral Deviation	0.665 (0.443 - 0.887)	<0.001*
Pelvic tilt	0.251 (0.143 - 0.358)	<0.001*

Significant P-value; † Adjusted for age, gender, weight, and height; B: Regression coefficient; 95% CI: 95% confidence interval.

lateral deviation (for a one-degree increase, Cobb's angle increases by 0.665, B = 0.665, 95% CI = 0.443 – 0.887, P < 0.001), and pelvic tilt (for a one-degree increase, Cobb's angle increases by 0.252, B = 0.251, 95% CI = 0.143 – 0.358, P < 0.001) (Table 3).

Discussion

The purpose of this study was to investigate the association between Cobb's angle and Formetric 4D surface topography system in evaluating spinal and pelvic deformity in children with cerebral palsy. Since the development of the Scoliometer, efforts have been made to identify a dependable and efficient technique for using surface topography to monitor the evolution of spinal curves in scoliosis patients. Although several surface topography-based devices have been created, none of them have received general acceptance. Clinicians can be reluctant to rely on a method other than radiography for getting information that helps them decide whether to do surgery or other extreme treatments on a patient. This is probably related to the earlier findings that surface topography-based spinal imaging instruments do not consistently reproduce and compare well. The results of current research illustrated that there were positive correlations between Cobb's angle and formetric parameters, including trunk imbalance, lateral deviation, and pelvic tilt. Also, Results revealed that formetric parameters were significant predictors of Cobb's angle, including trunk imbalance (for a one-degree increase, Cobb's angle increases by 0.227, lateral deviation (for a one-degree increase, Cobb's angle increases by 0.665, and pelvic tilt (for a one-degree increase, Cobb's angle increases by 0.252. Most importantly, it was found that there was a good correlation between Cobb angle measures from children with cerebral palsy using the Formetric 4D system and those from conventional radiography. It is not necessary for the surface topography and radiography measurements to match, even though this device cannot forecast curve magnitude with absolute accuracy, as topography serves largely as a change indicator. The clinician will be made aware of the potential for progression in the actual scoliosis curve by this change in topography. The Formetric 4D can be used effectively in the monitoring of children with cerebral palsy, the authors suggest[24]. According to the results of current research, the Formetric 4D was very reliable and reproducible measurements with standard deviations that are consistent with those found when taking standing radiographs[25]. The Formetric 4D provides useful clinical parameters for follow-up like trunk imbalance, pelvic tilt, pelvis torsion, lateral deviation, surface rotation, and a complete set of values from the analysis of the sagittal profile of the spine[26-28]. Although the Cobb angle is a reliable indicator of the deformity, it is insufficient given the complexity of this problem. The specialist's decision-making process and the definition of various principles of correction to be employed in conservative as well as surgical treatment will be aided by a better understanding of the three-dimensional nature and natural history of scoliosis. Monitoring the effects of various therapies requires a thorough understanding of the connection between spinal deformity and trunk deformity[29]. Our results investigate that Formetric 4D surface topography system was effective in evaluating spinal and pelvic deformity in children with cerebral palsy which is consistent with Kumar et al, who concluded that the Formetric scanner could replace X-rays for follow up patients within boundaries of magnitude of curve, but that it could not replace X-rays for early diagnosis or when the patient is having a pre-operative assessment[30].

Study limitations

The present study has limitations, including: 1) Diagnosed spastic cerebral palsy and being limited to children aged 4 to 6 years, which will affect the generalizability of the findings to pediatric populations with CP. 2) Further studies are certainly needed to confirm the long-term effectiveness of using Formetric 4D in clinical decision-making. 3) Surface topography will not completely replace radiographic analysis in monitoring patients in need to spinal and pelvic analysis, as it cannot evaluate the actual bone morphology the way a radiograph can.

Conclusion

Formetric 4D surface topography system was effective in evaluating spinal and pelvic deformity in children with cerebral palsy when compared with x-ray to analyze the pelvic and spinal deformities. so, the Formetric scanner could replace X-rays for follow up children within boundaries of magnitude of curve. Future recommendations include measuring cobb's angle and formetric topographic in different age groups of children and adolescents with CP.

Acknowledgments

All appreciation and thanks to the children who participated in this study and their parents.

Ethical approval

The current study has been approved by the Cairo University faculty of physical therapy's Ethical committee (No: P.T.REC/012/004088).

Consent to participate

Written informed consent was obtained from the parents/ legal guardians before the start of the study.

Authors' contributions

MSM conceived and designed the study, conducted the research, provided research materials, and collected and organized the data. MU and MSM analyzed and interpreted data, wrote the initial and final drafts of the article, and provided logistical support. All authors have critically reviewed and approved the final draft and are responsible for the content and similarity index of the manuscript.

References

1. Bax M, Goldstein M, Rosenbaum P, Leviton A, Paneth N, Dan B, Jacobsson B, Damiano D. Proposed definition and classification of cerebral palsy. Developmental Medicine & Child Neurology 2005;47(8):571-6.
2. Rosenbaum P. The definition and classification of cerebral palsy. Developmental Medicine & Child Neurology 2007; 49(s109):1-44.
3. Honan I, Finch-Edmondson M, Imms C, Novak I, Hogan A, Clough S, Bonyhady B, McIntyre S, Elliott C, Wong S, Bink M. Is the search for cerebral palsy 'cures'a reasonable and appropriate goal in the 2020s? Developmental Medicine & Child Neurology 2022;64(1):49-55.
4. Kurz MJ, Arpin DJ, Corr B. Differences in the dynamic gait stability of children with cerebral palsy and typically developing children. Gait & Posture 2012;36(3):600-4.
5. van der Heide JC, Hadders-Algra M. Postural muscle dyscoordination in children with cerebral palsy. Neural Plasticity 2005;12(2-3):197-203.
6. El-Basatiny HM, Abdel-Aziem AA. Effect of trunk exercises on trunk control, balance and mobility function in children with hemiparetic cerebral palsy. International Journal of Therapies and Rehabilitation Research 2015; 4(5):236.
7. Bartonek A, Lidbeck CM, Pettersson R, Weidenhielm EB, Eriksson M, Gutierrez-Farewik E. Influence of heel lifts during standing in children with motor disorders. Gait & Posture 2011;34(3):426-31.
8. Lidbeck CM, Gutierrez-Farewik EM, Broström E, Bartonek Å. Postural orientation during standing in children with bilateral cerebral palsy. Pediatric Physical Therapy 2014;26(2):223-9.
9. Domagalska-Szopa M, Szopa A. Postural orientation and standing postural alignment in ambulant children with bilateral cerebral palsy. Clinical Biomechanics 2017;49:22-7.
10. Miller F. Pelvic Alignment and Spondylolisthesis in Children with Cerebral Palsy. Cerebral Palsy 2020:1823-32.
11. Li YW, Cui W, Yan XY, Wang HJ. Epidemiology of congenital scoliosis in Luohe. Chinese Journal of Pediatric Surgery 2017;38:221-4.
12. Frerich JM, Hertzler K, Knott P, Mardjetko S. Comparison of radiographic and surface topography measurements in adolescents with idiopathic scoliosis. The Open Orthopaedics Journal 2012;6:261-5.
13. Doody MM, Lonstein JE, Stovall M, Hacker DG, Luckyanov N, Land CE, US Scoliosis Cohort Study Collaborators. Breast cancer mortality after diagnostic radiography: findings from the US Scoliosis Cohort Study. Spine 2000;25(16):2052-63.
14. Ronckers CM, Land CE, Miller JS, Stovall M, Lonstein JE, Doody MM. Cancer mortality among women frequently exposed to radiographic examinations for spinal disorders. Radiation Research 2010;174(1):83-90.
15. Jin C, Wang S, Yang G, Li E, Liang Z. A Review of the Methods on Cobb Angle Measurements for Spinal Curvature. Sensors 2022;22(9):3258.
16. Parent EC, Damaraju S, Hill DL, Lou E, Smetaniuk D. Identifying the best surface topography parameters for detecting idiopathic scoliosis curve progression. Stud

Health Technol Inform 2010;158:78-82.
17. He JW, Yan ZH, Liu J, Yu ZK, Wang XY, Bai GH, Ye XJ, Zhang X. Accuracy and repeatability of a new method for measuring scoliosis curvature. Spine 2009;34(9): E323-9.
18. Cobb JR. Outline for the study of scoliosis. Instructional Course Lectures 1948;5:261-75.
19. Horng MH, Kuok CP, Fu MJ, Lin CJ, Sun YN. Cobb angle measurement of spine from X-ray images using convolutional neural network. Computational and Mathematical Methods in Medicine 2019:6357171.
20. Hurtado-Avilés J, Santonja-Medina F, León-Muñoz VJ, Sainz de Baranda P, Collazo-Diéguez M, Cabañero-Castillo M, Ponce-Garrido AB, Fuentes-Santos VE, Santonja-Renedo F, González-Ballester M, Sánchez-Martínez FJ. Validity and absolute reliability of the Cobb angle in idiopathic scoliosis with TraumaMeter software. International Journal of Environmental Research and Public Health 2022;19(8):4655.
21. Tabard-Fougère A, Bonnefoy-Mazure A, Hanquinet S, Lascombes P, Armand S, Dayer R. Validity and reliability of spine rasterstereography in patients with adolescent idiopathic scoliosis. Spine 2017;42(2):98-105.
22. Betsch M, Wild M, Johnstone B, Jungbluth P, Hakimi M, Kühlmann B, Rapp W. Evaluation of a novel spine and surface topography system for dynamic spinal curvature analysis during gait. PloS one 2013;8(7): e70581.
23. Allah NE, Kamal HM, El-Nabie WA. Association between pelvic inclination and balance in children with spastic diplegia. Bulletin of Faculty of Physical Therapy 2023; 28(1):4.
24. Jason M. Frerich, Kristen Hertzler, Patrick Knott and Steven Mardjetko. Comparison of Radiographic and Surface Topography Measurements in Adolescents with Idiopathic Scoliosis. The Open Orthopaedics Journal 2012;6:261-265.
25. Patrick Knott, Steven Mardjetko, Michelle Rollet, Scott Baute, Magdelina Riemenschneider, Laura Muncie. Evaluation of the reproducibility of the formetric 4D measurements for scoliosis, 7th International Conference on Conservative Management of Spinal Deformities, Montreal, Canada. 20-22 May 2010. Scoliosis 2010; 5(Suppl 1):O10.
26. Drerup B, Hierholzer E. Back shape measurement using raster stereography and three-dimensional reconstruction of the spinal shape. Clinical Biomechanics 1994:9:28–36.
27. Drerup B, Hierholzer E. Assessment of scoliotic deformity from back shape asymmetry using an improved mathematical model. Clinical Biomechanics 1996;11:376–383.
28. Drerup B, Hierholzer E, Ellger B. Shape analysis of the lateral and frontal projection of the spine curves assessed from rasterstereographs. Studies in Health Technology and Informatics 1997;37:271–276.
29. Manuel R. Patient evaluation in idiopathic scoliosis: Radiographic assessment, trunk deformity and back asymmetry. Physiotherapy Theory and Practice 2011; 27(1):7–25.
30. Kumar V, Cole A, Breakwell L, Michael AL. Comparison of the DIERS Formetric 4D Scanner and Plain Radiographs in Terms of Accuracy in Idiopathic Scoliosis Patients. Global Spine Journal 2017.