Selected aspects of using surface topography and scoliometer in screening for scoliotic postural asymmetry in girls

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Abstract

Background & Study Aim: Adolescent idiopathic scoliosis is a multi-factor, three-dimensional spine and trunk deformation. This abnormal posture is a major medical and social problem. The "gold standard" in evaluation of scoliosis is radiological examination but frequent exposition to ionizing radiation may be harmful for a young body. There are other non-invasive methods used to diagnose scoliosis. Analysis of Moiré topograms of the back enables verification of body posture asymmetries and disorders, or method used to assess changes in the transverse plane is measurement of the angle of trunk rotation with a scoliometer. The aim of the study was the knowledge about possible changes in sagittal and frontal plane of the spine and about usefulness of surface topography and scoliometer in screening for scoliotic postural asymmetry.

Material & Methods: The sample consisted of 49 girls aged 9-13. The observational cross-sectional study involved: an interview, a anthropometrics test (body weight and height), a photogrammetrical assessment of posture using Moiré topography, a measurement of angle of trunk rotation using Bunnell scoliometer, and clinical tests: Thomas, Thomayer and Dega.

Results: The results show positive correlation between asymmetry of trunk rotation and Moiré Scoliosis Angle indicators (rho = 0.819; p<0.0001) and angles describing changes in the sagittal plane. However, no correlation was recorded between asymmetry of trunk rotation and Moiré Scoliosis Angle values and Thomayer and Thomas tests.

Conclusions: Scoliometer examination and Moiré topography can be an important factor towards the improved effectiveness of screening for scoliotic postural asymmetry and monitoring the effects of therapy.

Key words: early diagnosis • idiopathic scoliosis • Moiré topography • posture • spine

Conflict of interest: Authors have declared that no competing interest exists

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Idiopathic scoliosis – is a spinal deformity characterized by lateral bending and fixed rotation of the spine in the absence of any known cause.

Moiré Topography – a method of three-dimensional morphometry in which contour maps are produced from the overlapping interference fringes created when an object is illuminated by beams of coherent light issuing from two different point sources.

Scoliometer – is a type of protractor used to measure the vertebral rotation and rib humping that is seen in scoliosis.

Pain – *noun* the feeling of severe discomfort that a person has when hurt (NOTE: Pain can be used in the plural to show that it recurs: ***She has pains in her left leg***) [51].

Scoliosis – *noun* a condition in which the spine curves sideways [51].

INTRODUCTION

Adolescent idiopathic scoliosis (AIS) is a multi-factor, three-dimensional (3D) spine and trunk deformation. This abnormal posture in children and youth is a major medical and social problem. Studies show that it is often present among the youngest population [1-3]. It may develop asymptomatically and its consequences can be felt later, affecting the quality of life, causing deformations of the osteoarticular system, pain and limited functioning of internal organs [4, 5]. AIS may occur at any age but it is most frequent during adolescence and may progress in any of the growth spurt [6]. Screening tests conducted in the years 1985-2011 suggest that the frequency of AIS occurrence ranges between 0.5% to 5.2% [7, 8].

In the light of these facts, early diagnosis is of key importance for quick, appropriate intervention and treatment. Early detection of scoliosis reduces the number of surgical interventions as it allow to introduce non-surgical treatment [9]. Studies carried out from the 1960's indicate that early detection may successfully prevent the progression of the disease [10], therefore some researchers recommend screening for scoliosis [11, 12].

The "gold standard" in evaluation of scoliosis is radiological examination but frequent exposition to ionizing radiation may be harmful for a young body. There is no doubt that diagnostics based on radiological images made in anterior-posterior position is a reliable confirmation of scoliosis but the method is very invasive and thus, it is not recommended to be used in screening and therefore less invasive testing techniques are used, e.g. TOF (Time-of-Flight Camera), inclinometers and others [13-18].

Since 1970, one of the first techniques used in clinical diagnostics of patients with scoliosis by means of surface topography (ST) was projection moiré [19]. There are also other non-invasive methods used to diagnose scoliosis, the most common are: raster stereography (Diers Formetric) [20], 3D USG imaging (Scolioscan system) [21] infrared (IR) thermography [22] and TOF [23]. All the technologies using the surface topography, including rastereography and Formetric ST system, play an important role in monitoring scoliosis, examinations and reducing exposure to ionizing radiation. These technologies are also a useful addition to X-ray images when monitoring the progress of the disease [24]. Analysis of moiré topograms of the back enables verification of body posture asymmetries and disorders, and it may be not only qualitative [25, 26] but also quantitative [27, 28].

Other popular examination method used to assess changes in the transverse plane is Adams test often performed together with the measurement of the angle of trunk rotation with a scoliometer [29, 30]. Adams described FBT (forward bending test) as a screening technique for assessing the probability of scoliosis [31]. The reliability of scoliometer measurements is evaluated as very high to excellent [32, 33] and the reliability of measurements with this device correlated with Cobb angle – as sufficient to high [34].

FBT is still quite commonly used AIS screening technique because it is, among others, simple, non-invasive and cost-effective. Despite these advantages, some researchers still think that it yields high percentage of false positive and false negative results [11]. This may lead to a wrong diagnosis and, consequently, unnecessary specialist treatment administered. An alternative to FBT are optic methods such as Moiré topography which uses images of the back contour to determine the degree of scoliotic deformities [35].

The goal of the study was the knowledge about possible changes in sagittal and frontal plane of the spine and usefulness of surface topography (ST) and scoliometer in screening for scoliotic postural asymmetry in girls.

Table 1. Data of the observation group (n = 49).

Variable	Statistical indicators		
	M	SD	Min ÷ max
age [years]	11.0	1.07	9.1 ÷ 13.2
body weight [kg]	40.6	6.52	21 ÷ 55
height [cm]	147.8	9.23	121 ÷ 164

M mean, **SD** standard deviation

MATERIAL AND METHODS

Participants

The first author qualified 50 girls from 24 primary schools from Małopolskie, Silesian and Podkarpackie regions to the study. Due to the withdrawal of the parent/guardian's written consent, 49 girls were qualified to the final stage of the tests (Table 1).

Eligibility criteria: age 9-13 years; female sex; ATR – trunk rotation asymmetry minimum 3 deg; no coexisting diseases which could affect the test results; written consent of a parent (guardian) for the patient to participate in the study; consent of the school directors for the tests to be performed. Eligibility criteria: age 9-13 years; female sex; ATR – trunk rotation asymmetry minimum 3 deg; no coexisting diseases which could affect the test results; written consent of a parent (guardian) for the patient to participate in the study; consent of the school directors for the tests to be performed. Excluding criteria: lack of written consent of a parent (guardian); age under 9 years and over 13 years; coexisting diseases which prevent from performing the tests or which could affect the results (injuries, limb or spinal fractures) – the qualification stages Figure 1.

The study was approved by the Bioethics Committee at the Regional Medical Chamber in Krakow No. 68/KBL/OIL/2021. The tests were performed based on written consent of parents or legal guardians of the minor respondents. The examinations were conducted in primary schools in Małopolskie, Silesian and Podkarpackie regions between September and December 2019.

Design

The method used in the study was an observational cross-sectional study. The study protocol follows the guidelines of the Helsinki Declaration. This study was conducted in compliance with the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) Statement: guidelines for reporting observational studies [36].

Intervention

The examination involved:

1. Interview: date of birth, age in years and months, coexisting diseases.

2. Anthropometrics tests: weight and height measurement while standing using a verified medical column scale C315.60/150.OW-3

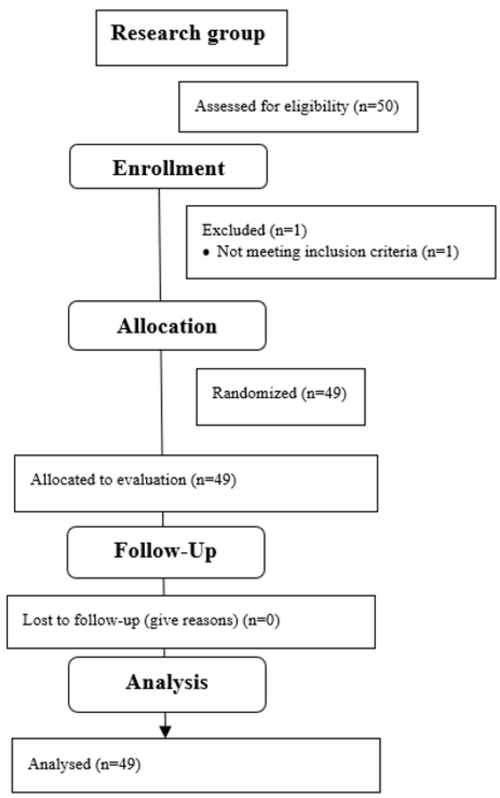

Figure 1. Flow diagram.

– a 100–200 cm height measuring device (UNIWAG – Professional electronic scales, Krakow, Poland), assessment of the course of the spinous processes of thoracic and lumbar vertebrae, assessment of the set of selected anatomical trunk points: shoulder processes and bottom angle of the shoulder-blades, waist triangles, anterior superior and posterior superior iliac spines, greater trochanter of the femurs. A medical skin marker from Covidien was used to mark the characteristic anthropometric points on the skin (Medtronic, Minneapolis, MN, USA),

3. Subject examination:

   a. photogrammetric posture assessment using projection moiré (MORA 4G system, Computer Postural Assessment Device, Wroclaw, Poland) [37];

   b. measurement of the angle of trunk rotation using Bunnel scoliometer (Citomedical, Rzeszów, Poland) – Figure 2;

   c. Thomas Test – to detect potential hip flexion contraction. Execution: patient lays on their back on a mattress. From this position, the lower right limb then the lower left limb was flexed in hip joint and knee joint, and pulled to the chest. The behaviour of the other leg, lying freely on the mattress, was observed. Interpretation: the thigh of the lower limb on the mattress lifts up 1, the thigh of the lower limb on the mattress does not lift up 0;

   d. Thomayer Test – assessment of contraction of the ischiocrural muscles and mobility of the entire spine. Execution: patients bends forward from the standing position with straight legs and tries to touch the ground with their fingertips. Interpretation: failure to touch the floor with the fingertips 1, touching floor with the fingertips 0;

   e. Dega wall-test – determination of the upper limb flexion and rise deficit. Execution: patient does half-squat with the back against a wall. From this position, they bend and lift upper limbs as much as they can. Interpretation: touching the wall was not possible or with accompanying, deepening compensatory lumbar lordosis 1, touching the wall was possible without compensatory deepening of lumbar lordosis 0.

Outcome measures

In order to assess the shape of the back surface, the photogrammetric method and moiré topography by means of the device made by Q Elektronik System from Wrocław were used. To perform the examination, the room had to be darkened, the distance of 2.6 m between the camera and the examination spot was set and the equipment and central unit were positioned (Figure 3).

Prior to the examination, selected anatomical points were marked on a patient's body: spinous processes of the vertebrae C7 to S1, posterior superior iliac spines and inferior angles of the blades. The examination was performed in standing position, with legs slightly apart and

Figure 2. Bunnel's Scoliometer [own source].

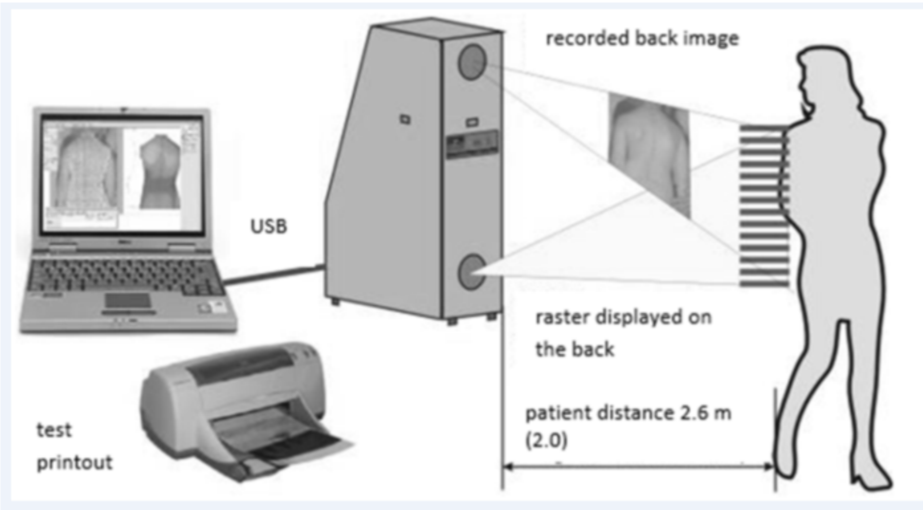

Figure 3. The moiré system [35].

heels set on the previously set line 2.6 m from the camera. Patient looked straight ahead with their upper limbs hanging relaxed along the torso. Several to several dozen of images were recorded in this position. Out of them, one was selected, which met the criterion of proper positioning of the pelvis and reflected the most typical posture of the patient. Indicators showing changes in sagittal and frontal plane of the spine were analysed: ALPHA angle [α] – the inclination of the lumbosacral section; BETA angle [β] – the inclination of the thoracic-lumbar section; GAMMA angle [γ] – the slope of the thoracic-upper segment; KPH angle – kyphosis angle calculated as the sum of β and γ; LRD angle – lordosis angle calculated as the sum of α and β; DELTA angle [δ] – the sum of α, β and γ; UK – maximum inclination of the spinal processes line from the C7-S1 line; MSA – Moire Scoliosis Angle, the angle of the right scoliosis curve.

ATR – asymmetry of trunk rotation was measured using Bunnell scoliometer. It was placed, without pressing, across the spine longitudinal axis. The patients bent in a way to enable placing the device perpendicular to the floor, at the top of the thoracic curve. The examination was performed while patients were bending forward in a standing position. During the test, the lower limbs remained straight in the knee joints, feet were placed in a line and slightly apart. Bending forward began with pulling the chin to the chest, hands joined together and moved between the feet.

Statistical analysis methods

The statistical analysis of the results was conducted using MedCalc ver.2-.110 software. The distribution of the variables was characterized by means of Shapiro-Wilk test. The main measures of the descriptive statistics were calculated. The correlations between the variables were analysed using Spearman rank correlation coefficient. In case of statistically significant correlations, the regression analysis was performed. The differences between the qualitative variables were determined by means of chi-squared test.

Rho – Spearman's rank correlation coefficient or Spearman's is a nonparametric measure of rank correlation (statistical dependence between the rankings of two variables). The remaining statistical symbols are explained in the descriptions of tables and figures.

RESULTS

Tables 2 and 3 present the mean values of the indicators of changes in sagittal and frontal plane.

The strong correlation is setting between ATR and MSA indicators (rho = 0.819; $p<0.0001$) and δ and γ (rho = 0.750; $p<0.0001$); as well as moderate correlation between α and δ (rho = 0.421; p = 0.0026) and β and δ (rho = 0.551; $p<0.0001$) (Table 4).

Table 2. Characteristics of the size (n = 49) of spinal curvatures in the sagittal plane.

Variable	Statistical indicators		
	M	SD	Me
α [°]	8.9	1.14	9.0
β [°]	7.9	1.05	7.8
γ [°]	9.7	1.64	9.7
KPH [°]	17.6	2.04	16.7
LRD [°]	16.9	1.51	17.3
δ [°]	26.6	2.24	26.7

α alpha angle – the inclination of the lumbosacral segment; **β** beta angle the inclination of the thoracic-lumbar segment; **γ** gamma angle – the slope of the upper thoracic segment; **δ** the sum of α, β and γ; **KPH** kyphosis angle; **LRD** – lordosis angle; **M** mean; **SD** standard deviation; **Me** median

Table 3. Characteristics of the size (n = 49) of ATR, MSA and UK.

Variable	Statistical indicators		
	M	SD	Me
ATR [°]	5.7	1.78	6.0
MSA [°]	16.1	5,41	16
UK [mm]	12.7	7.56	12.6

ATR asymmetry of trunk rotation; **MSA** Moire Scoliosis Angle; **UK** maximum deviation of the spinal processes line from the C7-S1 line

Table 4. Spearman Correlation coefficient (rho).

	Variable					
	ATR	MSA	UK	α	β	γ
MSA	**0.819*** **					
UK	0.081	–0.138				
α	–0.050	0.052	–0.210			
β	–0.168	–0.119	–0.081	–0.049		
γ	–0.173	–0.176	0.233	0.025	0.154	
δ	–0.228	–0.165	0.036	**0.421***	**0.551*** **	**0.750*** **

ATR asymmetry of trunk rotation; **MSA** Moire Scoliosis Angle; **UK** maximum deviation of the spinal processes line from the C7-S1 line; **α** alpha angle – the inclination of the lumbosacral segment; **β** – beta angle the inclination of the thoracic-lumbar segment; **γ** gamma angle – the slope of the upper thoracic segment; **δ** the sum of α, β and γ; *p<0.05; ***p<0.0001

The results of the analysis of regression between the scoliosis angle and the trunk rotation asymmetry show a significant correlation between the investigated indicators ($r = 0.68$; $p<0.001$) (Figure 4).

The analysis of different frequency of coexisting ATR and pectoral muscle contracture does not show correlation between these characteristics ($Chi^2 = 1.232$; $p = 0.5400$) (Figure 5).

Similar results were obtained from the analysis of coexistence of iliolumbar muscle contraction and frequency of asymmetry of trunk rotation. There were no significant differences in the sample depending on the variables studied ($Chi^2 = 0.290$, $p = 0.8650$) (Figure 6).

The analysis of correlations between the values of Thomayer test and ATR (Rho = 0.0889; p = 0.5434) and MSA (Rh0 = 0.145; p = 0.3209) calculated

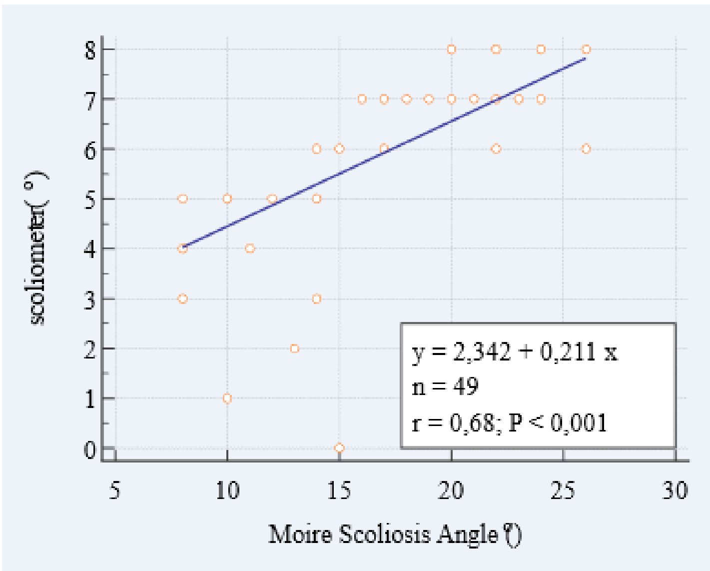

Figure 4. ATR MSA regression analysis.

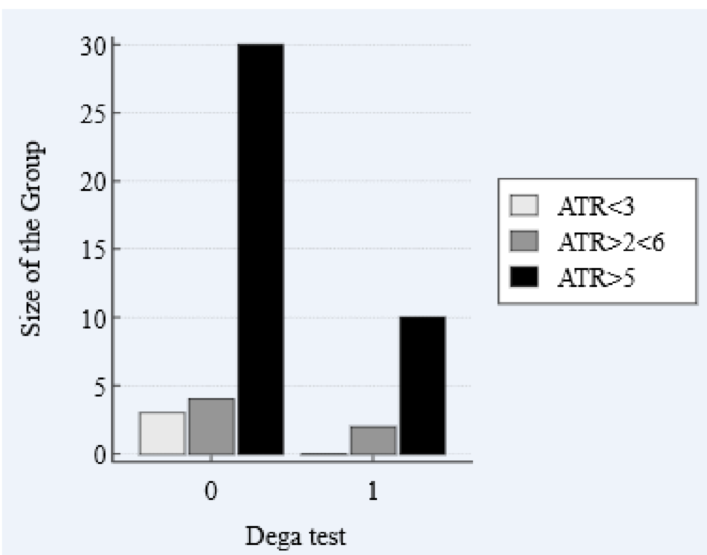

Figure 5. Differentiation of coexistence pectoral muscle contracture (Dega test) and asymmetry of trunk rotation (ATR): **0** negative, **1** positive, **ATR** angle of trunk rotation.

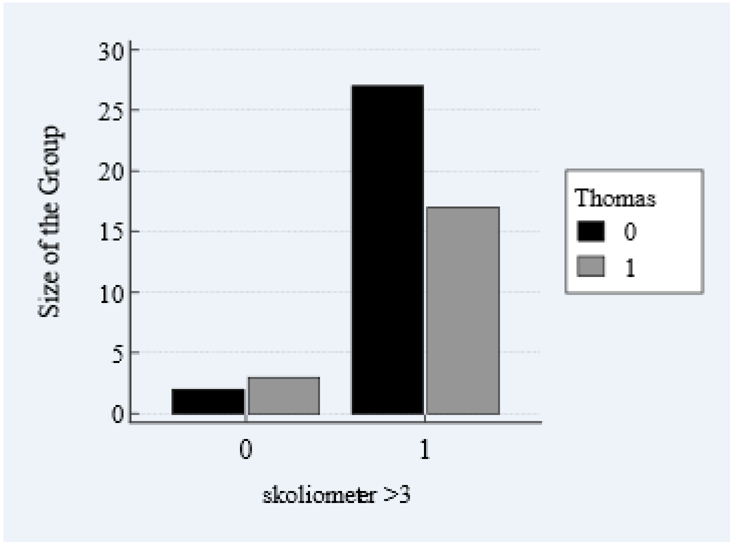

Figure 6. Differentiation of coexistence of iliolumbar muscle contraction (Thomas test) and asymmetry of trunk rotation (ATR): **0** negative, **1** positive, **Thomas** Thomas test.

based on Moire topography did not show linear relations between the studied variables.

DISCUSSION

The results of the original research show positive correlation between ATR and MSA indicators (rho = 0.819; $p<0.0001$) and angles describing changes in the sagittal plane: δ and γ (rho = 0.750; $p<0.0001$); as well as moderate correlation between α and δ (rho = 0.421; p = 0.0026) and β and δ (rho = 0.551; $p<0.0001$). The analysis of regression between ATR and MSA also shows a significant correlation between the studied indicators. However, no correlation was recorded between ATR and MSA values and the results of Thomayer and Thomas tests.

There are many publications proving that prevention which includes screening is a very important element of therapeutic activities [38, 39]. Thanks to the analysis with the use of ST and scoliometer, we can state that using the selected examination tools becomes justified in screening for scoliosis in children. It enables quick and first of all, non-invasive examination. The authors of this study believe that using both tools simultaneously can increase the effectiveness of detecting changes within the spine in the initial stage of scoliosis, in transverse and frontal plane.

These conclusions are confirmed in the subject matter literature. In their overview of publications in three large databases (PubMed, Google Scholar and CINAHL) Fong et al. declare that there is a need to conduct wide-scale, retrospective cohort studies. They point out to the fact that screening in schools must involve adequately broad clinical assessment of children in order to detect lateral curvatures of the spine early [40]. Luk et al. [11] performed a clinical assessment of the efficiency of long-term screening tests for scoliosis. The sample consisted of 157,444 children who were examined every two years. 2.8% of the respondents were referred to radiological examinations, out of whom 9.4% required treatment. It was the biggest research into scoliosis conducted in Hong Kong.

Karachalios et al. [41] led a 10-year screening program among children aged 8-16 on Samos island. They used different indicators and research methods. Based on the results obtained, they concluded that sensitivity of the Moiré topography was 100% (similar results, 90.62%, – were recorded using scoliometer; they also observed that Adams test was not the right tool for early detection of scoliosis). These results show that using projection moiré and scoliometer may reduce the number of radiological examinations and, consequently, lower the cost of diagnosis.

Prowse et al. examined 31 teenagers with idiopathic scoliosis (13.6 ±0.6 years old) with the curvature 25° ±12°. They used the Baseline® Body Level / Scoliosis measuring device, changes in transverse plane were assessed by means of scoliometer and compared to the golden standard in spinal deformity determination, that is Cobb angle measured in posterior-anterior radiograms. The authors proved that Baseline® Body Level/Scoliosis measuring device provides reliable assessment of changes in the transverse plane in case of mild and moderate scoliosis [42].

Maragkoudakis et al. [43] used scoliometer and surface topography to assess the trunk asymmetry in 134 children (86 girls and 48 boys) with scoliosis. The authors think that trunk asymmetry in children and adolescents is not the same in bent and upright position. This is probably due to complex connection of the entire bone and joint construction of the spine, thorax and pelvis. They also concluded that the need to measure scoliosis resulted in developing a school screening program where the spine is examined in two measuring positions. The authors also think that due to technological evolution of the surface topography equipment and wide use of computers in everyday life, scoliosis will be assessed in the future in both bent and upright position.

Knott et al. [20] state that surface topography is a repetitive method of quantitative evaluation of spine deformities and enables regular observations of these changes without the need to perform series of radiograms. Thus, it can be used as a tool to monitor the progress of scoliosis. Prujis et al. [38] tried to determine the applicability of screening techniques for scoliosis and compared the accuracy of the measurements of vertebral rotation, angle of trunk rotation and topography with the results of Cobb angle measurements. They stated that these methods can be used as school screening techniques, however, they do not enable clear differentiation between normal and pathological cases. Kuroki et al. [44] reached similar conclusions about the usefulness of projection moiré in screening tests.

In turn, Ng and Bettany-Saltikov [39] think that surface topography does not prevent the measurement of Cobb angle, especially when the patient is in a corset.

However, there are reports saying that using ST in screening is controversial. Chowańska et al. [45] analysed whether ST can replace scoliometer in screening for scoliosis. They used the photogrammetric method and projection moiré with the device made by Q Elektronik System and determined that ST is not suitable in detecting scoliosis through screening. The sensitivity and specificity of imaging were not satisfactory. And vice versa, by using similar ST configuration, Pino-Almero et al. [46] concluded that ST provides higher specificity and sensitivity in scoliosis detection than scoliometer and recommended this method to reduce the application of radiography. These divergent opinions may result from the fact that Chowańska et al. [45] analysed practical aspects of ST method while Pino-Almero et al. [46] studied only its technical aspect. But Amendt et al. [47] suggest that scoliometer should not be the only tool used in the diagnosis and assessment of scoliosis due to unsatisfactory reliability of measurements. It can be successfully used for screening but together with other instruments monitoring the progress of the deformity.

It was also proved that ST is an effective method of monitoring the progression of scoliosis. Schulte et al. noticed that the increase in lateral curvature and trunk rotation correlates well with the progression of curvature and suggested that ST may be used to monitor the progress of scoliosis [48]. Theologis et al. [49] and De Korvin et al. [50] reached similar conclusions.

As seen above, numerous studies have been conducted overt the years and many opinions have been formed regarding the diagnostics with projection moiré. The method is considered good or not, but the unquestionable fact is that it may be an alternative to very expensive and invasive radiology when it comes to screening. It can be used if certain procedures are performed with diligence and precision. The authors think that ST in connection with the assessment of the angle of trunk rotation with a scoliometer may increase significantly the effectiveness in diagnosing and evaluating changes in scoliosis in frontal and transverse plane. In addition, both devices used together enable presentation of different clinical issues regarding an objective and quantitative analysis od body posture and scoliosis.

STUDY LIMITATIONS

This study is not without limitations. Different European countries have various recommendations regarding screening for idiopathic scoliosis, thus it seems important to continue studies intended to set the standards which would improve the sensitivity and specificity during detecting and assessing this disease. The authors of this paper intend to continue their research in a much larger group of girls as well as boys. They also realize that their functional evaluation of the patients was not comprehensive (only 3 tests were performed). The next stage of examinations may include the evaluation of impact of pelvic asymmetry on scoliotic changes and evaluation of hip abductors contraction.

CONCLUSIONS

In connection with the scoliometer examination, *Moiré topography* can be an important factor towards the improved effectiveness of screening for scoliotic postural asymmetry and monitoring the effects of therapy.

There is a clear linear correlation between the progressing scoliosis measured with *Moiré topography* and the angle of trunk rotation measured with a scoliometer.

There were no significant correlations observed between functional tests results and variables obtained through scoliometer examination and *Moiré topography*.

HIGHLIGHTS

There are many non-invasive methods used to detect and monitor scoliosis. They can also be useful in addition to X-rays to monitor disease progression. One of them is the assessment of the trunk rotation angle using a scoliometer, the reliability of which, correlated with the Cobb angle, is rated from satisfactory to good. According to the authors, the additional use of surface topography in conjunction with the assessment of the trunk rotation angle using a scoliometer can significantly increase the effectiveness of detecting and assessing changes in scoliosis in relation to the frontal and transverse planes.

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