Reliability, repeatability and comparison to normal of a set of new stereophotogrammetric parameters to detect trunk asymmetries

Francesco Negrini[1], Kjell Heitmann[2], Francesco Luceri[1], Sabrina Donzelli[3], Fabio Zaina[3], Stefano Negrini[1,4]

1. IRCCS Istituto Ortopedico Galeazzi, Milano (MI), Italy

2. Diers International GmbH, Schlangenbad, Germany

3. ISICO (Italian Scientific Spine Institute), Via Roberto Bellarmino 13/1, 20141 Milan (MI), Italy

4. Department of Biomedical, Surgical and Dental Sciences, University of Milan "La Statale", Italy

Corresponding author: Dr. Francesco Luceri

Abstract

Background

Aesthetic impairment is a crucial issue in Adolescent Idiopathic Scoliosis (AIS), but to date there is not an objective measurement.

Objective

Aim of the study is to evaluate the repeatability of 17 parameters measured by surface topography in a group of AIS subjects and verify their diagnostic validity.

Methods

The paper is divided into three cross-sectional observational studies. We evaluated 17 selected surface topography parameters that could be good predictors of scoliosis' impact on the patients' trunk. We analysed short-term (30 seconds, 38 subjects) and medium-term (90 minutes, 14 subjects) repeatability of surface topography measures and their diagnostic validity in AIS (74 subjects, 33 AIS patients and 41 healthy subjects).

Results

All examined parameters were highly correlated as far as short and medium-term repeatability is concerned. We found a statistically significant difference between the scoliosis group and the control group in 3 surface rotation parameters, 1 shoulders parameter and 3 waist parameters.

Conclusions

In conclusion, surface topography showed a good repeatability. Moreover, some of its parameters are correlated with AIS, enabling us to find differences between pathological and healthy subjects. Thanks to these findings, it will be possible to develop a tool that can objectively evaluate aesthetics is AIS patients.

Keywords: Adolescent Idiopathic Scoliosis; Aesthetics; Trunk deformity; Surface Topography

Introduction

Adolescent idiopathic scoliosis (AIS) is a fairly common disease: epidemiological studies estimate that 1%–3% of the at-risk population (children aged 10–14) have a curvature of at least 10° (1), and approximately 3 in 1000 adolescents require specific treatment (2). By definition, AIS affects patients from the age of 10 years until bone maturity; it is more common in girls than in boys (3). AIS does not usually cause clinically important pain during growth. Nevertheless, the deformity has a significant impact on the quality of life of scoliotic patients and, in some cases, important psychological consequences (4–7). Many orthopaedic surgeons agree on the importance of aesthetic deformity in the treatment of scoliosis, its severity being the most important aspect considered when proposing a surgical treatment to the patients (8). Aesthetic deformity due to scoliosis and its impact on the patient is considered by the members of SOSORT (International Society On Scoliosis Orthopaedic and Rehabilitation Treatment) as the most important reason for treating AIS; unfortunately, only a few of scoliosis studies were found in PubMed on this topic (9).

Some of the above-mentioned studies report on tools for self-evaluation. For instance, some questionnaires included a domain for the evaluation of the aesthetics of the scoliotic patient, such as the SRS-22 (10). Other tools were developed specifically for the assessment of the aesthetic deformity perceived by scoliotic patients (or scoliotic patients' relatives). These tools are the "Walter Reed Visual Assessment Scale" (6), the "Spinal Appearance Questionnaire" (11) and the recent "Trunk Appearance Perception Scale" (12). They can be used to assess subjective perception of the aesthetic deformity but cannot describe the objective aesthetic deformity. They are more concerned with psychological damage due to scoliotic deformity than with the deformity itself. However, it is important to find a method of objectively assessing the deformity caused by scoliosis, this being one of the possible resulting impairments (13). There are a few such methods, for example, the Posterior Trunk Symmetry Index (POTSI), the Anterior Trunk Symmetry Index (ATSI) (14) or the Trunk Aesthetic Clinical Evaluation (TRACE) (15). However, the POTSI and ATSI are difficult to use in everyday clinical practice, and the TRACE is operator dependent and does not have good repeatability.

A possible more objective way to assess the deformity is by using surface topography, such as rasterstereography (16). A set of parameters can be measured by rasterstereography regarding waist, shoulder and scapulae asymmetries; surface rotation and sagittal measures, but so far, its reliability has not been documented. Moreover, we do not know if these correlate with the deformity, even if they are an instrumental evaluation of the parameters usually evaluated in the clinical assessment of the trunk. These parameters could be instrumental to obtain a measure not of skeletal deformity, but of the sum of skeletal and soft tissue deformity. A tool of this kind could not, of course, replace the role of x-rays for diagnosis, but can give us a completely new measure of asymmetry not currently available, and that can be strongly linked to aesthetic impact of scoliosis.

In order to validate this instrument for clinical practice, the first step and aim of this study is to evaluate the repeatability of the parameters measured by surface topography in a group of AIS subjects and to test if they can distinguish healthy subjects from AIS patients in order to develop an objective tool for deformity evaluation of the trunk in AIS patients.

Materials and methods

Design of the study

This was a cross-sectional diagnostic study that included the short-term (30 seconds) and medium-term (90 minutes) repeatability of surface topography measures and their diagnostic validity in AIS.

Setting

Tertiary specialized clinic.

Samples

We analysed different samples because we wanted to investigate different characteristics of the surface topography parameters considered. For the repeatability evaluation, 38 consecutive AIS subjects with no other concurrent spinal pathologies were included (34 females) by convenience sampling from among patients attending our institute. All of them participated in the short-term repeatability study, which was based on two sets of measures, with a 30-second rest between them. Fourteen of them were retested 90 minutes after the first assessment in order to assess the medium-term repeatability and to take into consideration the possible postural reassessment that probably do not happen in just 30 seconds. We collected the sample during May-June 2013.

For diagnostic validity, we used a database of 398 consecutive adolescents who underwent a surface topography examination at our institute between January 2012 and June 2013. We excluded those with a diagnosis of spinal pathology other than scoliosis (Scheuermann's disease, spondylolisthesis and spondylolysis) and those under treatment with a brace. In clinical practice stersterography is regularly used for sagittal spine issues and only seldom for scoliosis, so after this selection, only 74 patients remained and were included in the study; we further divided them into two groups. In the scoliosis group (SG, 33 patients) we included all patients who had a scoliotic curve (measured on an x-ray) of 11° Cobb or more and with 5° or more of the Bunnell angle of trunk rotation (ATR). The control group (CG) consisted of the other 41 participants. of Participant characteristics are reported in tables 1 and 2.

We did not perform a sample size calculation, because no similar study was available from which to obtain data for this purpose.

Device

For our evaluations, we used a device for surface topography based on the principles of sterstereography. This device (Formetric™, Diers Biomedical Solutions) can reconstruct digitally in three dimensions the back of any person. It does not require radiation nor reflective markers, as it can find anatomic markers using a "touchless" technique without manual intervention. For the data collection, we used a standard machine. Data were then elaborated using a software specifically designed and currently not implemented in other machines.

Evaluations with this device give many parameters as outcomes. We selected 15 parameters that we consider good predictors of the aesthetic impact of the scoliotic patient's spine. They can be divided into four main groups: parameters which take into consideration the whole back of the patient and those parameters which take into consideration the patient's shoulders [figure 1], thorax or waist. We list and describe them in appendix 1. The outcome of the study has a feasibility character because all measurement results are based on a preliminary testing software, which is not clinically verified and evaluated. The result can be a platform for further developments and improvements.

Methodology and data analysis

To assess repeatability, the same operator, trained in the use of the device, performed all the tests twice in a clinical setting. The short-term repeatability test required an immediate repetition of the exam after some trunk movements (30 seconds), whereas for medium-term repeatability, the second exam was repeated after an exercise therapy session (90 minutes).

Concerning both short- and medium-term repeatability, we Pearson's correlation analysis and checked the dispersion of the data obtained by measuring the R-squared. We also used the Bland and Altman statistics (17) for each of the surface topography parameters in order to identify the minimum change in a parameter required to determine with certainty a real change (repeatability coefficient). These data are useful to have in everyday clinical practice.

As far as diagnostic validity is concerned, we tested for a statistically significant difference in the personal and anthropometric parameters between the two groups by using a *t*-test for independent samples (age, weight, height, BMI, time since menarche). We then compared the two samples using a χ^2 test and tested for a statistically significant difference between the two groups in the surface topography parameters by using a *t*-test for independent samples.

All the patients or their parents (in the case of minors) gave written informed consent, and the local ethical committee authorized this study.

Results

Of the 38 patients who performed the short-term repeatability test, 18 were performing regular specific exercise therapy (18) and 25 were wearing a brace for an average of 16.7 hours per day (DS 5.2). Patient characteristics are reported in tables 1 and 2.

For the medium-term repeatability test, all patients were performing exercise therapy, and 11 of them were wearing a brace for 19.1 hours a day on average (DS 4.0). Patient characteristics are reported in tables 1 and 2.

As far as diagnostic validity sample is concerned, the scoliotic group had a mean Cobb angle of the principal curve of 25.8° (DS 14.7)[tables 1,2 and 3]. Using a t-test for independent samples we could not find any statistical significant difference between the group of scoliotic patients and healthy subjects in the personal and anthropometric parameters samples (age, weight, height, BMI, time since menarche).

Repeatability correlations

All examined parameters were highly correlated [table 3]. In short-term repeatability analysis, we found a strong correlation for each value ($r > 0.5$) except thorax thoracic torsion, for which we found a good correlation ($r = 0.338$). In the medium term, only two parameters had an $r < 0.5$: surface rotation max ($r = 0.329$) and thorax axilla height difference ($r = 0.275$). Nevertheless, the data were skewed (R-square>0,5) for 8 out of 17 parameters in short-term repeatability and 10 out of 17 in medium-term repeatability [table 3].

Repeatability coefficient

Concerning short-term repeatability, we found high values (less clinically reliable parameters) for surface rotation max, thoracic torsion, axilla height difference, waist bottom angle difference, waist-arm distance difference and waist height difference. Concerning medium-term repeatability, we found high values for lordotic angle, surface rotation max, thoracic torsion, thorax axilla height difference, waist top angle difference and waist lumbar torsion [table 3].

Diagnostic validity

We found a statistically significant difference between the scoliosis group and the control group in the parameters that measured the surface rotation (surface rotation root mean square (rms) deg, surface rotation max deg, surface rotation amplitude deg) [Table 4]. Concerning the shoulders, there was a statistically significant difference only in the shoulder slope difference, whereas for the thorax, there were no statistically significant differences. Waist parameters showed a statistically significant difference in the waist bottom angle, waist lumbar torsion and waist height difference.

Discussion

The aim of this paper was to verify the repeatability and diagnostic validity of a newly developed set of surface topography parameters. This is a basic requirement before they are used in clinical practice to objectively evaluate the deformity of scoliosis patients. We found the short-and medium-term repeatability to be good for almost all parameters. We also found that some parameters could distinguish healthy subjects from scoliosis patients: these are related to surface rotation (standing humps) and waist shape, in contrast to shoulder and upper thorax characteristics.

Theoretically, the most important reasons why aesthetic parameters could have a low repeatability are the following: 1. The error due to the device used; 2. The error due to the way the exam is executed; 3. The error due to postural changes of the patient. However, it has already been proven that the accuracy of surface topography is very good (19), and there are no critical issues with the execution of the exam: in fact, the patient indications for the exam are few and simple, and the exam is rapid to perform. Even if this last aspect could have influenced our work, postural changes are the main issue that we should consider. The ability (or incapability) of the patient to maintain posture over a short or medium time span is one of the main issues not only for our work but also for all devices used to assess surface topography of the spine and, in general, for all postural exams (13). It is interesting to note that some parameters have better medium-term than short-term repeatability. This probably means it is easier that for the patient to assume the same original relaxed posture after 1.5 hours than after rapid mobilization of the spine.

Although some parameters have a high repeatability coefficient (measured using the statistical method of Bland and Altman), correlation between the first and the second measures and R-squared were good. Two examples are the shoulder slope difference and shoulder height difference.

In 2012 a paper was published that measured the repeatability of another surface topography device for the evaluation of the trunk in scoliotic and non-scoliotic patients (20). To verify the repeatability of the device, the authors used the correlation between the values obtained in two different sessions; their correlation analysis results were similar to ours. Their conclusion was that the device they used for topographic evaluation had a good repeatability.

The population considered in this study was rigorously selected, focusing exclusively on scoliosis; this reduced the sample size but gave more strength to the results. Unfortunately, this precluded the possibility of looking at different sub-populations of scoliosis patients. It is possible that the diagnostic validity would be higher in higher degree scoliosis and/or subpopulations with different topographic classifications. This aspect should be investigated further in future studies.

A comparison with a normal population has not been performed for other objective aesthetic evaluation tools like TRACE (15) and POTSI (21). Conversely, it is the basis of subjective evaluations using questionnaires (11,12,22); however, these data are not comparable to ours. A study compared surface measurements obtained through ISIS in a normal population of two different ages (10–16 vs 21–59), without identifying specific differences (23).

Although an improved aesthetic is considered as a possible outcome of scoliosis treatment (8,9), the currently existing tools are only subjective and consequently reflect the psychological attitudes of patients more than the objective reality. This is a serious limitation for clinics and research.

This study has some limitations: firstly, the sample size was quite small; nevertheless, it was large enough to demonstrate that our hypothesis was correct. We could not perform a subgroup analysis to test if some curve patterns are more correlated with surface topography findings; therefore, we probably missed some relevant information. Moreover, we used a dedicated software for the analysis, that still needs some testing and fine tuning being this the first clinical test so far. The patients with a low r-factor are related to new selected and not verified parameter. In a clinical trial and iteration process this result can be improved.

In conclusion, surface topography showed a good repeatability. Moreover, some of its parameters are correlated with scoliosis, showing that could very well evaluate deformity due to this pathology. Thanks to these findings, it will be possible to develop a tool that can objectively evaluate aesthetics is AIS patients.

Conflict of interest statement

FN has no conflict of interest

KH is employed at the company Diers

SD has no conflict of interest

FZ has no conflict of interest

SN owns stock of ISICO, consults Medtronic and is on the Scientific Advisory Board of Janssen Pharmaceutical

Founding

No founding received.

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Appendix 1. Surface topography parameters

Back

The following parameters take into consideration the whole back of the patient:

- Kyphotic angle ICT-ITL max: represents the angle between the tangents to the sagittal curve in the cervico-thoracic inversion and the thoraco-lumbar inversion. This is the maximum kyphotic angle.
- Lordotic angle ITL-ILS max: represents the angle between the tangents to the sagittal curve in the thoraco-lumbar inversion and the lumbo-sacral inversion. This is the maximum lordotic angle.
- Surface rotation RMS/max and amplitude: represents the surface rotation and the rotation of the vertebral bodies. RMS means root mean square.

Shoulders

The following parameters take into consideration the patient's shoulders:

- Shoulder slope: the rasterstereography measures the angle between each of the two shoulders and a straight line parallel to the ground and calculates, in degrees, the difference in the angulation of the two shoulders (slope height differential).
- Shoulder height differential: the rasterstereography draws a straight line passing through the two acromial processes and calculates the angulation between it and a straight line parallel to the ground.

Thorax

The following parameters take into consideration the patient's thorax:

- Scapula angle: the rasterstereography measures the angulation between each of the two scapulae and a straight line parallel to the ground and calculates, in degrees, the difference in the angulation of the two scapulae (scapula angle differential).
- Thoracic torsion: the rasterstereography measures the torsion of the torso seen from above, taking as markers the straight line passing through the middle point of the axilla and the straight line passing through the Fossae lumbales laterales (dimples of Venus).
- Axilla height differential: the rasterstereography draws the straight line passing through the middle points of the axillae and calculates the angulation between it and a straight line parallel to the ground.

Waist

The following parameters take into consideration the patient's waist:

- Waist opening angles: the rasterstereography measures the amplitude in degrees of the two waist opening angles and calculates the difference between the two of them (opening angle differential).
- Waist top angles: the surface topography measures the amplitude in degrees of the two waist top angles and calculates the difference between them (top angle differential).
- Waist bottom angles: the rasterstereography measures the amplitude in degree of the two waist bottom angles and calculates the difference between them (bottom angle differential).

- Normalized waist triangle area: the rasterstereography measures the area of the two waist triangles and calculates the difference between them, in percentage of the total.
- Waist arm distance: the rasterstereography measures the maximum distance between the patient's arm and basin, measures the height of the waist triangle and calculates the difference (waist arm distance differential) between them, in percentage of the total.
- Waist height differential: the rasterstereography draws a straight line passing through the vertex of the two waist triangles and calculates the angulation between it and a straight line parallel to the ground.
- Waist lumbar torsion: the rasterstereography measures the lumbar torsion seen from above, taking as markers the straight line passing through the vertex of the two waist triangles and the straight line passing through the Fossae lumbales laterales (dimples of Venus).

Tables

Table 1: Demographic data, Cobb degrees and hours of brace of our samples.

	Age	Height (cm)	Weight (kg)	BMI	Distance to Menarche (years)	Cobb Max	Hours of bracing
Short term repeatability							
N	**38**	**38**	**38**	**38**	**24**	**38**	**25**
Min	10	143	32,0	12,98	,12	11	8
Max	20	181	71,5	24,59	6,82	70	23
Mean	14,5	161,4	51,2	19,5	3,1	28,8	16,7
STD	2,5	9,0	10,1	2,7	2,0	13,1	5,2
Medium term repeatability							
N	**14**	**14**	**14**	**14**	**10**	**14**	**11**
Min	12,7	153	33,0	13,56	1,08	10	12
Max	19,6	179	63,0	24,59	6,82	70	23
Mean	15,1	161,5	52,2	19,9	3,5	33,1	19,1
STD	2,3	7,2	8,9	2,8	2,0	14,7	4
Diagnostic validity							
N	**74**	**74**	**74**	**74**	**41**	**41**	**NA**
Min	10,0	30,0	138,0	14,0	0,0	11	NA
Max	16,4	79,0	186,0	27,0	4,4	71	NA
Mean	13,4	49,9	162,5	18,8	1,5	25,8	NA
STD	1,6	9,9	10,3	2,5	1,2	14,7	NA

Table 2: Trace and Risser data of our samples.

	Trace	**Risser**
Short term repeatability		
Median	4	2
Min	1	0
Max	9	5
Medium term repeatability		
Median	3	3
Min	1	0
Max	9	5
Diagnostic validity (scoliotic group)		
Median	6	2
Min	1	0
Max	12	5

Table 3: Repeatability correlations and coefficients of the rasterstereography parameters.

	Short term				**Medium term**		
	Pearson	**R square**	**Repeatability coefficient**		**Pearson**	**R square**	**Repeatability coefficient**
Cyphotic Angle Max	0,924	0,855	10,06		0,873	0,762	13,97
Lordotic Angle Max	0,872	0,760	10,67		0,559	0,313	20,12
Surface Rotation Rms °	0,661	0,437	4,13		0,685	0,469	3,87
Surface Rotation Max °	0,619	0,246	23,99		0,330	0,109	29,33
Surface Rotation Amplitude °	0,781	0,657	6,74		0,804	0,646	6,98
Shoulder slope difference R-L °	0,766	0,587	8,17		0,840	0,706	8,30
Shoulder height difference R-L °	0,815	0,665	2,97		0,865	0,749	3,39
Thorax scapula angle difference R-L °	0,694	0,481	15,80		0,855	0,732	11,38
Thorax thoracic torsion °	0,338	0,114	9,18		0,678	0,460	9,82
Thorax axilla height difference R-L °	0,612	0,374	3,50		0,276	0,076	6,68
Waist opening angle difference R-L °	0,724	0,524	20,25		0,912	0,833	12,82
Waist top angle difference R-L °	0,862	0,743	5,94		0,646	0,417	13,22
Waist bottom angle difference R-L °	0,620	0,384	17,08		0,925	0,856	6,77
Waist triangle area (normalized) difference R-L %	0,842	0,709	22,49		0,917	0,840	19,69
Waist waist-arm distance difference R-L %	0,534	0,285	45,01		0,916	0,839	25,80
Waist height difference °	0,596	0,355	9,94		0,882	0,779	5,27
Waist lumbar torsion °	0,622	0,387	3,21		0,572	0,327	4,61

Table 4: Results of t-test for independent samples between the group of scoliotic patients and healthy subjects for the rasterstereography parameters.

		N	**Mean**	**STD**	**T-test (sig.)**
Kyphotic Angle ICT-ITL max	**Control group**	41	42,93	12,16	0,21
	Scoliotic group	33	46,06	8,13	
Lordotic Angle ITL-ILS max	**Control group**	41	39,59	9,91	0,14
	Scoliotic group	33	42,79	8,21	
Surface Rotation Rms	**Control group**	41	5,61	2,41	0,00
	Scoliotic group	33	3,70	1,57	
Surface Rotation Max	**Control group**	41	10,61	3,96	0,00
	Scoliotic group	33	7,27	2,49	
Surface Rotation Amplitude	**Control group**	41	16,27	6,12	0,00
	Scoliotic group	33	9,24	2,84	
Shoulder slope difference R-L	**Control group**	41	5,29	3,69	0,03
	Scoliotic group	33	3,45	3,54	
Shoulder height difference R-L	**Control group**	41	1,63	1,13	0,75
	Scoliotic group	33	1,55	1,25	
Thorax scapula angle difference R-L	**Control group**	41	8,41	9,65	0,52
	Scoliotic group	33	9,73	7,35	
Thorax thoracic torsion	**Control group**	41	2,39	1,87	0,64

	Scoliotic group	33	2,21	1,29	
Thorax axilla height difference R-L	**Control group**	41	2,15	2,08	0,87
	Scoliotic group	33	2,06	2,36	
Waist opening angle difference R-L	**Control group**	41	7,34	5,45	0,19
	Scoliotic group	33	5,70	5,06	
Waist top angle difference R-L	**Control group**	41	3,34	4,99	0,56
	Scoliotic group	33	2,73	3,66	
Waist bottom angle difference R-L	**Control group**	41	7,51	6,05	0,00
	Scoliotic group	33	4,00	3,18	
Waist triangle area (normalized) difference R-L %	**Control group**	41	15,46	13,47	0,47
	Scoliotic group	33	13,15	13,56	
Waist waist-arm distance difference R-L %	**Control group**	41	12,78	12,38	0,36
	Scoliotic group	33	15,45	12,62	
Waist height difference	**Control group**	41	3,90	4,01	0,04
	Scoliotic group	33	2,42	2,02	
Waist lumbar torsion	**Control group**	41	1,59	1,28	0,00
	Scoliotic group	33	0,64	0,65	

Figures

Fig. 1: An example of parameters we can measure using rasterstereography: Shoulders slope and Shoulders height differential.