Journal of Bodywork & Movement Therapies (2012) **16**, 210—216

available at www.sciencedirect.com

ScienceDirect

journal homepage: www.elsevier.com/jbmt

CLINICAL IMAGING

Reliability of photogrammetry in the evaluation of the postural aspects of individuals with structural scoliosis

Karen Ruggeri Saad, Ms.D., Professor of Morphology [a,*], Alexandra Siqueira Colombo, Chief of Physiotherapeutic Service [b], Ana Paula Ribeiro, Ms.D., Physiotherapist [c], Sílvia Maria Amado João, Ph.D., Professor [d]

[a] *School of Medicine, Vale do São Francisco Federal University, Av. Jose de Sá Maniçoba, s/n Centro, Petrolina, PE 56304-917, Brazil*
[b] *Chief of Physiotherapeutic Service of the University Hospital of São Paulo University, São Paulo, SP, Brazil*
[c] *Laboratory of Musculoskeletal Assessment — LAME, School of Medicine, São Paulo University, São Paulo, SP, Brazil*
[d] *Department of Physiotherapy, Speech Therapy and Occupational Therapy, School of Medicine, São Paulo University, São Paulo, SP, Brazil*

Received 1 December 2010; received in revised form 23 March 2011; accepted 30 March 2011

KEYWORDS
Scoliosis;
Photogrammetry;
Reliability;
Physical therapy

Summary *Purpose:* The purpose of this study was to investigate the reliability of photogrammetry in the measurement of the postural deviations in individuals with idiopathic scoliosis.
Methods: Twenty participants with scoliosis (17 women and three men), with a mean age of 23.1 ± 9 yrs, were photographed from the posterior and lateral views. The postural aspects were measured with CorelDRAW software.
Results: High inter-rater and test—retest reliability indices were found. It was observed that with more severity of scoliosis, greater were the variations between the thoracic kyphosis and lumbar lordosis measures obtained by the same examiner from the left lateral view photographs. A greater body mass index (BMI) was associated with greater variability of the trunk rotation measures obtained by two independent examiners from the right, lateral view ($r = 0.656$; $p = 0.002$). The severity of scoliosis was also associated with greater inter-rater variability measures of trunk rotation obtained from the left, lateral view ($r = 0.483$; $p = 0.036$).
Conclusions: Photogrammetry demonstrated to be a reliable method for the measurement of postural deviations from the posterior and lateral views of individuals with idiopathic scoliosis

* Corresponding author.
E-mail addresses: karen.ruggeri@univasf.edu.br, karenruggeri@usp.br (K.R. Saad).

doi:10.1016/j.jbmt.2011.03.005

and could be complementarily employed for the assessment procedures, which could reduce the number of X-rays used for the follow-up assessments of these individuals.

Introduction

Idiopathic scoliosis in adolescents refers to tri-dimensional structural changes of the vertebral column. The scoliotic curvature is not reduced during the movement of lateral trunk inclinations, thus being in a fixed position. (Skaggs and Basset, 1996). Earlier diagnoses, assessments, and treatments of this type of scoliosis remain a challenge for both orthopaedic doctors and physical therapists.

Traditionally, radiographic measures, as assessed by the Cobb method, are recognized as the gold standards for the assessment of the progression of scoliosis. The Cobb method has been used to assess the progression of the curvatures, to select the types of interventions, and to assess their effectiveness (Weinstein and Buckwalter, 2000). However, health professionals worry regarding the amount of radiation imposed on these adolescents during the follow-up assessments (Almén and Mattsson, 1996; Levy et al., 1996). This is because, in some cases, X-rays from the anterior—posterior (AP) and the lateral views, need to be performed every three months (Weiss et al., 2006). In addition, many studies regarding idiopathic scoliosis, have considered other important aspects for the follow-ups and the planning of therapeutic interventions, which cannot be provided by radiographic assessments. X-rays provide only bi-dimensional information, whereas in scoliosis, the inclinations of the vertebral column are associated with vertebral rotations, leading to tri-dimensional postural deviations (Dawson et al., 1993; D'Osualdo et al., 2002; Hackemberg et al., 2003; Jarenko et al., 2001; Mínguez et al., 2007; Ovadia et al., 2007; Pazos et al., 2005; Ramirez et al., 2006; Thometz et al., 2000; Zabjek et al., 2005).

Thus, over the last 30 years, other methods for the evaluation and study of observed asymmetries of the trunk of individuals with scoliosis have been developed. Some of these methods, such as the scoliometer and postural observations are described in the literature as methods which can be employed for the detection of postural changes associated with scoliosis and are commonly used in the annual assessments of adolescents and pre-adolescents (Amendt et al., 1990; Grivas et al., 2006; Vercauteren et al., 1982). However, none of these techniques were able to replace the X-rays for the follow-ups of the progression of scoliosis.

Some postural assessment instruments are quite expensive, employ sophisticated technologies, provide complex measurements to be understood, and require specialized personnel to interpret the results, such as scanners, stereophotogrammetry, and special softwares (Dawson et al., 1993; D'Osualdo et al., 2002; Hackemberg et al., 2003; Jarenko et al., 2001; Mínguez et al., 2007; Ovadia et al., 2007; Pazos et al., 2005; Ramirez et al., 2006; Thometz et al., 2000; Zabjek et al., 2005). Therefore, digital photogrammetry could be an alternative for the quantitative assessment of postural deviations, because it is cost-effective, can be repetitively applied in clinical contexts, and has the capacity to provide objective measures regarding the progression of postural deviations.

Previously, Saad et al. (2009) assessed the validity and reliability of photogrammetry for the measurement of the angles of inclination of the vertebral column of patients with idiopathic scoliosis in the frontal plane. Their results suggested the impossibility of replacing radiographic exams for the assessment of the lateral spinal curves. They observed high levels of test—retest reliability and inter-rater reliability of the photogrammetric measurements. These findings suggested that other dimensions of posture for individuals with scoliosis could also demonstrate high reliability levels and, thus, validated photogrammetry as an auxiliary instrument for the evaluation of scoliosis. This method could provide additional, complementary information by identifying asymmetries and allow the visualization of the cosmetic aspects of these deformities. In our clinical experiences, for adolescents, the cosmetic aspect of the scoliosis appeared to be more important than their classification, as determined by the measurement of vertebral inclinations provided by the Cobb angle.

A more recent study of Döhnert and Tomasi (2008) attempted to validate computerized photogrammetry for the detection of idiopathic scoliosis in 224 students and concluded that photogrammetry should not be used as a screening instrument for scoliosis, especially for low levels. However, the criteria used to identify individuals with scoliosis were not clear and, possibly, their methods could have underestimated the results. It is well known that the identification and measurement of spinal inclinations in the frontal plane based upon the spinal processes do not correspond to the reference landmarks employed for the radiographic measurements of the Cobb angles which use the plateaus of the vertebral bodies as anatomical reference points (Herzenberg et al., 1990; Saad et al., 2009). Possibly, other postural aspects which are not only related to the trunk lateral inclinations or the presence of gibbosity, might be elements of the diagnostic criteria.

Several studies employed photogrammetry for the characterization and assessment of specific postural types (Braun and Amundson, 1989; Dunk et al., 2005; Guimarães et al. 2007; Jeferray 2001; Lima et al., 2004; Penha et al., 2008, 2009; Raine and Twomey, 1997) and others validated the photogrammetry for the postural assessments of individuals without scoliosis (Caillet, 1996; Dunk et al., 2004; Ferreira et al., 2010; Iunes et al., 2005; Sacco et al., 2007; Zonnemberg et al., 1996). However, some limitations exist regarding the reliability of photogrammetry as a quantitative measure to characterize the postural changes in individuals with structural scoliosis.

Therefore, the purpose of this study was to investigate the reliability of the photogrammetric measures for postural assessments of individuals with idiopathic scoliosis.

Methods

One-hundred and twenty nine medical records of patients with diagnoses of scoliosis over the last five years in the orthopaedic clinics of the University hospital were studied. Forty-eight subjects were excluded because their scoliosis was due to lower limb discrepancies, neurological diseases, hemi-vertebrae, fractures, previous spinal surgeries, and degenerative changes of the inter-vertebral disks. Subjects with scoliosis of less than 10°, as determined by the radiographic Cobb method were also excluded.

The other 81 patients were contacted by telephone and invited to participate in the study, but only 40 agreed to participate. Of the 40 participants, only 20 could complete all of the photographic sessions based upon the present protocol. All subjects had diagnoses of idiopathic scoliosis, as confirmed by the anterior—posterior radiographs of the trunk.

All subjects or their legal guardians signed the consent form, which was approved by the Institution Ethical Review Committee (#0187/07). All subjects were interviewed to obtain their ages, time since their diagnoses, and therapeutic interventions, along with their body mass and height to calculate their body mass index (BMI).

Each participant was assessed on two different days. During the first visit, the subject was prepared and photographed by two independent examiners. During the second visit, which was 15 days later, the patient was photographed again by the first examiner. Both examiners were physical therapists and had experience with postural assessments and treatments. The training for the determination of the bony references, the photographic sessions, and the use of CorelDRAW software (version 11.0) were carried out in a pilot study, where the examiners assessed together two subjects, who did not take part in the study. For this study, the investigators independently recorded the measurements without communicating their results to each other.

Each photographic session consisted of recording the digital photos in the frontal and sagittal planes, which were standardized for the individuals' and the camera positioning (Sony P200 7.2 mp), and the distance between the camera and the subjects. All photographic sessions were carried out in the physical therapy outpatient clinic of the University Hospital, with the same light and temperature conditions. All sessions were carried out in the afternoon (between 13 and 17 p.m.) (Beauchamp et al., 1993.)

The subjects' preparation comprised the identification of the anatomical landmarks with circular tapes of 1 cm in width (3 M®) and circular-shaped markers with the same dimensions, which were placed on the subjects' skin after careful palpation to identify the acromion, inferior angles of the scapulae, anterior and superior iliac spines (ASIS), posterior superior iliac spines (PSIS), and the lateral malleoli with an additional marker placed 2.5 cm in front of the latter. The markers were placed on the subjects while in the standing position and wearing appropriate clothes.

The subjects were positioned behind a symmetrographic apparatus (CARCI®) on a 12 cm high wooden platform. Their feet were always placed in the same manner with the aid of two reference lines marked on the platform. The wooden platform, the symmetrograph, and the tripod on which the camera was fixed, had a leveling system to correct for support differences, and the tripod heights were regulated to half of the subjects' height. At the end of the procedures, the digital pictures were transferred to the Corel Draw program®, which enabled the measurement of the following postural aspects (Fig 1):

1. The pelvic alignment was determined by the distance from the ASIS to the horizontal line of the symmetrograph, immediately superior to the iliac crest.
2. The shoulder levels were assessed as the distance from the acromion to the horizontal line of the symmetrograph.
3. The levels of the inferior angles of the scapulae were measured as the distance from the inferior angle of the scapular to the horizontal line of the symmetrograph.
4. The displacement of the acromion was determined as the distance between the axillary fold and the center of the acromion.
5. Thoracic kyphosis was assessed as the angle formed between the points of greater concavity of the cervical and lumbar spine and the point of the highest convexity of the thoracic spine.
6. Lumbar lordosis was considered as the angle between the points of the greatest convexity of the thoracic spine and gluteal regions, and the point of greatest concavity of the lumbar spine.
7. Pelvic drop was the angle between the ASIS and the PSIS related to a horizontal line at the level of the ASIS,
8. Trunk rotations, in that the real trunk rotational angles were not measured, but their displacements were, in relation to a reference line from the lateral view. For this, the trunk marker corresponded to mid-axillary line and the reference line was perpendicularly traced to the ground, 2.5 cm in front of the lateral malleolus (Kendall et al., 1995).

During the analyses of the photos, the researchers had no previous knowledge of the radiographic Cobb angular measurements. The Cobb angles were determined by

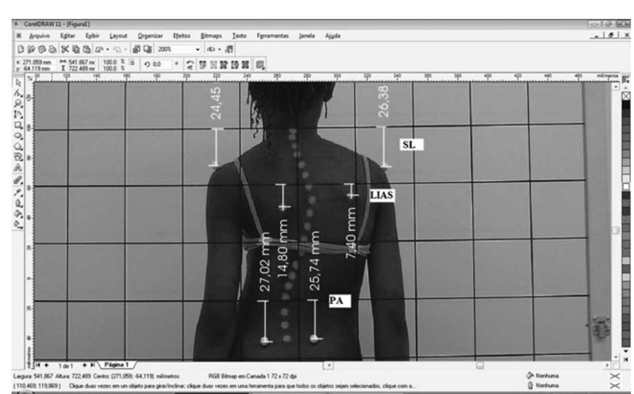

Figure 1 Measurements from the posterior view: Pelvic alignment (PA); shoulder levels (SL), and levels of the inferior angles of the scapulae (LIAS).

means of anterior–posterior radiographs, following the instructions of Amendt et al. (1990).

All statistical analyses were carried out with the SPSS software (version 13.0), with the significance level of $\alpha < 0.05$. Due to the interval nature of the outcome variables, tests for normality were carried out (Shapiro Wilk), followed by tests for homogeneity of variance. After assuming normality and homogeneity, intra-class correlation coefficients (ICCs) were calculated to evaluate the levels of agreement between the two examiners (inter-rater reliability coefficients) and between the measures obtained by the same examiner during the two visits (test–retest reliability coefficients). The ICC values were classified as being excellent (ICC > 0.90), very good (0.80 < ICC < 0.89), acceptable (0.71 < ICC < 0.79), and unacceptable (ICC < 0.70), according to Wahlund et al. (1998).

Spearman correlation coefficients were employed to verify the associations between the variables related to age, BMI, and the severity of the scoliosis, based upon the radiographic Cobb angles and the variability of the measures obtained by the same and different examiners. The objective of these analyses was to investigate whether age, BMI, and the severity of the scoliosis could interfere with the postural measures, by their increased variability.

Results

Of the 20 participants, 17 were women and three were men, with their ages ranging between 11 and 44 years (23.1 ± 9). Nine had 1 and 11 had double lateral spinal curves. The mean Cobb angle of the 31 curves was 32.45 ± 16.68° for the thoracic, 27.85 ± 13.37° for the lumbar, and 22.57 ± 8.26° for the thoraco-lumbar curves. The mean calculated BMI was 22.28 ± 5.27 kg/m^2.

Tables 1 and 2 show the test–retest reliability and inter-rater reliability coefficients. The Spearman correlation coefficient values demonstrated positive associations between the severity of the scoliosis and the variability of the measures obtained by the same investigator for thoracic kyphosis ($r = 0.498$; $p = 0.03$) and the lumbar curves ($r = 0.608$; $p = 0.007$), both obtained from the left lateral view, which indicated that the more severe scoliosis was associated with greater variability of the measures obtained by the same investigator for the thoracic kyphosis and lumbar lordosis from the left lateral view. There were also observed positive associations between the BMI and the variability of the measures obtained between the two investigators for the trunk rotations in the right and left lateral views ($r = 0.656$; $p = 0.002$) and positive associations between trunk rotations from the left lateral view and the severity of the scoliosis ($r = 0.483$; $p = 0.036$).

Discussion

The results of the present study demonstrated excellent test–retest and inter-rater agreement levels for the photogrammetric measures obtained from the posterior, as well as from the right and left lateral views, except for the trunk rotation measures from the right lateral view obtained by the same examiner. For the acromial displacement and lumbar lordosis measures obtained by the two examiners from the right and left lateral views, the ICC values were considered very good.

For the photogrammetric measures from the posterior view, all of the three variables showed excellent levels of test–retest and inter-rater reliabilities. These findings could be explained by the simplicity of the method (Figure 1) and also because the obtained measures were linear and were taken in the horizontal plane, which were probably less influenced by physiological body sways in the standing position. According to Nault et al. (2002), individuals with idiopathic scoliosis have higher amplitudes of physiological body sways in the standing position.

Table 1 Test–retest reliability coefficients of postural variables by means of photogrammetry.

Variable	ICC	Classification	*p*-Value
Pelvic alignment (right)	0.93	Excellent	0.416
Pelvic alignment (left)	0.97	Excellent	0.184
Shoulder level (right)	0.98	Excellent	0.910
Shoulder level (left)	0.98	Excellent	0.785
Level of the inferior angle of the scapulae (right)	0.95	Excellent	0.960
Level of the inferior angle of the scapulae (left)	0.95	Excellent	0.960
Trunk rotation (right)	0.85	Very good	0.369
Trunk rotation (left)	0.90	Excellent	0.148
Displacement of the acromium (right)	0.98	Excellent	0.734
Displacement of the acromium (left)	0.98	Excellent	0.165
Thoracic kyphosis (right)	0.93	Excellent	0.157
Thoracic kyphosis (left)	0.95	Excellent	0.575
Lumbar lordosis (right)	0.90	Excellent	0.920
Lumbar lordosis (left)	0.85	Excellent	0.835
Pelvic drop (right)	0.85	Excellent	0.068
Pelvic drop (left)	0.80	Excellent	0.982
Pelvic alignment	0.95	Excellent	0.567
Shoulder level	0.98	Excellent	0.345
Level of the inferior angle of the scapulae	0.95	Excellent	0.757

Table 2 Inter-rater reliability coefficients of postural variables by means of photogrammetry.

Variable	ICC	Classification	*p*-Value
Pelvic alignment (right)	0.97	Excellent	0.884
Pelvic alignment (left)	0.97	Excellent	0.956
Shoulder level (right)	0.90	Excellent	0.705
Shoulder level (left)	0.90	Excellent	0.665
Level of the inferior angle of the scapulae (right)	0.98	Excellent	0.708
Level of the inferior angle of the scapulae (left)	0.98	Excellent	0.975
Trunk rotation (right)	0.98	Excellent	0.128
Trunk rotation (left)	0.97	Excellent	0.284
Displacement of the acromium (right)	0.80	Very good	0.705
Displacement of the acromium (left)	0.82	Very good	0.665
Thoracic kyphosis (right)	0.97	Excellent	0.965
Thoracic kyphosis (left)	0.97	Excellent	0.473
Lumbar lordosis (right)	0.89	Very good	0.388
Lumbar lordosis (left)	0.85	Very good	0.445
Pelvic drop (right)	0.95	Excellent	0.682
Pelvic drop (left)	0.98	Excellent	0.980
Pelvic alignment	0.95	Excellent	0.335
Shouder level	0.90	Excellent	0.678
Level of the inferior angle of the scapulae	0.90	Excellent	0.557

The discrete reduction of test—retest reliability for the trunk rotations from the right lateral side view, may be attributed to physiological body sway, since for the calculations of this measure, a fixed reference line and a movable (sway) point in the body were considered. However, this isolated result appeared not to be a significant finding, since the intra-rater reliability indices were not reduced, i.e., the variability of the measures obtained by the same examiner was higher than that obtained by the two examiners, which probably occurred by chance.

Related to the discrete reduction of inter-rater agreement for the lumbar lordosis measures, it could be inferred that the fact that idiopathic scoliosis could be characterized by important rotational components of the trunk, this might have prevented the correct visualization of the posterior trunk contours from the left side view. This might be explained by the fact that the majority of the subjects with structural idiopathic scoliosis demonstrated right thoracic convexity and right trunk rotations. Thus, when assessing more severe scoliotic curves from the left side view, the posterior region of the trunk was observed, but not its contour in the sagittal plane (Figure 2). These findings corroborated the positive correlations observed between the severity of the scoliosis and the test—retest variability for the thoracic kyphosis and lumbar lordosis measures from the left and right side views, i.e., the more severe the scoliosis, the higher was the variability between the measures obtained by the two examiners. In spite of the high indices of reliability found for the thoracic kyphosis measures from the right and left side views, both examiners reported doubts and substantial difficulties in obtaining them, mainly from the left side view.

The literature suggests caution for the measurement of thoracic kyphosis and lumbar lordosis by means of photogrammetry, even for the assessment of asymptomatic individuals. Iunes et al. (2005) found unacceptable inter-rater correlation levels for both variables, whereas Leroux et al. (2000) reported adequate reliability levels for the assessment of these curves, although they emphasized the low levels of precision for the measurement of the thoracic kyphosis.

It should be emphasized that the purpose of the angular measurements of thoracic kyphosis by means of photogrammetry, was to quantify the contour of the trunk from the sagittal view, which provided different information than that obtained through X-rays, that is, the measures of the thoracic kyphosis and lumbar lordosis did not correspond to the radiographic Cobb angles. However, photogrammetry also provided information regarding the inclination of the vertebral column in the sagittal plane, which could be used for the follow-up measures of these individuals.

There were observed high reliability levels for the measures of the acromion and pelvic asymmetry. These results were in agreement with those reported by Ferreira et al. (2010), who employed similar methodologies (Figure 3) and also found high test—retest and inter-rater agreement indices for the angular measures of both the pelvic (0.999; 0.996) and shoulder asymmetries (0.992; 0.957). Probably,

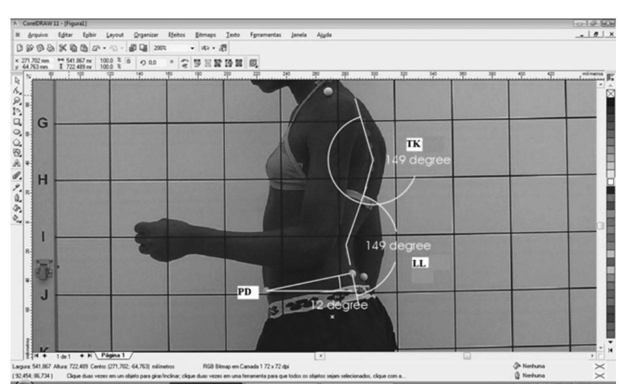

Figure 2 Measurements from the right and left lateral views: thoracic kyphosis (TK); lumbar lordosis (LL), and pelvic drop (PD).

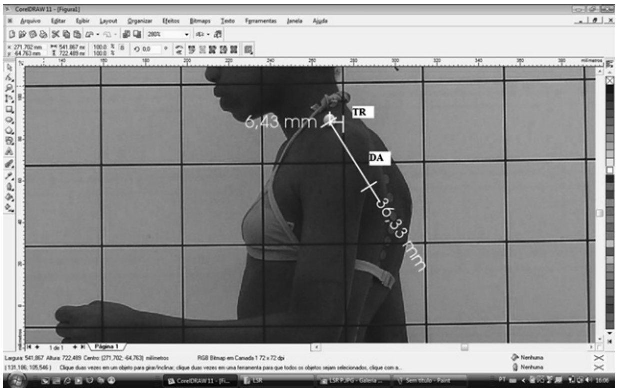

Figure 3 Measurements from the right and left lateral views: displacement of the acromion (DA) and trunk rotation (TR).

these high reliability indices could be associated with the fact that the measures were carried out through the body anatomical landmarks of the subjects and the simetrographic horizontal lines, since other reference lines were not used. That is, the measures were not affected by the trunk rotations, nor by the physiological body sways.

Differently from what was expected, the interferences of the BMI in the variability of the measures were only observed for the measurement of trunk rotations from the right side. It is generally accepted that high BMI values make the palpation and identification of the reference bony landmarks difficult, which reduces the reliability of photogrammetric measures. However, it should be noted that the mean BMI value of the participants was $22.28 \pm 5.27\ kg/m^2$, which characterize a sample composed of individuals with adequate BMI and could certainly be associated with less interference of this variable during data collection.

Zabjek et al. (2005) employed three-dimensional images of the trunk curvatures which allowed the possibility of measuring the postural aspects, taking into account, the rotational components which are important characteristics observed in these individuals. Although the instrument employed in the present study only allowed a two-dimensional characterization of the postural aspects of the scoliosis, it showed to be a reliable tool. Based upon the present findings, further studies are necessary to verify the sensitivity of the photogrammetry to detect subtle postural changes during a determined period of time of physical therapy interventions, or during the progressions of the scoliotic curve.

Conclusions

Photogrammetry was shown to be a reliable method for the assessment of postural changes in individuals with structural scoliosis. However, the design of the present study did not allow the affirmation that the radiologic assessments could be replaced by photogrammetry. Orthopaedic doctors and physical therapists may employ the photogrammetric data as complementary information to radiologic assessments to reduce the number of X-rays necessary as follow-up parameters for the progression of the scoliotic curves and treatment of these individuals.

References

Almén, A.J., Mattsson, S., 1996. Dose distributions at radiographic examinations of the spine in pediatric radiology. Spine 21, 750—756.

Amendt, L.E., Ause-Ellias, K.L., Eybers, J.L., Wadsworth, C.T., Nielsen, D.H., Weinstein, S.L., 1990. Validity and reliability testing of the scoliometer. Phys Ther 70, 108—117.

Beauchamp, M., Labelle, H., Grimard, G., Stanciu, C., Poitras, B., Dansereau, J., 1993. Diurnal variation of Cobb angle measurement in adolescent idiopathic scoliosis. Spine 18, 1581—1583.

Braun, B.L., Amundson, L.R., 1989. Quantitative analysis of head and shoulder posture. Arch Phys Med Rehabil 70, 322—329.

Caillet, R., 1996. Low Back Pain Syndrome. FA Davis Company, Philadelphia.

Dawson, E.G., Kropf, M.A., Purcell, G., Kabo, J.M., Kanin, L.E.A., Burt, C., 1993. Optoelectronic evaluation of trunk deformity in Scoliosis. Spine 18, 326—331.

Döhnert, M.B., Tomasi, E., 2008. Validity of computed photogrammetry for detecting idiopathic scoliosis in adolescents. Rev. Bras. Fisioter 12, 290—297. doi:10.1590/S1413-35552008000400007. Available from: http://www.scielo.br/scielo.php?script=sci_arttext&pid=S1413-35552008000400007&lng=en.

D'Osualdo, F., Schierano, S., Soldano, F.M., Isola, M., 2002. New tridimensional approach to the evaluation of the spine through surface measurement: the BACES system. J. Med. Eng. Technol. 26, 95—105.

Dunk, N.M., Chung, Y.Y., Compton, D.S., Calghan, J.P., 2004. The reliability of quantifying upright standing postures as a baseline diagnostic clinical tool. J. Manipulative Physiol. Ther. 27, 91—96.

Dunk, N.M., Lalonde, J., Callaghan, J.P., 2005. Implications for the use of postural analysis as a clinical diagnostic tool: reliability of quantifying upright standing spinal postures from photographic images. J. Manipulative Physiol. Ther. 28, 386—392.

Ferreira, E.A.G., Duarte, M., Maldonado, E.P., Burke, T.N., Marques, A.P., 2010. Postural assessment (PAS/SAPO): validation and reability. Clinics 65, 675—681.

Grivas, T.B., Vasiliadis, E.S., Koufopoulos, G., Segos, D., Triantafyllopoulos, G., Mouzakis, V., 2006. Study of trunk asymmetry in normal children and adolescents. Scoliosis. http://www.scoliosisjournal.com/content/1/1/19 Available from:

Guimarães, M.B.B., Sacco, I.C.N., João, S.M.A., 2007. Postural characterization of young participants in Olympic gymnastics. Rev. Bras. Fisioter. 11, 213—219.

Hackemberg, L., Hierholzen, E., Potzl, W., Gotze, C., Liljeenqvist, U., 2003. Rastersteriographic back shape analysis in idiopathic scoliosis after anterior correction and fusion. Clin. Biomech. 18, 1—8.

Herzenberg, J.E., Waanders, N.A., Closkey, R.F., Schultz, A.B., Hensinger, R.N., 1990. Cobb angle versus spinous process angle in adolescent idiopathic scoliosis: the relationships of the anterior and posterior deformities. Spine 15, 874—879.

Iunes, D.H., Castro, F.A., Salgado, H.S., Moura, I.C., Oliveira, A.S., Bevilaqua-Grossi, D., 2005. Intra and inter-examiner reliability and method repeatability of postural evaluation via photogrammetry. Rev. Bras. Fisioter. 9, 327—334.

Jarenko, J.L., Poncet, P., Ronsky, J., Harder, J., Dansereau, J., Labelle, H., et al., 2001. Estimation of spinal deformity in scoliosis from torso surface cross sections. Spine 26, 1583—1591.

Jeferray, M., 2001. Using digital images processing for the assessment of postural changes and movement patterns in bodywork clients. J. Bodywork Mov. Ther. 5, 11—20.

Kendall, F.P., McCreary, E.K., Provance, P.G., 1995. Músculos provas e funções. Manole, São Paulo, SP.

Leroux, M.A., Zabjek, K., Simard, G., Badeaux, C.C., Rivard, C.H., 2000. A noninvasive anthropometric technique for measuring kyphosis and lordosis. Spine 25, 1694—1698.

Levy, A.R., Goldberg, M.S., Mayo, M.E., Hanley, J.A., Poitras, B., 1996. Reducing the lifetime risks of cancer from spinal radiographs among people with adolescent idiopathic scoliosis. Spine 21, 1540—1548.

Lima, L.C.O., Baraúna, M.A., Sologurem, M.J.J., Canto, R.S.T., Gastaldi, A.C., 2004. Postural alterations in children with mouth breathing assessed by computerized biophotogrammetry. J. Appl. Oral Sci. 12, 232—237.

Mínguez, M.F., Buendía, M., Cibriàn, R.M., Salvador, R., Languía, M., Martín, A., et al., 2007. Quantifier variables of back surface deformity obtained with a noninvasive structured light method: evaluation of their usefulness in idiopathic scoliosis diagnosis. Eur. Spine J. 16, 73—82.

Nault, M.L., Allard, P., Hinse, S., Le Blanc, R., Caron, O., Labelle, H., et al., 2002. Relations between standing stability and body posture parameters in adolescent idiopathic scoliosis. Spine 27, 1911—1917.

Ovadia, D., Bar-On, E., Fragnière, B., Rigo, M., Leitner, J., Wientroub, S., et al., 2007. Radiation-free quantitative assessment of scoliosis: A multi-center prospective study. Eur. Spine J. 16, 97—105.

Pazos, V., Cheriet, F., Song, L., Labelle, H., Dansereau, J., 2005. Accuracy assessment of human trunk surface 3D reconstructions from an optical digitising system. Med. Biol. Eng. Comput. 43, 11—15.

Penha, P.J., Casarotto, R.A., Sacco, I.C.N., Marques, A.P., João, S.M.A., 2008. Qualitative postural analysis among boys and girls of seven to ten years of age. Rev. Bras. Fisioter 12, 386—391.

Penha, P.J., Baldini, M., João, S.M.A., 2009. Spinal postural alignment variance according to sex and age in 7 and 8 year old children. J. Manipulative Physiol. Ther. 32, 154—159.

Raine, S., Twomey, L.T., 1997. Head and shoulder posture variations in 160 asymptomatic women and men. Arch. Phys. Med. Rehabil. 78, 1215—1223.

Ramirez, L., Durdle, N.G., Raso, V.J., Hill, D.L., 2006. A support vector machines classifier to assess the severity of idiopathic scoliosis from surface topography. IEEE Trans. Inf. Technol. Biomed. 10, 84—91.

Saad, K.R., Colombo, A.S., João, S.M., 2009. Reliability and validity of the photogrammetry for scoliosis evaluation: a cross-sectional prospective study. J. Manipulative Physiol. Ther. 32, 423—430.

Sacco, I.C.N., Alibert, S., Queiroz, B.W.C., Pripas, D., Kieling, I., Kimura, A.A., et al., 2007. Reliability of photogrammetry in relation to goniometry for postural lower limb assessment. Rev. Bras. Fisioter 11, 411—417.

Skaggs, D.L., Basset, G.S., 1996. Adolescent idiopathic scoliosis: an update. Am. Fam. Phys. 53, 2327—2334.

Thometz, J.G., Lamdam, R., Liu, X.C., Lyon, R., 2000. Relationships between Quantec measurement and Cobb angle in patients with idiopathic scoliosis. J. Pediatr. Orthop. 20, 512—516.

Vercauteren, M., Van Beneden, M., Verplaetse, R., Croene, P., Uyttendaele, D., Verdonk, R., 1982. Trunk asymmetries in Belgian school population. Spine 7, 555—562.

Wahlund, K., List, T., Dworkin, 1998. Temporomandibular disorders in children and adolescents: reliability of a questionnaire, clinical examination and diagnosis. J. Orofac. Pain 12, 42—51.

Weinstein, S.L., Buckwalter, J.A., 2000. Ortopedia de Turek: Princípios e suas aplicações. Manole, São Paulo.

Weiss, H.R., Negrini, S., Rigo, M., Kotwicki, T., Hawes, M.C., Grivas, T.B., et al., 2006. Indications for conservative management of scoliosis (guidelines). Scoliosis 1, 1—5.

Zabjek, K.F., Leroux, M.A., Coillard, C., Rivard, C.H., Prince, F., 2005. Evaluation of segmental postural characteristics during quiet standing in control and idiopathic scoliosis patients. Clin. Biomech. 20, 483—490.

Zonnemberg, A.J.J., Maanen, C.J., Elvers, J.W.H., Oostendorp, R.A.B., 1996. Inter/intrarater reliability of measurements on body posture photographs. Phys. Ther. 14, 326—331.