Intra-rater and inter-rater reliability of Surgimap Spine software for measuring spinal postural angles from digital photographs

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Background and purpose
An accurate noninvasive measurement of spinal angles is crucial for detecting postural problems and for assessing therapeutic intervention for students in school. This study was conducted to evaluate the intra-rater and inter-rater reliability of Surgimap Spine software for measuring spinal postural angles from digital photos of adolescents in schools.

Participants and methods
Twenty-two adolescent students of both sexes (10 boys and 12 girls) participated in this reliability study. The researcher took four photographs of each adolescent from different standing views; at intra-rater analysis, one rater analyzed the four photos at three different time, whereas at inter-rater analysis three raters analyzed them once. Reliability was quantified with intraclass correlation coefficient (ICC), repeated measurement analysis (RMA), and standard of measurement error (SEM).

Results
Intra-rater reliability of all spinal postural angles [head tilt, shoulder tilt, pelvic tilt from anterior view, scapular tilt, gaze angle, craniovertebral angle, trunk angle, lumbar angle, pelvic tilt from lateral view, and sway angle for right and left sides] showed excellent results, with ICC above 0.9, whereas ICC for pelvic tilt from the posterior view (0.813) was very good. SEM ranged from 0.28 to 1.5° and RMA showed no statistical difference between measurements of the same rater. ICC values for inter-rater reliability of all spinal postural angles ranged from 0.836 to 0.992. SEM ranged from 0.3 to 1.63° and RMA showed no statistical difference in measurements between different raters.

Conclusion
Surgimap Spine software is a reliable method for measuring spinal postural angles of adolescents from different views in standing position from digital photographs.

Keywords:
adolescent, photographic analysis, reliability, spinal postural angles, Surgimap Spine software

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Introduction

Posture is a state of muscular and skeletal balance. It protects the supporting structures of the body against injury or progressive deformity irrespective of position (erect, lying, or squatting) during working or resting states [1]. Postural deformities appear commonly in children [2]. Nowadays obtaining a normal posture in children and youth is a great challenge. Many studies have dealt with the problem of hypomobility or hypermobility of sagittal vertebral curves, pelvic tilt, scoliosis, or trunk list and its influence on the functional characteristics and locomotor status of children. Alterations in physiological spinal curvatures are associated with increasing risk of injury because of an increase in intervertebral stress, viscoelastic deformation of spinal tissues, or higher intradiscal pressure and influence on spinal motion and muscle activity in different positions [2–8].

There is no standard approach for measuring posture [9]. Photographic observations made visually or by means of simple equipment such as a tape measure, pencilled landmarks, or a plumb line represent a subjective evaluation of posture [10]. Angular measurements between anatomical landmarks of the body are considered a quantitative assessment of posture [11].

There is lack of adequate clinical quantitative measurement tools to monitor change in posture. Although there are sophisticated three-dimensional posture analysis systems such as Optotrak, Vicon, Motion Analysis, and surface topography systems, these systems are not accessible to most clinicians. The *Guide to physical therapist practice* recommended the use of an objective clinical tool to document impairment of posture [12].

Computerized photographic analysis is a valuable approach for measuring postural angles, for monitoring of postural changes over time, and for correlating between different body parts [9,12]. It is a simple, easily applicable and interpreted, economic, objective, high-precision, reliable technique; it also has the ability to store and access records. These advantages explain the wide application of this approach in physical therapy. Angular measurements of spinal posture is used for the investigation of joint dysfunction, in monitoring the effects of physical therapy, for motivating and assessing the treatment compliance of patients, for quantification of disorders, for evaluation of the efficacy of interventions, and for fabrication of orthoses [13].

Surgimap Spine is a software package developed for the medical community. It is a free computer program used to view, store, and transport images. Wu *et al.* [14] studied the reliability of Surgimap in measuring the Cobb angle and assessing the sagittal plane. They concluded that Surgimap Spine measurement is an equivalent measuring tool to the traditional manual technique in measuring the coronal Cobb angle. Surgimap is markedly advantageous in spinopelvic measurement [14]. Surgimap Spine software had been used for radiological purposes by orthopedists but it was not used before for photographic analysis. Thus, the purpose of this study was to assess intra-rater and inter-rater reliability of Surgimap in measuring spinal postural angles from images of normal adolescent students in schools.

Participants and methods

School and participant selection

The Egyptian Ministry of Education gave researchers permission to conduct the study in four educational administrations, and five schools' managers agreed to conduct the study in their schools. Selection of schools and students took place using a random table, and Fatma Al Zahra Experimental School was selected from the five schools. As in the study by Ferreira *et al.* [15] and Perry *et al.* [16], the table selected 22 adolescent students who fulfilled the inclusion and exclusion criteria to participate in the reliability study from among 50 volunteer adolescent students. Adolescent students with true leg-length discrepancy more than 2.5 cm, previous spinal surgery, associated pathology that may interfere with maintaining an erect standing posture, such as cerebellar or inner ear disorders, and associated pathology of lower limbs that may interfere with global posture, such as foot, knee, and hip deformities, were excluded from the study. The Institutional Review Board of the Faculty of Physical Therapy, Cairo University, approved the study protocol. Students and their parents signed the consent form for their participation and protection for their rights.

The study was conducted from October 2013 to November 2013 with a one-shot repeated-measure design to assess reliability. The students' ages ranged from 12 to 18 years (mean age: 14.45 ± 2.5 years) [17] and were of both sexes (10 boys and 12 girls). Their mean BMI was 21.35 ± 3.88 kg/m2; their mean height was 1.5 ± 0.06 m; and their mean weight was 50.818 ± 10.9 kg.

Instrumentation

A Sony DSC-H2 digital still camera (Cyber Shot; 6 megapixels, 12´ optical zoom; Sony Corp., Japan) was used. A wall grid and Surgimap Spine software, a free computer program downloaded from *http://www.Surgimap.com* (Nemaris Inc., New York, New York, USA), were used to measure spinal postural angles in the adolescent students.

Assessment procedure

(1) The researcher placed reflective dots on certain anatomical landmarks on each student.
(2) According to Normand *et al.* [18] the camera was placed on a tripod that had been adjusted according to the umbilical level of the student. The perpendicular distance between the camera and the midline of the wall grid was 3.4 m; the distance between the student and the wall grid was 0.4 m and the distance between the students' feet was 0.2 m, centred on a line drawn from the midwall grid. Each student was asked to stand, nod his or her head up and down with eyes closed, and then open the eyes; a photograph was then taken. Four photographs were taken for each student from anterior, posterior, right, and left lateral views in the standing position using the Sony digital camera. The images of the 22 students (88 images) were then transferred to a computer.
(3) For intra-rater reliability, the researcher analyzed four images of 22 students using Surgimap software at three different time points with a 1-week interval between each time. The researcher measured the gaze angle, the craniovertebral angle (CVA), the trunk angle, the lumbar angle, the sway angle, head tilt, shoulder tilt, scapular tilt, and pelvic tilt in the anterior, posterior, and both lateral views using Surgimap Spine software. The data were stored on Surgimap databases each time

and a third person collected them immediately after analysis at each time point in an excel sheet to avoid bias of research findings.

(4) Concerning inter-rater reliability, three physiotherapists had at least 5 years of experience in their field and a Master's degree in physical therapy. The researcher gave them two training sessions on Surgimap to familiarize them with the test procedure. Each of them had to individually measure spinal postural angles of 22 students from sets of photographs on a computer using Surgimap Spine software. They measured the CVA, trunk angle, lumbar angle, shoulder tilt, scapular tilt, and pelvic tilt in anterior, posterior, and both lateral views. Each investigator stored the data on Surgimap databases and a third person collected them in an excel sheet.

Marker placement

Marker placement was based on the protocol followed in previous studies [8,12,13,15,16], as shown in Fig. 1. Reflective dots were placed on the following anatomical landmarks: glabella, seventh cervical vertebra (C7), T12 spinous process, right and left canthus, acromion, ear tragus, inferior angle of scapula, anterior superior iliac spine (ASIS), posterior superior iliac spine (PSIS), greater trochanter, and lateral malleolus.

Spinal postural angles measured by Surgimap Spine software

From right and left lateral views (as shown in Fig. 2)

(1) Gaze angle: the angle formed by a line connecting the eye canthus with the ear tragus and a horizontal line through the ear tragus [11–13].
(2) CVA: the angle formed at the intersection of the horizontal line through the spinous process of C7 and a line through the ear tragus [19,20].
(3) Trunk angle: the angle formed between the line connecting C7 to T12 and the line connecting T12 to the greater trochanter [16,21].
(4) Lumbar angle: the angle formed between the line connecting T12 to ASIS and the line connecting ASIS to the greater trochanter [16,21].
(5) Pelvic tilt from lateral view: the angle formed between the line connecting ASIS and PSIS with the horizontal line [9,12,13,15].
(6) Sway angle: the angle formed between the line connecting C7 to the greater trochanter and the line connecting the greater trochanter to the lateral malleolus [16].

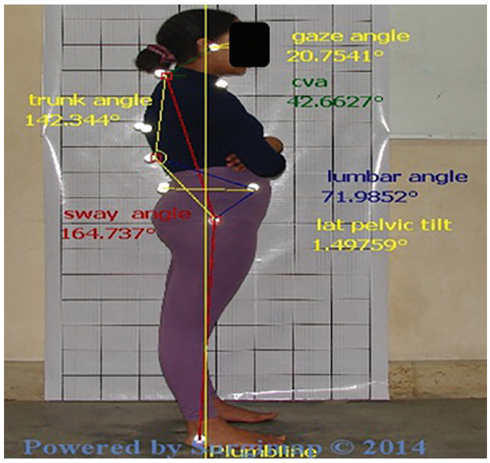
From anterior view (as shown in Fig. 3)

(1) Head tilt: the angle formed between the right and the left tragus connected with a horizontal line [9,12,13].

Figure 1

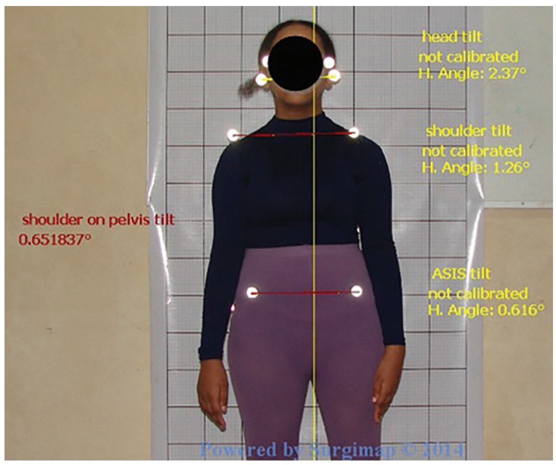
Student position with marker placement; photographs obtained from different views in standing position.

Figure 2



Angles measured from lateral view exported from Surgimap spine software.

Figure 3



Angles measured from anterior view exported from Surgimap spine software.

(2) Shoulder tilt: the angle formed when connecting the right and left acromion with a horizontal line [9,12,13,15].
(3) Pelvic tilt from the anterior view: the angle formed when connecting the right and left ASIS with a horizontal line [9,12,13,15].
(4) Shoulder on pelvis tilt: the angle formed between the line connecting the right and left acromion and the line connecting the right and left ASIS [9,12,13,15].

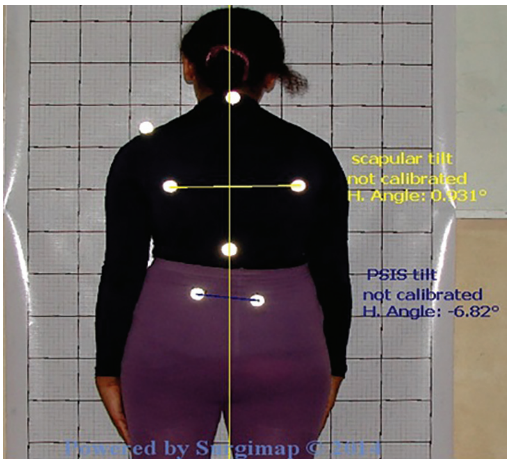
From posterior view (as shown in Fig. 4)

(1) Scapular tilt: the angle formed between the line connecting the right and left inferior angle of the scapula and the horizontal line [9,12,13,15].
(2) Pelvic tilt from posterior view: the angle formed between the line connecting the right and left PSIS and the horizontal line [9,12,13,15].

Data analysis

The Shapiro–Wilk test with SPSS (version 18; SPSS Inc., Chicago, Illinois, USA) was used to assess the normality of data and descriptive statistics such as the mean and SD of measured variables for each rater. The spinal angles were measured in degrees. Inferential statistical analysis was performed using repeated measurement analysis (RMA) within and between raters, standard of measurement error (SEM), and intraclass correlation coefficient (ICC): 0.90–0.99 for higher reliability, 0.80–0.89 for good reliability, 0.70–0.79 for fair reliability, and 0.69 and below for poor reliability. The level of significance for all tests was set at *P* value less than or equal to 0.05.

Figure 4



Angles measured from posterior view exported from Surgimap spine software.

Results

The Shapiro–Wilk test was used to ensure normal distribution of data among 22 adolescent students before determining the ICC.

Intra-rater reliability

Descriptive data in the form of mean and SD of spinal postural angles determined by the same rater at different times are illustrated in Table 1. The degree of reproducibility of Surgimap with the same rater was assessed using ICC (3, 1) (two-way mixed-type absolute agreement, single measure). As shown in Table 2, the *P* value of RMA of all spinal postural angles was more than 0.05; therefore, there was no significant difference in spinal postural angle measurements within the same rater. The ICC gave relative measures of reliability, whereas the SEM provided an absolute index of reliability [22]. The SEM equation was as follows: $\mathrm{SEM} = \mathrm{SD} \times \sqrt{(1-\mathrm{ICC})}$.SEM was low when the reliability of Surgimap was high; SEM ranged from 0.28° to 1.5°.

Inter-rater reliability

Descriptive data in the form of mean and SD of spinal postural angles determined by three raters are illustrated in Table 3. The degree of reproducibility of Surgimap among them was assessed with ICC (1, 3) (one-way random, average measure). As shown in Table 4, the *P* value of RMA of all spinal postural angles was more than 0.05; therefore, there was no significant difference in spinal postural angle measurements among the three raters. SEM was low when reliability of Surgimap was high; SEM ranged from 0.3° to 1.63°.

Discussion

The results of the current study revealed that the ICC values of intra-rater reliability and inter-rater reliability for all spinal postural angles ranged from 0.813 to 0.995 and from 0.836 to 0.992, respectively. The ICC is based on two-way mixed-type effects analysis of variance for a single measurement labelled ICC (3, 1) to assess intra-rater reliability and one-way random-type effect analysis of variance for average measure labelled ICC (1, 3) to assess inter-rater reliability.

Interpreting or defining values of ICC that the researcher considers the minimum for acceptable reliability is an arbitrary process. Hayes *et al.* [23] have suggested an ICC value of 0.4–0.75 to have good reliability and more than 0.75 to have excellent reliability. Jordan *et al.* [24] considered the lower limit of accepted reliability to be higher than 0.6. This explained that the lower limit of

Table 1 Descriptive data of angular measures measured by degree as obtained by the same rater at three different time points

Spinal postural angles	Time 1 (mean ± SD)	Time 2 (mean ± SD)	Time 3 (mean ± SD)	3 times (mean ± SD)
Gaze angle left	−10.4 ± 8.8	−10.3 ± 8.6	−10.1 ± 8.6	−10.3 ± 8.7
CVA left	48.2 ± 7.3	48.5 ± 7	48.8 ± 8	48.4 ± 7.4
Trunk angle left	164.1 ± 9.8	164.6 ± 9.4	163.6 ± 9.5	164.1 ± 9.6
Lumbar left	66.73 ± 8	66.86 ± 7.5	66.32 ± 7.8	66.6 ± 7.8
Pelvic tilt from lateral view left	−9.6 ± 5.1	−9.4 ± 5	−9.66 ± 5	−9.6 ± 5.0
Sway left	172.23 ± 4.3	172.05 ± 3.8	172.23 ± 3.9	172.2 ± 4
Head tilt angle	2.1 ± 3.2	2.01 ± 3.2	2 ± 3.4	2 ± 3.3
Shoulder tilt angle	1.35 ± 2.1	1.36 ± 1.9	1.33 ± 2.1	1.3 ± 2
Pelvic tilt from anterior view	0.38 ± 2.6	0.4 ± 2.6	0.38 ± 2.6	0.4 ± 2.6
Shoulder on pelvic tilt angle	1 ± 4.1	1 ± 4	1 ± 4.2	1 ± 4.1
Scapular tilt angle	−0.8 ± 2.2	−0.81 ± 2.3	−0.84 ± 2.5	−0.8 ± 2.3
Pelvic tilt from posterior view	0.27 ± 2	0.13 ± 1.9	0.25 ± 2.76	0.2 ± 2.2
Gaze angle right	−12.5 ± 10.56	−12.6 ± 10.33	−12.6 ± 10.43	−12.6 ± 10.4
CVA right	51.7 ± 7.4	51.7 ± 7.6	52.1 ± 7.6	51.8 ± 7.5
Trunk angle right	166.3 ± 8	166.9 ± 8	166.4 ± 8	166.5 ± 8.0
Lumbar angler right	67.5 ± 7.2	68.1 ± 7.2	67.36 ± 7.3	67.7 ± 7.2
Pelvic tilt from lateral view right	−8.5 ± 6.8	−8.7 ± 6.7	−8.8 ± 6.5	−8.7 ± 6.7
Sway angle right	173.05 ± 4.8	173.05 ± 4.9	173 ± 4.9	173 ± 4.9

Negative value means tilt to right in scapular tilt, pelvic tilt from posterior view, anterior pelvic tilt in pelvic tilt from lateral view, and flexion in head in gaze angle; positive value means tilt to right in head tilt, shoulder tilt, pelvic tilt from anterior view, shoulder on pelvis tilt, pelvic tilt from posterior view tilt to left in scapular tilt, pelvic tilt from posterior view, posterior pelvic tilt in pelvic tilt from lateral view, and extension in head in gaze angle; CVA, craniovertebral angle; SD, standard deviation.

Table 2 Repeated measurement analysis, standard of measurement error, intraclass correlation coefficient, and level of reliability of the angular measures obtained by the same rater

Spinal postural angles	SEM	ICC	Level of reliability	RMA (*P* value)	Significance
Head tilt	0.51°	0.976	Excellent	0.626	NS
Shoulder tilt	0.37°	0.967	Excellent	0.95	NS
Pelvic tilt from anterior view	0.28°	0.988	Excellent	0.946	NS
Shoulder on pelvis tilt	0.66°	0.974	Excellent	0.998	NS
Scapular tilt	0.62°	0.929	Excellent	0.961	NS
Pelvic tilt from posterior view	0.96°	0.813	Very good	0.875	NS
Gaze angle right	0.99°	0.991	Excellent	0.478	NS
CVA right	1.30°	0.97	Excellent	0.08	NS
Trunk angle right	1.50°	0.965	Excellent	0.063	NS
Lumbar angle right	1.07°	0.978	Excellent	0.272	NS
Pelvic tilt from right lateral view	0.76°	0.987	Excellent	0.331	NS
Sway angle right	0.75°	0.976	Excellent	0.551	NS
Gaze angle left	0.61°	0.995	Excellent	0.897	NS
CVA left	1.00°	0.982	Excellent	0.27	NS
Trunk angle left	1.05°	0.988	Excellent	0.56	NS
Lumbar angle left	1.39°	0.968	Excellent	0.142	NS
Pelvic tilt from left lateral view	0.45°	0.992	Excellent	0.31	NS
Sway angle left	0.38°	0.991	Excellent	0.76	NS

CVA, craniovertebral angle; ICC, intraclass correlation coefficient; RMA, repeated measurement analysis; SEM, standard of measurement error.

acceptable ICC value was dependent on the purpose of the study according to the authors' point of view. Our current study used the previously reported ICC values for reliability: 0.90–0.99 for high reliability, 0.80–0.89 for good reliability, 0.70–0.79 for fair reliability, and 0.69 and below for poor reliability [25].

The present study demonstrated that intra-rater reliability was higher than inter-rater reliability for spinal postural angles, which agreed with previous literature [23–25]. The higher intra-rater reliability is believed to be due to the fixed position for each participant and the same rater for each measurement. The inter-rater reliability for sagittal plane is better than that for frontal plane, which can be attributed to both the high accuracy and the precision of photographic analysis utilized.

There is an agreement in intra-rater reliability of the Surgimap spine tool for spinal measurements between the present study and that of Wu *et al.* [14], although the present study measured spinal angles from photographic analysis, whereas Wu *et al.* [14] measured spinal angles

Table 3 Descriptive data of angular measures measured by degree as obtained by three raters

Spinal postural angles	Rater 1 (mean ± SD)	Rater 2 (mean ± SD)	Rater 3 (mean ± SD)	Raters (mean ± SD)
Shoulder tilt angle	1.16 ± 2.1	1.02 ± 2.1	1.3 ± 2.1	1.16 ± 2.1
Pelvic tilt from anterior view right	0.5 ± 2.7	0.3 ± 2.8	0.4 ± 2.7	0.4 ± 2.7
Scapular tilt angle	0.6 ± 2.9	0.6 ± 2.3	0.8 ± 2.5	0.67 ± 2.6
Pelvic tilt from posterior view	−0.005 ± 3	−0.4 ± 2.8	−0.1 ± 2.8	−0.17 ± 2.9
Shoulder on pelvis tilt	0.4 ± 3.5	1 ± 4.2	1 ± 4.2	0.8 ± 4.0
CVA right	50.6 ± 8.2	50.7 ± 8.1	51.5 ± 8.5	50.7 ± 8.3
Trunk angle right	164.8 ± 7.6	163.7 ± 9.6	165.4 ± 8.2	164.6 ± 8.5
Lumbar angle right	67.6 ± 7.8	67.3 ± 7.5	67.14 ± 7.3	67.4 ± 7.5
Pelvic tilt from lateral view	−8.7 ± 7	−9 ± 6.5	−8.8 ± 6.5	−8.8 ± 6.7
CVA left	48.4 ± 8.4	48.7 ± 7.6	48.8 ± 8.3	48.63 ± 8.1
Trunk angle left	162.3 ± 10.3	164 ± 10	163.1 ± 10.4	163.1 ± 10.2
Lumbar angle left	67.5 ± 9	67.3 ± 8.6	66.8 ± 9	67.2 ± 8.9
Pelvic tilt from lateral view left	−9.7 ± 5.2	−9.1 ± 4.5	−9.7 ± 5	−9.5 ± 4.9

Negative value means tilt to right in scapular tilt, pelvic tilt from posterior view, anterior pelvic tilt in pelvic tilt from lateral view, and flexion in head in gaze angle; Positive value means tilt to right in shoulder tilt, pelvic tilt from anterior view, shoulder on pelvis tilt pelvic tilt from posterior view tilt to left in scapular tilt, pelvic tilt from posterior view, posterior pelvic tilt in pelvic tilt from lateral view; CVA, craniovertebral angle.

Table 4 Repeated measurement analysis, intraclass correlation coefficient, and level of reliability of the angular measures obtained by three raters

Spinal postural angles	SEM	ICC	Level of reliability	RMA (*P* value)	Significance
Shoulder tilt	0.74°	0.875	Very good	0.69	NS
Pelvic tilt from anterior view	0.30°	0.988	Excellent	0.292	NS
scapular tilt	0.60°	0.946	Excellent	0.588	NS
Pelvic tilt from posterior view	1.16°	0.836	Very good	0.28	NS
Shoulder on pelvis tilt	1.36°	0.883	Very good	0.603	NS
CVA right	0.83°	0.99	Excellent	0.054	NS
Trunk angle right	1.63°	0.963	Excellent	0.142	NS
Lumbar angle right	0.86°	0.987	Excellent	0.542	NS
Pelvic tilt from right lateral view	0.87°	0.983	Excellent	0.647	NS
CVA left	0.72°	0.992	Excellent	0.5	NS
Trunk angle left	1.48°	0.979	Excellent	0.09	NS
Lumbar angle left	0.93°	0.989	Excellent	0.256	NS
Pelvic tilt from left lateral view	0.60°	0.985	Excellent	0.118	NS

CVA, craniovertebral angle; ICC, intraclass correlation coefficient; SEM, standard of measurement error.

from radiographic film. The intra-rater reliability had excellent ICC above 0.9, except for pelvic tilt from posterior ICC, which was very good at 0.813, whereas Wu *et al.* [14] classified excellent ICC above 0.75.

The results of the inter-rater reliability of the current study revealed that sagittal measurement ICC was excellent at above 0.9, and was better than coronal view angles, which showed very good ICC values in scapular tilt (0.836), shoulder on pelvic tilt (0.883), and shoulder tilt (0.875). This interpretation agreed with the inter-rater reliability study of Surgimap conducted by Wu *et al.* [14] in which they found inter-rater reliability of spinal angles for sagittal plane to be better than that of coronal plane.

A few studies have investigated the reliability of spinal postural angle measurements using software [12,13,16,18,25–30]. Some of them did not report ICC for reliability [25–29], and others reported low ICC values and poor posture reliability [25,27,28].

According to Perry *et al.* [16], computerized photographic analysis of standing sagittal posture of adolescents has fair reliability, with excellent ICC for sway, lumbar, and thoracic angles. Their ICC results are in agreement with the ICC results of the current study; however, the SEM of raters for postural angle measurements on Surgimap is lower than the SEM in the study of Perry *et al.* [16]. The results of the present study are in agreement with those of Fortin *et al.* [12], who reported that the gaze angle, CVA, and pelvic tilt from lateral view had excellent reliability, whereas the pelvic tilt from anterior and posterior view varied from very good to excellent reliability.

The inter-rater reliability of angles reported by Souza *et al.* [13] from anterior and posterior view agreed with the results of the current study. In this respect, Van Maanen *et al.* [31] concluded that photographic analysis provided reliable data and consistent measures [31]. However, some studies disagreed with the current study and reported that reliability of computerized photographic analysis was poor to moderate. Dunk *et al.* [25,28]

studied the reproducibility of the photographic method and reported low ICC with poor intertester and intratester reliability. Iunes *et al.* [32] concluded that reliability of spinal angles measured in sagittal view was less than that of spinal angles measured in frontal one; this disagrees with the current study [32]. This study was limited by placement of reflective dots over fitted tight clothes because it is not acceptable in Egyptian culture to ask women to wear shorts and a vest.

Conclusion

Surgimap Spine software has high intra-rater and inter-rater reliability for measuring spinal postural angles of adolescents from digital photos. Therapists can use it in many forms of physical therapy interventions as an easy, clinical, objective two-dimensional assessment for measuring spinal postural angles.

Declaration of patient consent

The authors certify that they have obtained all appropriate patient consent forms. In the form the patient(s) has/have given his/her/their consent for his/her/their images and other clinical information to be reported in the journal. The patients understand that their names and initials will not be published and due efforts will be made to conceal their identity, but anonymity cannot be guaranteed.

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Nil.

Conflicts of interest

There are no conflicts of interest.

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