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Biophotogrammetry: reliability of measurements obtained with a posture assessment software (SAPO)

Biofotogrametria confiabilidade das medidas do protocolo do software para avaliação postural (SAPO)

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Abstract – Photogrammetry is a valuable tool for the diagnosis and measurement of postural changes, but the lack of standardization of anatomical references and angular measures impairs the comparison between studies and compromises the reliability of the results. The objective of this study was to evaluate the inter- and intraexaminer reliability of angular measures proposed by the SAPO posture assessment software (v. 0.68). Twenty-four subjects were photographed in the standing position according to the recommendations of the SAPO software. Three examiners (A, B and C) experienced in the use of the software analyzed the images and repeated the analysis after 7 days. Variance, intraclass correlation coefficient (ICC), and t-test adopting a level of significance of 5% were applied. With respect to interexaminer reliability among the 20 angles measured, two were classified as unacceptable (A13: ICC = 0.623; A14: ICC = 0.568), one as acceptable (A19: ICC = 0.743), one as very good (A20: ICC = 0.860), and 16 as excellent (ICC ≥ 0.90). Evaluation of repeatability of the method by the same examiner showed that two angles measured by examiner A differed significantly between the two measurements (A11: p = 0.015; A12: p = 0.026), as did two angles measured by examiner B (A2: p = 0.019; A12: p = 0.015) and one angle measured by examiner C (A16, p = 0.011). In conclusion, comparison between different examiners showed that the angles proposed by the SAPO protocol are reliable for the measurement of body segments.
Key words: Evaluation of research programs and tool; Photogrammetry; Posture; Reproducibility.

Resumo – *A fotogrametria vem sendo utilizada como um valioso recurso diagnóstico para a verificação e mensuração de alterações posturais, porém a ausência de padronização das referências anatômicas, dos ângulos obtidos entre estas e sua significância dificulta a comparação entre estudos e a confiabilidade dos resultados encontrados. O objetivo do estudo foi verificar a confiabilidade inter e intra-examinadores das medidas angulares propostas pelo software de avaliação postural SAPO v. 0.68. Participaram do estudo 24 sujeitos, os quais foram fotografados na postura em pé, seguindo as recomendações do SAPO. Três avaliadores (A, B e C) experientes no uso do programa analisaram as imagens, repetindo essa análise sete dias após. A variância, o coeficiente de correlação intraclasse (ICC) e teste T com nível significância de 5% foram aplicados. Resultados indicaram que na confiabilidade interexaminadores dos 20 ângulos mensurados, dois foram classificados como não aceitáveis (A13: ICC=0,623 e A14: ICC=0,568), um como aceitável (A19: ICC=0,743), um como muito bom (A20: ICC=0,860) e 16 como excelentes (ICC ≥ 0,90). Na avaliação da repetibilidade do método, por um mesmo avaliador, dois ângulos mensurados pelo examinador A foram significativamente diferentes em duas medidas (A11:p=0,015; A12:p=0,026); também dois ângulos pelo examinador B (A2:p=0,019; A12:p=0,015) e um ângulo pelo examinador C (A16;p=0,011). Concluíu-se que os ângulos propostos pelo protocolo SAPO mostraram-se confiáveis após avaliação entre diferentes examinadores para mensurar os segmentos corporais*
Palavras-chave: *Fotogrametria; Reprodutibilidade dos testes; Postura; Avaliação de programas e instrumentos de pesquisa.*

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INTRODUCTION

Body posture is defined as the balanced arrangement of body structures and is determined by the relative position of body segments at a given time[1-3]. In the ideal postural alignment, it is expected that the muscles, joints and their underlying structures are in a state of dynamic balance that causes minimum stress and overload and permits the most efficient performance of the locomotor apparatus[1]. However, although consensus exists regarding good posture and its implications, body posture is a complex phenomenon that is difficult to measure[4].

The evaluation of body posture in the standing position has been widely used over several decades in both clinical practice and scientific studies as a diagnostic tool and for the planning and monitoring of physiotherapeutic treatment[4-6]. Different methods such as digital photogrammetry are available for the biomechanical analysis of posture in a static position[7-14]. The American Society of Photogrammetry defines photogrammetry as "the art, science and technology of obtaining reliable information about physical objects and the environment through the processes of recording, measuring and interpreting photographic images and patterns of radiant electromagnetic energy and other sources". According to Ribeiro et al[15], photogrammetry is a relatively simple, easily applied and objective technique. Its low cost, easy photo-interpretation, high precision, and reproducibility of the results, as well as the possibility to store and access records, are advantages that explain the wide application of this method. Photogrammetry is also a valuable tool for the monitoring of postural changes over time since it permits to capture subtle changes and to correlate different parts of the body that are difficult to measure[16]. However, the repeatability of the technique for this temporal evaluation, as well as in scientific studies, should be guaranteed by a series of methodological parameters[7].

The combination of digital photography and softwares that permit the measurement of angles and horizontal and vertical distances such as Corel Draw and AutoCAD, or programs specifically developed for posture assessment such as the Alcimagem and SAPO (Posture Assessment Software) programs has led to the widespread use of photogrammetry. The SAPO software is a computer program developed by researchers of the University of São Paulo that is freely available on the internet. The software is based on the digitization of images and comprises different functions such as image calibration, zoom, marking of anatomical landmarks, and measurement of distances and body angles[17,18]. The SAPO protocol is a proposal of landmarks and measures that can be used for postural assessment. The choice of these landmarks was based on clinical relevance, scientific evidence, methodological viability, and applicability[18].

Angular measurements in the human body are used for the investigation of joint dysfunction and are an important parameter for physiotherapeutic monitoring, motivation and treatment compliance of the patient, quantification of disorders, evaluation of the efficacy of interventions, and fabrication of orthoses [19]. However, the lack of standardization of anatomical landmarks and angular measurements used in photogrammetry studies impairs the comparison between investigations and the validation of the results found.

Despite the increasing number of studies using photogrammetry[11,13,16,20], there is no standardization of the angles used for the determination of certain postural changes. In addition, only few studies have evaluated the reliability and reproducibility of the posture assessment programs used. Therefore, the objective of the present study was to evaluate the inter- and intraobserver reliability of the angular measures defined in the protocol of the SAPO v. 0.68 software.

METHODOLOGICAL PROCEDURES

Subjects

Twenty-four subjects ranging in age from 20 to 35 years (mean: 25 years) were randomly selected from a posture assessment database of patients with temporomandibular disorders. Excluded were amputated patients, patients with neurological problems, systemic diseases, congenital clubfoot, lower limb fracture and balance disorders, and patients undergoing physiotherapeutic treatment.

The study was approved by the Ethics Committee of the Federal University of Santa Maria (protocol 0048.0.243.000-08). The volunteers signed a formal consent form to participate in the study according to Resolution 196/96 of the National Health Council.

Photographic recording

The photographs were taken according to the recommendations of the SAPO software. For this purpose, a plumb line was attached to the ceiling and two styrofoam balls were fixed to the wire 1 meter apart for subsequent image calibration. The subject was positioned in such a way that he and the plumb line were on the same plane perpendicular to the axis of the digital camera (Sony, DSC--S40, resolution of 4.1 megapixels, 3.0x zoom). The camera was positioned at a distance of 3 meters and supported on a tripod at a height of about half the height of the subject.

The subject was photographed in the anterior, left lateral and posterior views. According to the SAPO protocol, the bony landmarks, which served as guides for calculation of the angular measures, were marked with styrofoam balls at the anatomical landmarks illustrated in Figure 1. The angles used by the protocol are shown in Picture 1. The marking of anatomical landmarks and photographic recording were always performed by two trained examiners.

Photogrammetry

After acquisition of the photographs, the images were transferred to a computer and copies were given to three examiners, who were experienced in the use of the SAPO program, for photogrammetric analysis of the body posture of all subjects. The instructions were to calibrate the image, mark the landmarks used by the protocol, create a report of analysis, and export it to Excel. This procedure was repeated after one week for the evaluation of repeatability and reliability. The angles between the anatomical landmarks determined by the protocol were quantified automatically according to software conventions.

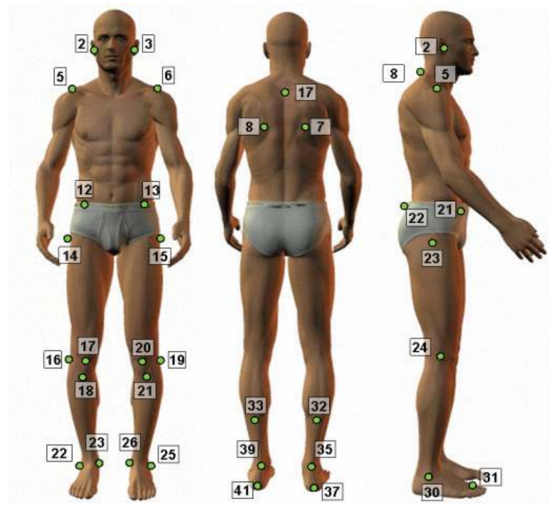

Figure 1. Bony landmarks used by the protocol of the SAPO software. Anterior view: 2, 3 right and left tragus; 5, 6 right and left acromion; 12, 13 right and left anterior superior iliac spine; 14, 15 right and left greater trochanter; 16, 19 lateral projection of the right and left knee joint line; 17, 20 center of the right and left patella; 18, 21 right and left tibial tuberosity; 22, 25 lateral malleoli; 23, 26 medial malleoli. Posterior view: 7, 8 inferior angle of the right and left scapula; 17 third thoracic vertebra; 32, 33 midpoint of the leg; 35, 39 intermalleolar line; 37, 41 bilateral calcaneal tendon. Lateral view: 2 tragus; 8 seventh cervical vertebra; 5 acromion; 21 anterior superior iliac spine; 22 posterior superior iliac spine; 23 greater trochanter; 24 projection of the knee joint line; 30 lateral malleolus; 31 region between the second and third metatarsus.

Data analysis

The SPSS 17.0 and SAS 9.1 programs were used for statistical analysis. The normality of the angular data was tested by the Shapiro-Wilks test. One-way analysis of variance (ANOVA) was then applied to

Picture 1. Angles used by the protocol of the SAPO software.

Anterior view	Head	**A1** – Horizontal alignment of the head: 2-3 and horizontal.
	Trunk	**A2** – Horizontal alignment of the acromia: 5-6 and horizontal. **A3** – Horizontal alignment of the anterior superior iliac spines: 12-13 **A4** – Angle between the two acromia and the two anterior superior iliac spines: 5-6; 12-13.
	Lower limbs	**A5** – Frontal angle of the right lower limb: 14-16-22 (outside angle). **A6** – Frontal angle of the left lower limb: 15-19-25 (outside angle). **A7** – Difference in lower limb length: D (12;23)-D (13;26). **A8 –** Horizontal alignment of the tibial tuberosities: 18-21 and horizontal. **A9** – Right Q angle: angle between 12-17 and 17-18. **A10** – Left Q angle: angle between 13-20 and 20-21.
Left lateral view	Head	**A11** – Horizontal alignment of the head (C7): 2-8 and horizontal. **A12** – Vertical alignment of the head (acromion): 5-2 and vertical.
	Trunk	**A13** – Vertical alignment of the trunk: 5-23 and vertical. **A14** – Hip angle (trunk and lower limb): 5-23-30. **A15** – Vertical alignment of the body: 5-30 and vertical. **A16** – Horizontal alignment of the pelvis: 21-22 and horizontal.
	Lower limbs	**A17** – Knee angle: 23-24-30. **A18** – Angle of ankle: 24-30 and horizontal.
Posterior view	Trunk	Horizontal asymmetry of the scapula in relation to T3.
	Lower limbs	**A19** – Leg/right hindfoot angle: 32-35-37. **A20** – Leg/left hindfoot angle: 33-39-41.

the set of data of the three examiners to evaluate differences between variances, and the Tukey multiple comparisons post-test was used to determine which means were significantly different.

Interobserver reproducibility, i.e., the fact that the same result is obtained for the same angle provides by different examiner, was evaluated using the intraclass correlation coefficient (ICC). An ICC higher than 0.7 is commonly used in reliability studies as the threshold to indicate a "sufficiently reproducible" method. An ICC of 1 indicates identical angular measures in the comparisons performed. ICC values lower than 0.70 are classified as not acceptable, values of 0.71 to 0.79 as acceptable, values of 0.80 to 0.89 as very good, and values higher than 0.90 as excellent[4,21,22].

Intraobserver repeatability, which is defined as the ability of an examiner to provide the same result for the same angle on different occasions, was evaluated based on the degree of systematic difference between pairwise measurements (the same examiner at two distinct time points) using the paired *t*-test. A level of significance of 5% was adopted in this study.

Table 1. Analysis of variance (ANOVA), intraclass correlation coefficient and level of reliability of the angular measures obtained by examiners A, B and C (reproducibility) in the anterior, lateral and posterior views.

View	Angle	ANOVA (p)	ICC	Level of reliability
Anterior	A1	0.514	0.949	Excellent
	A2	0.826	0.987	Excellent
	A3	0.993	0.957	Excellent
	A4	0.993	0.982	Excellent
	A5	0.985	0.987	Excellent
	A6	0.668	0.992	Excellent
	A7	0.893	0.958	Excellent
	A8	0.963	0.911	Excellent
	A9	0.904	0.969	Excellent
	A10	0.949	0.982	Excellent
Lateral	A11	0.992	0.987	Excellent
	A12	0.992	0.995	Excellent
	A13	0.074	0.623	Not acceptable
	A14	0.119	0.568	Not acceptable
	A15	0.974	0.993	Excellent
	A16	0.906	0.942	Excellent
	A17	0.431	0.906	Excellent
	A18	0.974	0.995	Excellent
Posterior	A19	0.649	0.743	Acceptable
	A20	0.897	0.860	Very good
	%	0.536	0.964	Excellent

n=24. ICC: intraclass correlation coefficient; p: level of significance.

RESULTS

Table 1 shows the results of ANOVA obtained for the angles measured by the three examiners and the interobserver ICC. The angular measures obtained by the three examiners during photogrammetric analysis by the SAPO protocol in the two situations proposed are shown in Table 2. This table also shows the systematic differences between the two measurements obtained by the same examiner (paired *t*-test).

ANOVA revealed no significant differences between the measurements obtained by the three examiners. Similarly, the level of reliability and reproducibility of the angles were confirmed by the ICC: two of the 20 angles measured were classified as not acceptable (A13 and A14), one as acceptable (A19), one as very good (A20), and 16 as excellent.

Evaluation of the repeatability of the method performed by the same examiner on different days showed that two angles measured by examiner A were significantly different (A11, A12), as were two angles measured by examiner B (A2, A12), and one angle measured by examiner C (A16).

DISCUSSION

A reliable diagnostic procedure is defined as a method in which repeated measures of the same variable always yield the same result within acceptable variations. Reliability is related to the precision of the procedure, which should be consistent and stable and present a minimum systematic or random error. Measurement errors are due to variations between observers, assessment tools or the variable to be measured. If reliability is low, the validity of the method cannot be determined[23].

The reliability of most angles described in this study has not been evaluated, although they are widely used in scientific studies[11,16,20]. In this respect, using intra- and interobserver assessment, Zonnenberg et al.[8] found that photogrammetry provides reliable data and consistent measures. Iunes et al.[4] evaluated the intra- and interobserver reliability of 22 angles measured with the Alcimagem software. Four of these angles are also used in the SAPO protocol (A3, A9, A10, and A11). In the present study, excellent reliability was obtained for four angles upon interobserver assessment, and intraobserver evaluation revealed only one angle (A11) that differed between the two measurements performed by examiner A. In the study of Iunes et al.[4], angles A3, A9 and A10 showed excellent interobserver reliability and angle A11 very good reliability. Intraobserver evaluation showed that angles A3 and A9 did not reach acceptable levels, whereas the reliability of angles A10 and A11 was

Table 2. Mean angular values, standard deviation and result of the paired *t*-test for angles obtained by the same examiner (repeatability) in the anterior, lateral and posterior views.

View	Angle	A					B					C				
		$\bar{X}$ 1	SD	$\bar{X}$ 2	SD	p	$\bar{X}$ 1	SD	$\bar{X}$ 2	SD	P	$\bar{X}$ 1	SD	$\bar{X}$ 2	SD	p
Anterior	A1	0.99	2.24	1.02	1.91	0.402	0.35	1.93	0.32	1.89	0.372	0.30	2.10	0.25	1.96	0.313
	A2	-0.58	1.85	0.27	1.91	0.220	-0.41	2.17	0.05	2.22	0.019*	-0.31	2.17	0.28	2.02	1.717
	A3	-0.78	1.36	-0.56	1.37	0.481	-0.57	1.68	-0.42	1.63	0.473	-0.59	1.44	-0.28	1.52	0.282
	A4	-1.86	2.30	-0.82	2.49	0.315	-1.76	2.83	-0.46	2.88	0.211	-1.93	2.77	-0.54	2.71	0.287
	A5	-1.91	3.15	-1.91	3.05	0.318	-1.85	3.44	-1.75	3.11	0.279	-1.96	3.22	-1.98	3.16	0.356
	A6	0.02	3.10	-1.99	2.96	0.200	0.05	3.11	-1.74	2.85	0.063	-0.23	3.00	-1.95	3.07	0.398
	A7	0.01	1.06	0.00	0.87	0.453	-0.11	1.24	0.14	1.49	0.206	-0.23	1.08	-0.22	1.04	0.370
	A8	0.20	1.97	-0.11	2.48	0.160	0.16	2.14	-0.16	2.21	0.471	0.30	2.39	-0.30	2.11	0.350
	A9	27.29	8.63	24.05	8.65	0.152	26.14	9.07	23.32	9.03	0.067	26.43	8.70	23.52	9.15	0.080
	A10	23.50	10.31	27.43	8.74	0.395	22.79	9.74	26.13	9.57	0.322	23.03	9.52	26.45	9.83	0.366
Lateral	A11	51.51	5.25	52.08	5.83	0.015*	50.72	6.03	50.70	5.66	0.418	50.79	5.59	50.78	5.47	0.459
	A12	15.20	7.50	14.76	8.07	0.026*	15.86	6.98	16.14	7.00	0.015*	15.87	6.67	15.91	6.72	0.353
	A13	-0.95	5.00	-1.53	4.13	0.126	-2.39	2.50	-2.41	2.37	0.287	-2.43	2.39	-2.39	2.41	0.086
	A14	-6.51	8.60	-7.55	6.35	0.066	-8.56	4.10	-8.58	4.14	0.287	-8.66	4.16	-8.63	4.09	0.432
	A15	1.13	0.99	1.15	0.97	0.291	1.07	0.96	1.06	0.94	0.500	1.10	0.92	1.13	0.90	0.060
	A16	-6.72	6.36	-6.73	4.88	0.438	-7.43	5.14	-7.48	5.16	0.325	-7.51	5.11	-7.73	5.26	0.011*
	A17	-4.49	6.44	-5.12	4.93	0.060	-5.62	4.36	-5.62	4.68	0.419	-5.51	4.62	-5.49	4.43	0.438
	A18	89.26	2.52	89.22	2.65	0.333	89.44	2.42	89.42	2.57	0.310	89.30	2.53	89.25	2.49	0.173
Posterior	A19	18.80	12.15	18.60	11.17	0.300	21.05	5.41	20.80	6.57	0.298	20.87	7.17	21.18	7.01	0.215
	A20	18.32	11.49	18.15	10.79	0.352	19.46	7.92	19.96	7.49	0.166	19.70	7.36	19.69	7.63	0.382
	%	10.65	17.33	10.65	15.30	0.444	5.28	18.71	5.74	19.78	0.332	8.46	19.23	10.28	18.59	0.112

n=24. A, B, C: examiners; SD: standard deviation; $\bar{X}$ 1: first measurement; $\bar{X}$ 2: second measurement after 7 days. *t*-test: *p<0,05.

acceptable. Braz, Goes and Carvalho[17] demonstrated the reliability and intra- and interobserver validity of the SAPO software, but the authors analyzed 15 different angular measures obtained with goniometers arranged in a panel. Sacco et al.[12] analyzed lower limb angles with the Corel Draw v. 12 and SAPO v. 0.63 programs and compared them to those obtained with a goniometer. The authors found the results obtained with the different methods to be reliable, except for angle Q which presented similar results with the photogrammetry tools but different values when measured with a goniometer. In the present study, angle Q (A9 and A10) showed an excellent level of inter- and intraobserver reliability, in agreement with the study of Caylor, Fites and Worrel[24].

The results of the inter- and intraobserver evaluation showed that most of the angular measurements of the SAPO protocol are reliable. Among the angles that showed non-acceptable ICC upon interobserver evaluation (A13 and A14) and non-repeatable intraobserver values (A2, A11, A12, and A16), five were obtained in the sagittal view. Iunes et al.[4] also observed that angular measurements made in the sagittal view were less reliable than those measured in the frontal view. Angles A13 and A14 are traced from the acromion, trochanter and vertical reference line and lateral malleolus, respectively. The lower reproducibility of these angles might have been due to subjectivity of the examiners or to occasional factors, suggesting caution when using these angles for lateral posture assessment. With respect to angles A11, A12 and A16 that consider the tragus, seventh cervical vertebra, acromion and iliac spines, variations in the deep views exist when localizing anatomical landmarks recorded on the photograph. This fact may explain the lack of repeatability between measurements. However, Dunk et al.[20] found the sagittal view to best reflect the clinical evolution of postural changes since in this view the angular measurements differ from zero, whereas in the frontal view they tend to approach zero (symmetry). The authors also emphasized that the results of photogrammetry are reliable when anatomical landmarks are used instead of an external vertical reference.

The reproducibility of the Alcimagem software investigated by Iunes et al.[4] using to photographs of the same subject was classified as unsatisfactory for 15 of the 22 angles analyzed. The authors explained these findings by the error inherent to the experimental procedure since the subjects were photographed at distinct time points. Analysis of the angular measurements of the SAPO protocol showed that four of the 20 angles were not reproducible in two measurements of the same examiner using the same photograph. One of these angles (A12) could not be reproduced by two of the three examiners (examiners A and B). Since the error inherent to the placement of the markers, i.e., the position of the apparatus, was controlled since the three examiners evaluated the same record, this difference may be explained by the low resolution of the photograph and/or by the interference of subjective factors of the examiner at the time of analysis. In addition, the small number of subjects may also have influenced the results.

Dunk et al.[25] studied the reliability of photogrammetry in determining a stable measure of individual posture. A wide coefficient of variation and low ICC indicated the poor repeatability of the method for the evaluation of subjects on the same day and on different days. The authors reported that the use of vertical references for the calculation of angles is subject to errors due to body variations in the standing position. This brings into question the validity of photogrammetry as a tool to monitor postural changes.

It should be emphasized that photogrammetry provides a two-dimensional quantification of the body and that the true postural change may be hidden by the plane evaluated. Thus, this method should not replace, but rather complement, clinical examination. The advantages of the protocol of the SAPO software are its practicality and that it permits the standardization of measures and application of photogrammetry, and the consequent comparison between studies. Its disadvantages are related to lateral postural assessment since postural changes, especially in relation to the spinal curves, are better visualized in this view and the current SAPO protocol does not evaluate these curves. However, this does not compromise the SAPO program, but suggests further analysis and inclusion of additional angular measurements obtained in the sagittal view in the protocol.

The reproducibility of this evaluation at distinct time points is still a gap in photogrammetry studies and this was not the objective of the present investigation. Further studies are needed to analyze angular measurements in subjects whose anatomical landmarks were marked on different days.

CONCLUSION

The present results showed that most of the angular measurements proposed for the quantification of postural asymmetries by the protocol of the SAPO software are satisfactorily reliable when evaluated by different examiners using the same photographic recording. Interobserver assessment revealed that two angles in the sagittal view did not reach an acceptable level of reliability. In contrast, evaluation of intraobserver reliability showed that two angles measured by examiner A differed significantly between the two measurements, as did two angles measured by examiner B, and one angle measured by examiner C. Thus, greater caution is needed when using these angles obtained in the sagittal view.

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