CLINICAL SCIENCE

POSTURAL ASSESSMENT SOFTWARE (PAS/SAPO): VALIDATION AND RELIABILIY

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OBJECTIVE: This study was designed to estimate the accuracy of the postural assessment software (PAS/SAPO) for measurement of corporal angles and distances as well as the inter- and intra-rater reliabilities.
INTRODUCTION: Postural assessment software was developed as a subsidiary tool for postural assessment. It is easy to use and available in the public domain. Nonetheless, validation studies are lacking.
METHODS: The study sample consisted of 88 pictures from 22 subjects, and each subject was assessed twice (1 week interval) by 5 blinded raters. Inter- and intra-rater reliabilities were estimated using the intraclass correlation coefficient. To estimate the accuracy of the software, an inanimate object was marked with hallmarks using pre-established parameters. Pictures of the object were rated, and values were checked against the known parameters.
RESULTS: Inter-rater reliability was excellent for 41% of the variables and very good for 35%. Ten percent of the variables had acceptable reliability, and 14% were defined as non-acceptable. For intra-rater reliability, 44.8% of the measurements were considered to be excellent, 23.5% were very good, 12.4% were acceptable and 19.3% were considered non-acceptable. Angular measurements had a mean error analisys of 0.11°, and the mean error analisys for distance was 1.8 mm.
DISCUSSION: Unacceptable intraclass correlation coefficient values typically used the vertical line as a reference, and this may have increased the inaccuracy of the estimates. Increased accuracies were obtained by younger raters with more sophisticated computer skills, suggesting that past experience influenced results.
CONCLUSION: The postural assessment software was accurate for measuring corporal angles and distances and should be considered as a reliable tool for postural assessment.

KEYWORDS: Postural assessment; Software; Validation; Reliability; Posture.

INTRODUCTION

Posture has been defined as the alignment of body segments at a particular time.[1] Posture is an important health indicator,[2] and postural abnormalities are associated with a large number of disorders, including pain syndromes,[3-5] generalized or regional musculoskeletal disorders,[6-7] and respiratory dysfunctions.[8] Postural abnormalities have also been associated with an increased risk of falls in the elderly[9-11] and cervical pain.[12] Postural realignment is a goal often sought by physicians, dentists, and physiotherapists.[13-16]

In clinical practice, posture assessments are conducted as part of the physical exam.[17] When conducted in the clinic, postural assessments are often subjective,[18] and abnormalities are visually inspected. This form of qualitative assessment has low sensitivity as well as low intra- and inter-rater reliabilities. It is largely dependent on past experiences and subjective interpretations. Accordingly, standardized and validated instruments are required for more precise and systematic assessments.[19]

Posture may be qualitatively and quantitatively assessed through the rigorous interpretation of photographic pictures,

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which may also be used to monitor treatment outcomes. Several independent companies have developed postural assessment software, which often consists of digital markers for photographic images and tools for measuring several variables.

Quantitative measurements allow physicians and researchers not only to make an accurate assessment of postural changes but also to monitor improvement. Nevertheless, studies are necessary to validate and estimate the reliability of each of these systems. Although partial validations have been conducted for several of these tools, most of these studies have only assessed specific regions of the body (not global posture assessments) or only examined small samples.[20-26]

Accordingly, comprehensive validation studies are necessary. Postural assessment software (PAS/SAPO) has been developed to assist posture assessment from digitalized pictures,[27] and this software is available in the public domain (http://sapo.incubadora.fapesp.br). PAS allows the measurement of distances and angles. The software is easy to use, and it is accompanied by scientific tutorials. We envision that PAS will be broadly used in both clinical practice and research.

The present study assessed the accuracy of PAS/SAPO for measuring angles and distances and also evaluated inter-rater (repeatability) and intra-rater (reproducibility) reliabilities. We hypothesized that PAS would be an accurate tool for postural assessments.

METHODS

Overview and acquisition of digital images

The study sample consisted of 22 subjects. In total, 88 pictures were taken from the anterior and posterior directions as well as from both sides. The sample size and number of pictures were chosen based on the relevant literature.[20, 21,26,28,29] Pictures were taken with subjects in the standing position, and the subjects were dressed to allow the visualization of 32 anatomic points (including 14 bilateral points). Points are presented in Figure 1.

To mark the points, styrofoam balls (15 mm circumference) were positioned using double-faced adhesive tape. Cameras (Sony Cyber-shot DSC-P93) were placed on tripods (height of 1.63 meters) with angles of 90 degrees (same distance). The first camera was placed 1.9 meters from the subject, and the other camera was 2.52 meters away. The cameras were adjusted to be perpendicular to the anatomical planes of the subject. The zoom of each camera was adjusted to allow about 0.5 meters of free space below and above the subject to minimize any distortion of the image extremities.

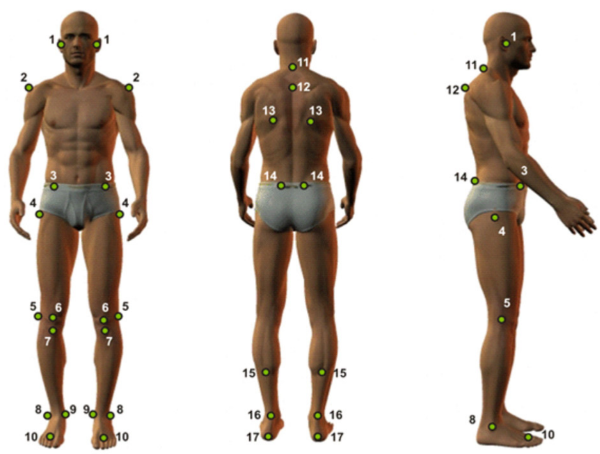

Figure 1 - This figure shows the anatomic points that were visualized. Footnote: tragus (1); medium point, acromion (2); anterior-superior iliac spine (ASIS) (3); femur, greater trochanter (4); knee, articular line (5); patella, medium point (6); tibia tuberosity (7); lateral malleoli (8); medial malleoli (9); medium point between second and third metatarsus (10); spinal process of C7 (11) and T3 (12); scapula, inferior angle (13); posterior-superior iliac spine (14); leg, point a medial line (15); calcaneum tendon between malleolus (16); and calcaneum (17).

A plumb line marked with two styrofoam balls was used for vertical calibration.

Assessments were conducted at the Laboratory of Biophysics, School of Physical Education, São Paulo University. All participants signed informed consent forms, and the project was approved by the Ethics Committee (758/02), School of Medicine, São Paulo University.

Procedures

Five physical therapists (all women from 26 to 37 years old) who were not regular users of the PAS/SAPO were invited to participate as raters; they were invited if they had used the software before, but not if they were a regular user. Raters were oriented about how to use the software, and they practiced by analyzing 8 pictures (4 from each subject). Each rater had 30 minutes to practice and could ask questions during this training phase. Pictures were calibrated according to distance and the guiding vertical line. Raters could use the zoom feature at their own discretion. The raters worked on desktop computers with the PAS software and optic mice.

For reliability analyses, all pictures were given to the investigators in random order (each investigator received a different sequence), and no time limit was established. Measured values are described in Table 1. After 1 week, procedures were repeated, and tests were compared to assess the intra-rater reliability.

Measurements of angles and distance

An object with known dimensions was marked with three styrofoam balls, each of them measuring 15 mm and placed at 90 degrees and 45 cm from each other. The object was photographed and given to participants. Pictures were calibrated as previously described. Using the PAS/SAPO, raters performed the measurements. The values obtained with the software PAS/SAPO were compared to the known positions (actual values) of the object, and the differences were evaluated as an error analyses. The error was calculated according to the differences between the rater's value and the actual value. The mean of five raters were calculated.

Data analysis

Analyses were conducted using Excel 2003, Minitab v.14 and Statistical v.7. The Shapiro-Wilk W test and the Levene test were used to assess normality and homogeneity of the variables. The intraclass correlation coefficient (ICC) model 2.1[30] was employed for the inter-rater tests and ICC 3.1[30] was employed for the intra-rater tests. The significance level was defined as $\alpha = 0.05$.

Inter-rater reliability (reproducibility)

Table 1 displays the inter-rater reliability (mean, standard error, ICC 2.1). The ICC was classified according to the methods of Wahlund, Listin and Dworkin.[31] ICCs < 0.7 were considered non-acceptable, 0.71 < ICCs < 0.79 were acceptable, 0.80 < ICCs < 0.89 were very good and ICCs > 0.90 were excellent. Of the total measurements, 41% had

Table 1 - Inter-rater reliability: mean, standard error, ICC and respective classifications.

Variable	Abbreviations	Mean	Standard error	ICC	Classification
Head – horizontal alignment	HHA	-0.05	1.07	0.68	NA
Acromion – horizontal alignment	AHA	0.24	0.47	0.83	VG
ASIS – horizontal alignment	ASISHA	-0.34	0.52	0.84	VG
Angle between acromion and ASIS	AAASIS	-0.63	0.63	0.81	VG
Right limb – frontal angle	RLFA	-3.27	0.61	0.96	EXC
Left limb – frontal angle	LLFA	-3.11	1.31	0.91	EXC
Length difference between right and left limbs	LDRLL	-0.07	0.41	0.65	NA
Tibia tuberosity – horizontal angle	TTHA	-0.32	0.87	0.21	NA
Right hip – angle	RRA	11.71	1.66	0.93	EXC
Left hip – angle	LRA	21.53	2.41	0.86	VG
Scapula - horizontal asymmetry – T3	SHAT3	-2.79	4.81	0.75	A
Angle between leg and foot dorsum-right	ALRR	7.93	2.66	0.83	VG
Angle between leg and foot dorsum-left	ALRL	8.51	2.28	0.82	VG
Head - C7 (right)– horizontal alignment	HHAC7	51.18	1.77	0.69	NA
Head - (right) – vertical alignment	HVAR	20.00	1.20	0.87	VG
Chest (right) – vertical alignment	CVAR	-1.40	0.85	0.81	VG
Hip (right) – angle	RRA	-5.43	2.11	0.76	A
Vertical alignment of the body (right)	VABR	1.68	0.44	0.81	VG
Horizontal alignment of the hip (right)	HARR	-7.26	1.86	0.79	A
Angle of the knee (right)	ARK	-0.20	1.41	0.95	EXC
Angle of the ankle (right)	ARA	86.04	0.52	0.96	EXC
C7 horizontal alignment (left)	HALC7	47.84	1.03	0.94	EXC
Head – C7 (left) – vertical alignment	HVAL	15.84	1.00	0.97	EXC
Chest (left) – vertical alignment	CVAL	-2.37	0.50	0.97	EXC
Hip (left) – angle	RAL	-7.01	1.86	0.91	EXC
Vertical alignment of the body (left)	VABL	1.53	0.36	0.91	EXC
Horizontal alignment of the hip (left)	HARL	-8.11	1.72	0.82	VG
Angle of the knee (left)	AKL	-1.02	1.81	0.96	EXC
Angle of the ankle (left)	AAL	85.95	0.48	0.97	EXC

NA: non-acceptable; A: acceptable; VG: very good; EXC: excellent

excellent reliability, 35% had very good reliability, 10% had acceptable reliability, and 14% had non-acceptable reliability.

Intra-rater reliability (repeatability)

Table 2 displays the intra-rater reliability (mean, standard error, and ICC 3.1) for each of the 5 raters according to the classification of Wahlund, Listin and Dworkin.[31] ICCs < 0.7 were considered non-acceptable, 0.71 < ICCs < 0.79 were acceptable, 0.80 < ICCs < 0.89 were very good and ICCs > 0.90 were excellent.

Table 3 summarizes measurements as non-acceptable, acceptable, very good, or excellent (using the same parameters described above). The measurements of

Table 2 - Intra-rater reliability: standard error, ICC, and classification for repetitive measurements using the PAS/SAPO.

Variable	Rater 1		Rater 2		Rater 3		Rater 4		Rater 5	
	ICC - Classification	Standard error	ICC - Classification	Standard error	ICC - Classification	Standard error	ICC - Classification	Standard error	ICC - Classification	Standard error
HHA	0.75 – A	1.03	0.47 – NA	1.52	0.86 – VG	0.58	0.62 – NA	0.98	0.88 – VG	0.59
AHA	0.92 – EXC	0.29	0.77 – A	0.58	0.95 – EXC	0.26	0.92 – EXC	0.33	0.87 – VG	0.39
ASISHA	0.85 – VG	0.52	0.59 – NA	0.99	0.47 – NA	1.12	0.84 – VG	0.58	0.86 – VG	0.49
AAASIS	0.82 – VG	0.60	0.52 – NA	1.11	0.59 – NA	1.00	0.84 – VG	0.46	0.88 – VG	0.46
RLFA	0.93 – EXC	0.56	0.86 – VG	0.81	0.73 – A	1.16	0.86 – VG	0.86	0.94 – EXC	0.49
LLFA	0.96 – EXC	0.36	0.89 – VG	0.62	0.67 – NA	1.15	0.86 – VG	0.66	0.93 – EXC	0.47
LDRLL	0.70 – A	0.42	0.42 – NA	0.62	0.40 – NA	0.51	0.73 – A	0.33	0.66 – NA	0.42
TTHA	0.53 – NA	0.63	0.14 – NA	1.27	0.47 – NA	0.69	0.92 – EXC	0.35	0.52 – NA	0.72
RRA	0.83 – VG	1.64	0.63 – NA	2.97	0.66 – NA	2.72	0.94 – EXC	0.94	0.92 – EXC	1.17
LRA	0.83 – VG	2.25	0.69 – NA	3.03	0.93 – EXC	1.26	0.95 – EXC	1.04	0.90 – EXC	1.69
SHAT3	0.87 – VG	4.58	0.74 – A	7.11	0.88 – VG	4.50	0.91 – EXC	3.44	0.88 – VG	4.15
ALRR	0.80 – VG	1.53	0.63 – NA	2.37	0.55 – NA	2.52	0.83 – VG	2.12	0.82 – VG	1.52
ALRL	0.77 – A	1.53	0.53 – NA	2.79	0.51 – NA	2.62	0.72 – A	2.05	0.69 – NA	1.89
HHAC7	0.93 – EXC	0.81	0.66 – NA	2.30	0.92 – EXC	0.81	0.71 – A	1.79	0.94 – EXC	0.70
HVAR	0.94 – EXC	3.46	0.87 – VG	1.51	0.96 – EXC	0.70	0.87 – VG	1.51	0.97 – EXC	0.60
CVAR	0.78 – A	0.53	0.67 – NA	0.68	0.91 – EXC	0.30	0.90 – EXC	0.36	0.94 – EXC	0.28
RRA	0.94 – EXC	0.59	0.77 – A	0.81	0.86 – VG	0.57	0.95 – EXC	0.63	0.96 – EXC	0.48
VABR	0.75 – A	0.26	0.66 – NA	0.37	0.80 – VG	0.28	0.79 – A	0.32	0.85 – VG	0.18
HARR	0.92 – EXC	0.71	0.82 – VG	1.28	0.93 – EXC	0.82	0.93 – EXC	0.71	0.89 – VG	0.86
ARK	0.97 – EXC	0.51	0.96 – EXC	0.64	0.95 – EXC	0.70	0.96 – EXC	0.64	0.97 – EXC	0.53
ARA	0.96 – EXC	0.34	0.90 – EXC	0.54	0.94 – EXC	0.43	0.88 – VG	0.55	0.96 – EXC	0.36
HALC7	0.94 – EXC	0.74	0.90 – EXC	0.93	0.54 – NA	2.33	0.86 – VG	1.19	0.96 – EXC	0.58
HVAL	0.96 – EXC	0.75	0.93 – EXC	0.97	0.52 – NA	2.88	0.90 – EXC	1.32	0.95 – EXC	0.74
CVAL	0.97 – EXC	0.25	0.94 – EXC	0.40	0.93 – EXC	0.42	0.96 – EXC	0.32	0.98 – EXC	0.22
RAL	0.86 – VG	0.37	0.94 – EXC	0.54	0.92 – EXC	0.65	0.97 – EXC	0.52	0.98 – EXC	0.41
VABL	0.76 – A	0.16	0.79 – A	0.34	0.86 – VG	0.24	0.94 – EXC	0.20	0.95 – EXC	0.14
HARL	0.81 – VG	0.77	0.68 – NA	1.84	0.78 – A	1.56	0.79 – A	1.41	0.90 – EXC	0.94
AKL	0.72 – A	2.29	0.91 – EXC	0.86	0.91 – EXC	0.86	0.96 – EXC	0.50	0.97 – EXC	0.46
AAL	0.92 – EXC	0.18	0.90 – EXC	0.54	0.96 – EXC	0.33	0.82 – VG	0.76	0.96 – EXC	0.32

NA: non-acceptable; A: acceptable; VG: very good; EXC: excellent

Table 3 - Intra-rater reliability: results for individual raters.

Classification	**Rater 1**	**Rater 2**	**Rater 3**	**Rater 4**	**Rater 5**
Non-acceptable	3.5%	44.8%	34.5%	3.4%	10.3%
Acceptable	24.1%	13.8%	6.9%	17.2%	0.0%
Very Good	27.6%	13.8%	17.2%	31.0%	27.6%
Excellent	44.8%	27.6%	41.4%	48.3%	62.1%

rater 5 were the most precise (62.1% excellent), and the measurements from rater 2 were the least precise (44.8% as non-acceptable).

Table 4 summarizes the data for measurements of angles and distance. The mean error analisys for angular measurements was 0.11 ± 0.32 degrees; for distance, it was 1.8 ± 0.9 mm.

Table 4 - PAS/SAPO computacional errors for angle and distance measurements: measurements obtained with the PAS/SAPO compared to the actual values (known measurements).

	Angle in degrees	Distance (mm)
Average error analisys	0.11	1.8
Standard deviation	0.32	0.9

DISCUSSION

The present study measured the accuracy of the PAS as well as its inter- and intra-rater reliabilities. We found that the PAS was a reliable tool for postural analysis because inter-rater and intra-rater agreement were very good or excellent at 75% (22 variables) and 64.8% (20 variables), respectively. The software was also accurate for measurements of angles and distances.

Inter-rater reliability (reproducibility)

Only 4 out of 29 assessed variables were classified as non-acceptable (ICCs < 0.70): 3 for angles and 1 for distance. The calibration of the system and/or the body region being examined may have contributed to the non-acceptable status of these variables. The use of the plumb line (true vertical line) to calibrate the system was required for some of the measurements, such as the horizontal alignment of the head. To execute this calibration, the rater had to click on two reference points on the plumb line to inform the software which line in the image was the true vertical line. Occasional deviations during identification of the markers during the calibration procedure may have increased the error of the final measurements. Indeed, the 4 non-acceptable variables required calibration using the vertical line. According to Dunk et al.,[21] the calibration of the vertical line is imprecise compared to biological references because the inherent error that occurs when measuring the vertical line is added to the error incurred when measuring the anatomic markers, thus biasing the results. Interestingly, 8 of the 11 parameters that were classified as excellent did not require calibration (i.e., they only involved biological markers).

The position of the head may also have influenced the results because small changes in the biomechanics of the neck (e.g., in the tragus or C7) can cause small rotations and inclinations that could impact the correct visualization of the markers when observed from the sagittal or coronal plane. These rotations may partially hide some markers, making their visualization and digitalization more difficult. Out of the four variables with the worst results, three were assessed from the frontal plane and were on the first picture, suggesting that performance improved with training.

Despite the limitations discussed above, we concluded that inter- and intra-rater reliability were high. Similar results were obtained by Niekerk et al.[32] when pictures were used for assessment of head, shoulder and chest positions. In addition, Iunes et al.[33] found similar results when assessing global posture while standing. Dunk et al.[20] investigated the importance of digitalization techniques and the use of reflexive markers for postural analyses and found ICCs varying from non-acceptable to acceptable for posture variables.

We also want to mention that the size of the adhesive markers, as well as the accuracy of the zoom, may have influenced the precision of the measurements. We placed small spherical markers (15 mm) on the skin as close as possible to the anatomical structure in an attempt to increase precision. Furthermore, PAS included a zoom feature that was used at the discretion of the rater, which could have created more variability between raters.

Intra-rater reliability (repeatability)

The data also suggested good intra-rater reliability because 68.4% of the measurements were considered very good or excellent. Dunk et al.[21] found greater inaccuracy, with ICCs ranging from 0.157 to 0.837. Table 3 shows that raters 2 and 3 had the worst results, but even the worst rater (rater 2) had 55% of the assessments considered acceptable, very good or excellent. Rater 5 had the highest reliability (62% excellent). Interestingly, raters 2 and 3 were older than the other raters, and they may have had less exposure to computer science during their professional careers. Rater 5, who had the best scores, was younger than raters 2 and 3 and had more computer experience. These findings suggest that increased experience with computers and software impacted the performance with PAS. Although the software was easy to use and all of the raters had been previously trained by the investigator, these factors may have influenced our results.

Validation for measuring angles and distance

We found good accuracy for measuring angles (error of 0.11 degrees) and distance (error of 1.8 mm). A comparison of our findings with the software assessments of the body regions in 3D showed that the PAS was more accurate. For example, one type of software (PosturePrint) yielded an error of 1.2 degrees for rotations, 1.6 mm for translation of the chest,[26] 1.38 degrees for rotation and 1.1 mm for translation of the head.[23]

It may be hypothesized that these small errors are the result of mathematical approximations of computerized methods and that these errors are of little clinical relevance.[26] Accordingly, the PAS may be considered a reliable instrument.

CONCLUSION

The PAS/SAPO is accurate for measuring angles and distances, has good inter- and intra-rater reliabilities, and should be considered a useful and reliable tool for measuring posture.

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