Journal of Research in Clinical Medicine
J Res Clin Med, 2021, 9: 3
doi: 10.34172/jrcm.2021.003
https://jrcm.tbzmed.ac.ir
TUOMS PRESS

Original Article

The reliability and validity of body vision system for assessing posture

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Article info
Article History:
Received: 8 June. 2020
Accepted: 6 Sep. 2020
e-Published: 16 Jan. 2021

Keywords:
- Body vision
- Reliability
- Validity

Abstract
Introduction: Body vision is a novel method which examines postural indices through photogrammetric essentials. Nevertheless, its reliability and validity has not been appraised till now. We aimed to evaluate the reliability and validity of body vision system for posture assessment.
Methods: This was a cross-sectional study in which two examiners evaluated photographs of 71 subjects using body vision system twice with a two-week interval. The body vision system involves a grid wall and a camera fixed in front of the grid wall at about 390 cm distances. Three standing photographs (anterior, right lateral, and posterior view) were captured for participants.
Results: The results for inter-rater reliability analysis showed that most of the parameters (74%) had excellent 95% confidence interval (CI), 10 % had good to excellent 95% CI, 13% had moderate to good 95% CI, and 1% had poor to moderate 95% CI. The results for intra-rater reliability analysis showed that 70%-72% of the parameters had excellent 95% CI, 6%-9% had good to excellent 95% CI, 12%-13% had moderate to good 95% CI, and 9% had poor to moderate 95% CI. The comparison between known distances and angles on grid wall and those obtained from photogrammetric measurements showed that there was no statistically significant difference ($P > 0.05$). Also, the regression analysis showed that there was a significant and positive relationship between them (R2 = 1, $P<0.05$).
Conclusion: The results of this study showed that body vision system is a valid and reliable tool for measuring postural parameters.

Introduction

Posture is the alignment between different parts of body. A good posture is where the musculoskeletal structures bear least stress due to balance between different components.[1,2] Deviations from proper postural alignment indicate that the balance has been disturbed and some parts are at risk of injury because of excess load.[3] Also, postural analysis has shown that disorders like spondylolisthesis,[4] adolescent idiopathic scoliosis,[5] osteoporosis, pain,[6] and nasal patency[7] might affect the subject's posture which causes additional problems.[8]

Posture assessment can be done with X-ray exam which might expose radiation or noninvasive methods like visual inspection, goniometry, photogrammetry and 3D laser scan.[9,10]

Photogrammetry is a simple and safe method for analyzing posture in a quantitative manner. There are different types of software programs like postural assessment software (SAPO) and Surgimap which helps to measure postural parameters faster and easier. The reliability of measurements using most of these software packages has been investigated previously. Body vision is a new system which analyzes postural parameters using photogrammetric basics. However, the reliability and validity of the measurements using body vision system has not been evaluated till now.

The purpose of this study was to determine the inter-rater and intra-rater reliability and validity of postural analysis using body vision system.

Methods

Subjects

Photographs were chosen from databases of posture assessment clinic of Imam Reza hospital. The protocol

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was reviewed and approved by Physical Medicine and Rehabilitation Research Center. The subjects wearing clothes more than underwear were excluded and 71 subjects remained for analyses. The objectives and the process of the study were explained and written informed consent was completed for each subject. The subjects were able to retract the projects during the study, without providing any reason. All subjects had three standing photographs (anterior, right lateral, and posterior view), looking forward and arms at sides. All photographs had been captured by posture clinic assistant who had marked some anatomical points with 1.5 * 1.5 cm sticking spheres. The percent of identified (and visible) markers in each view was as follows:

Anterior view: Greater trochanter 22.5%, ASIS 95.7%, suprasternal notch 15%, xiphoid 6%, acromion 6%.

Lateral view: Greater trochanter 9%, ASIS 91%, PSIS 100%, C7 spinous process 92.9%, T7 spinous process 62%, T12 spinous process 65%, suprasternal notch 15%, acromion 6%.

Posterior view: PSIS 100%, C7 spinous process 95%, T7 spinous process 63%, T12 spinous process 64%, inferior angle of scapula 15%.

Body vision

The body vision system consists of an 80*195 cm grid wall (with 10 cm sectors) and a camera (CANON Zoom Lens EF-S 18-55 mm 1:3:5-5.6 IS II 58 mm) which has been fixed in front of the grid wall at about 390 cm distance (on about 100 cm height). The camera is connected to the computer and examiner can take photos, restore them and analysis different angle and distance parameters of posture using the body vision software (Table 1). In this version of body vision software, the examiner has to identify different landmarks. The device has been developed in Tabriz, Iran by Tocea Tadbir Tavan Teb Company (Rehabsoon Co).

Procedures

Two physical therapists who were familiar with the use of the software were randomly chosen from students of Physical Medicine and Rehabilitation Department of Tabriz University of Medical Sciences. Evaluation of photographs was done using body vision software. The examiner defined the plumb line and then other landmarks orderly as shown in Figure 1. Each examiner evaluated the photographs twice with a two-week interval. The third investigator exported reports of each test in an excel form, stored them in other file and cleaned from software database in order to not allowing the examiners to see previous analysis.

To evaluate the validity of measurement, we used distances and angles on grid wall as the reference value and asked the examiners to mark and measure them using the body vision software. In order to perform blinding, the examiners were not allowed to see the results of measurements and the third investigator gathered the data.

Statistical analysis

The intra-rater reliability of measurements was evaluated by intraclass correlation test (ICC two ways mixed, average, absolute agreement). The inter-rater reliability of measurements was evaluated by ICC test (two ways random, average, absolute agreement). It has been suggested to define poor, moderate, good and excellent results if the ICC values equals to less than 0.5, 0.5 to 0.75, 0.75 to 0.9 and greater than 0.9, respectively.[11] Paired *t* test and regression analysis were used to evaluate the validity of measurements.

All analysis was done using SPSS software 16 and *P* value less than 0.05 was considered significant.

Results

The mean age of subjects was 21.13 years old (ranging from 4 to 67 year) and 62% of them were male.

The results for inter-rater reliability analysis showed that most of the parameters (74%) had excellent 95% confidence interval (CI), 10 % had good to excellent 95% CI, 13% had moderate to good 95% CI, and 1% had poor to moderate 95% CI (Table 2).

The results for intra-rater reliability analysis showed that 70%-72% of the parameters had excellent 95% CI, 6%-9% had good to excellent 95% CI, 12%-13% had moderate to good 95% CI, and 9% had poor to moderate 95% CI.

The comparison between known distances and angles on grid wall and those obtained from photogrammetric measurements showed that there was no statistically significant difference ($P > 0.05$). Also the regression analysis showed that there was a significant and positive relationship between them ($R^2 = 1$, $P < 0.05$) (Table 3).

Discussion

According to the results obtained in this study, most parameters had good to excellent inter-rater and intra-rater reliability. The low levels of reliability in some parameters might be attributed to the low resolution of the photographs or hiding of the markers due to relaxed position of the subject, for example in the case of tibial tuberosity or greater trochanter landmarks, respectively. So, it is necessary to mark those landmarks which might not be clear in photo and all landmarks should be visible; otherwise, the analysis will not be reliable. The results of other studies using different software were the same. Souza et al. have shown that postural assessment software (SAPO) is a reliable tool for postural analysis when bony landmarks were identified before photogrammetry.[12] Santos et al and Hazar et al have found same results in children and adolescents, respectively.[13,14] Helmya et al have shown that the Surgimap spine software is a reliable tool for posture assessment when placing markers on certain anatomical landmarks.[15] Muniandy et al concluded that web plot digitizer software was a reliable tool to assess forward

Table 1. Definition of postural parameters

Head lateral tilt angle	A1	The angle formed between the line connecting right and left tragus with the horizontal line
Head inclination angle	A2	The angle between the line connecting glabella and chin protuberance with vertical line through chin protuberance
Mid-head - plumb line distance	D1	The horizontal distance of mid-head line (the line connecting glabella to the chin protuberance) from plumb line in the chin protuberance point which indicates head rotation.
Shoulder tilt angle	A3	The angle formed between the line connecting right and left acromion process with the horizontal line.
Mid-chest - plumb line distance	D2	The horizontal distance of mid-chest line (the line connecting xiphoid process to the suprasternal notch) from plumb line in the suprasternal notch point.
Umbilicus-plumb line distance	D3	Horizontal distance of umbilicus from plumb line
Pelvic lateral tilt angle	A4	The angle formed between the line connecting ASISs with the horizontal line.
Shoulder on pelvis tilt angle	A5	The angle formed between the line connecting right and left acromion process and the line connecting right and left ASISs.
Greater trochanter tilt angle	A6	The angle formed between the line connecting right and left greater trochanter with the horizontal line.
ASIS to greater trochanter distance	D4	Distance between the ASIS and greater trochanter on same side.
Q angle	A7	The angle formed between the line connecting ASIS to patellar center and the line connecting tibial tuberosity to the patellar center.
Lateral thigh leg angle	A8	The angle formed between the line connecting greater trochanter to lateral mid knee joint line and the line connecting lateral mid knee joint line to the lateral malleolus in anterior view.
Femoral-tibial angle (anatomic knee angle)	A9	The angle between distal part of thigh and proximal part of leg
Intercondylar distance	D5	Horizontal distance between right and left medial femoral condyles.
Tibial tuberosity tilt angle	A10	The angle formed between the line connecting right and left tibial tuberosity with the horizontal line.
Femoral segment length	D6	Distance between greater Trochanter and lateral mid knee joint line on each side.
Tibial segment length	D7	Distance between lateral mid knee joint line and lateral malleolus on each side.
Lateral malleolus tilt angle	A11	The angle formed between the line connecting right and left lateral malleolus with the horizontal line.
Intermalleolar distance	D8	Horizontal distance between right and left medial malleolus.
True leg length	D9	Distance between the ASIS and medial malleolus on same side.
True discrepancy	D10	Difference between right and left true leg length.
Apparent leg length	D11	Distance between the umbilicus and medial malleolus on same side.
Apparent discrepancy	D12	Difference between right and left apparent leg length
Head gaze angle	A12	The angle formed at the intersection of a horizontal line through the ear tragus and a line connecting the ear tragus with the lateral eye canthus
Head horizontal angle	A13	The angle formed at the intersection of a horizontal line through the C7 spinous process and a line connecting the C7 spinous process with ear tragus
Head vertical angle	A14	The angle formed at the intersection of a vertical line through the C7 spinous process and a line connecting the C7 spinous process with ear tragus
Head positional angle	A15	The angle formed between tragus- chin protuberance line and tragus-suprasternal notch line. Indicate the vertical distance between the chin and sternum.
Tragus –plumb line distance	D13	The horizontal distance of ear tragus from plumb line
Shoulder angle	A16	The angle formed at the intersection of the line between the midpoint of the humerus head and spinous process of C7 and the horizontal line through the midpoint of the humeral head.
Acromion-plumb line distance	D14	The horizontal distance of acromion from plumb line
Thoracic kyphosis angle	A17	The angle formed by the straight lines between the C7 spinous process and the spinous process of T12 and that intersects the horizontal line between T7 (between T6 and T8) and the true vertical line
Lateral spinal angle	A18	The angle formed between the line connecting C7 spinous process to T12 and the line connecting T12 to the greater trochanter.
Lumbar lordosis angle	A19	The angle formed by the straight lines between the T12 spinous process and the spinous process of L5 (between L4 & S2) and that intersects the horizontal line between L3 (between L2 & L4) and the true vertical line
Lateral lumbar angle	A20	The angle formed between the line connecting T12 spinous process to ASIS and the line connecting ASIS to the greater trochanter.
Pelvic tilt angle	A21	The angle formed between the line connecting ASIS and PSIS and a horizontal line through PSIS.
Trunk sway angle	A22	The angle formed between the line connecting grater trochanter and acromion and a vertical line through grater trochanter.

Lateral trunk angle	A23	The angle formed between the line connecting grater trochanter and acromion and a line connecting grater trochanter and lateral malleolus.
Lateral hip angle	A24	The angle formed between the line connecting greater trochanter to lateral mid knee joint line and the line connecting greater trochanter to ASIS.
Hip–plumb line distance	D15	The horizontal distance of grater trochanter from plumb line
Lateral knee angle	A25	The angle formed between the line connecting greater trochanter to lateral mid knee joint line and the line connecting lateral mid knee joint line to the lateral malleolus.
Knee -plumb line distance	D16	Horizontal distance from lateral mid knee joint to the plumb line.
Lateral ankle angle	A26	The angle formed between the line connecting lateral mid knee joint line to the lateral malleolus and the horizontal line through the lateral malleolus.
Body sway angle	A27	The angle formed between the line connecting lateral malleolus and acromion and a vertical line through lateral malleolus.
Inferior angle - midline distance	D17	The horizontal distance from inferior angle of scapula to the mid line of thoracic spine.
Inferior angle –T2 distance	D18	The distance between inferior angle of scapula and T2 spinous process.
Scapular tilt angle	A28	The angle formed between the line connecting inferior angles of scapula of both sides with the horizontal line.
Thoracic spine alignment angle	A29	
Elbow – trunk distance	D19	Horizontal distance between medial elbow and trunk
Elbow trunk difference	D20	Difference between bilateral elbow-trunk distances
Coronal spinal balance	D21	The horizontal distance between the natal cleft upper point and a vertical line through the C7 spinous process
Trunk balance	D22	The horizontal distance between the natal cleft upper point and a vertical line which bisects the horizontal line connecting the edges of the chest at more shifted region
Lumbar spine alignment angle	A30	
Pelvis lateral tilt angle (posterior vision)	A31	The angle formed between the line connecting PSISs with the horizontal line.
Popliteal tilt angle	A32	The angle formed between the lines connecting right and left mid popliteal point with the horizontal line.
Rear foot angle	A33	The angle formed between the line connecting mid distal leg point to Achilles tendon and the line connecting Achilles tendon to the midpoint in the lower part of calcaneus

A: Angle, D: Distance.

head posture when using marker placement.[16] Szucs and Brown had found same results about mobile application for posture analysis.[17] Salahzadeh et al showed that the level of ICC to assess the reliability of photogrammetry was ranged from 0.75 to 0.94 when examining forward head and the intra subject reliability was 0.84 to 0.89.[18] Ferreira et al found that the SAPO software would be a reliable tool for posture analysis when marking the anatomical points and the low levels of reliability might be due to primary calibration of the photos.[19] We did not meet this issue because the calibration had been done once for all and before photogrammetry, so the raters did not calibrate each photo again.

The low values of reliability analysis in our study are most probably due to unclear location of anatomical points in some cases. Hébert-Losier and Abd Rahman did not use surface marker with the rational that it would be more practical when assessing great number of subjects and they found the inter-rater reliability of posture pro 8 software would be fair (ICC values of 0.40 to 0.75) to measure most parameters of posture analysis.[20] So, it is necessary to find out the least landmarks needed to be marked in order to obtain reliable results. According to data presented in our study, the authors suggest that it is necessary to mark C7, T7, T12, L1, L3, and L5 spinous process, bilateral ASIS, acromion, PSIS, greater trochanter, inferior angle of scapula, tibial tuberosity, mid-popliteal, lateral malleolus, mid-distal leg, Achilles tendon and calcaneus to have reliable results for all postural parameters. These results are consistent with the review of do Rosário.[21]

The other factor that is said to affect the results is the feet position.[4] However, Antoniolli et al found that the position of feet did not interfere with the results of the posture assessment.

Another aspect of using a measurement method is the validity which explain how results are accurate.[22] The validity of any measurement tool could be assessed when comparing the results with those obtained using standard methods.

Walicka-Cupryś et al have shown that the results of photogrammetry and inclinometer are comparable to measure thoracic kyphosis and lumbar lordosis.[23] Ludwig et al had compared the photometric method for posture index measurement with visual assessment to obtain the validity of photometric method.[24] Marques et al showed that goniometry and photogrammetry measurements of hip abduction and flexion have comparable results.[25]

However, the different landmarks in each test[26,27] or different unit calculation[28,29] might cause differences between results of various methods. As Marchetti et al had shown there might be ± 5.9 and 6.9-degree difference when comparing spinous process marker for measuring

Table 2. Intra-rater and Inter-rater reliability of posture assessment with body vision (N = 71)

			Inter-rater Reliability			Intra-rater Reliability					
						Examiner A			Examiner B		
			ICC	95% CI*		ICC	95% CI*		ICC	95% CI*	
Head Lateral Tilt A	A1	1	0.95	0.93- 0.97	E	0.96	0.93- 0.97	E	0.93	0.89- 0.95	G-E
Head inclination A	A2	2	0.98	0.97- 0.99	E	0.97	0.96- 0.98	E	0.97	0.95- 0.98	E
Midhead - plumb line D	D1	3	0.99	0.99- 0.99	E	0.99	0.99- 0.99	E	0.99	0.99- 0.99	E
Shoulder tilt A	A3	4	0.99	0.99- 0.99	E	0.99	0.98- 0.99	E	0.99	0.98- 0.99	E
Midchest - plumb line D	D2	5	0.99	0.99- 0.99	E	0.99	0.99- 0.99	E	0.98	0.98- 0.99	E
Umbilicus - plumb line D	D3	6	0.99	0.99- 0.99	E	0.99	0.99- 0.99	E	0.99	0.99- 0.99	E
Pelvic lateral tilt A	A4	7	0.98	0.97- 0.98	E	0.98	0.98- 0.99	E	0.94	0.90- 0.96	E
Shoulder on pelvis tilt A	A5	8	0.98	0.98- 0.99	E	0.97	0.96- 0.98	E	0.98	0.97- 0.98	E
Greater trochanter tilt A	A6	9	0.90	0.85- 0.94	G-E	0.79	0.67- 0.87	M-G	0.84	0.74- 0.90	M-G
ASIS to greater trochanter D	D4	10	0.97	0.95- 0.98	E	0.94	0.91- 0.96	E	0.97	0.95- 0.98	E
	D4-	11	0.98	0.96- 0.99	E	0.96	0.93- 0.97	E	0.97	0.96- 0.98	E
Q angle	A7	12	0.86	0.78- 0.91	G-E	0.77	0.64- 0.86	M-G	0.83	0.72- 0.89	M-G
	A7-	13	0.81	0.70-0.88	M-G	0.71	0.53- 0.82	M-G	0.75	0.60- 0.84	M-G
Lateral thigh leg A	A8	14	0.97	0.95- 0.98	E	0.95	0.92- 0.97	E	0.95	0.92- 0.97	E
	A8-	15	0.97	0.96- 0.98	E	0.94	0.91- 0.96	E	0.90	0.84- 0.94	G-E
Femoral-tibial (anatomic) A	A9	16	0.82	0.71- 0.89	M-G	0.69	0.51- 0.81	M-G	0.82	0.71- 0.88	M-G
	A9-	17	0.81	0.70- 0.88	M-G	0.63	0.40- 0.77	P-M	0.77	0.64- 0.86	M-G
Intercondylar D	D5	18	0.99	0.99- 0.99	E	0.98	0.97- 0.99	E	0.97	0.95- 0.98	E
Tibial tuberosity tilt A	A10	19	0.42	0.07-0.64	P-M	0.27	-0.14- 0.54	P-M	0.41	0.06- 0.63	P-M
Femoral segment length	D6	20	0.99	0.99- 0.99	E	0.99	0.98- 0.99	E	0.99	0.99- 0.99	E
	D6-	21	0.99	0.99- 0.99	E	0.99	0.99- 0.99	E	0.99	0.99- 0.99	E
Tibial segment length	D7	22	0.99	0.99- 0.99	E	0.99	0.99- 0.99	E	0.99	0.99- 0.99	E
	D7-	23	0.99	0.99- 0.99	E	0.99	0.99- 0.99	E	0.99	0.99- 0.99	E
Lateral malleolus tilt A	A11	24	0.70	0.52-0.81	M-G	0.63	0.41- 0.77	P-G	0.70	0.52- 0.81	M-G
Intermalleolar D	D8	25	0.99	0.99- 0.99	E	0.99	0.99- 0.99	E	0.99	0.99- 0.99	E
True leg length	D9	26	0.99	0.99- 0.99	E	0.99	0.99- 0.99	E	0.99	0.99- 0.99	E
	D9-	27	0.99	0.99- 0.99	E	0.99	0.99- 0.99	E	0.99	0.99- 0.99	E
True discrepancy	D10	28	0.98	0.98- 0.99	E	0.97	0.96- 0.98	E	0.97	0.95- 0.98	E
Apparent leg length	D11	29	0.99	0.99- 0.99	E	0.99	0.99- 0.99	E	0.99	0.99- 0.99	E
	D11-	30	0.99	0.99- 0.99	E	0.99	0.99- 0.99	E	0.99	0.99- 0.99	E
Apparent discrepancy	D12	31	0.90	0.84-0.93	G-E	0.77	0.63- 0.85	M-G	0.73	0.57- 0.83	M-G
Head gaze A	A12	32	0.99	0.98- 0.99	E	0.98	0.96- 0.98	E	0.97	0.96- 0.98	E
Head horizontal A	A13	33	0.98	0.98- 0.99	E	0.98	0.97- 0.98	E	0.98	0.97- 0.98	E
Head vertical A	A14	34	0.98	0.98- 0.99	E	0.98	0.97- 0.98	E	0.98	0.97- 0.98	E
Head positional A	A15	35	0.99	0.98- 0.99	E	0.97	0.96- 0.98	E	0.98	0.96- 0.99	E
Tragus –plumb line D	D13	36	0.99	0.99- 0.99	E	0.99	0.98- 0.99	E	0.99	0.98- 0.99	E
Shoulder A	A16	37	0.93	0.76-0.97	G-E	0.93	0.85- 0.96	G-E	0.96	0.94- 0.97	E
Acromion-plumb line D	D14	38	0.99	0.99- 0.99	E	0.98	0.97- 0.99	E	0.98	0.96- 0.98	E
Thoracic kyphosis A	A17	39	0.96	0.94- 0.97	E	0.97	0.95- 0.98	E	0.94	0.91- 0.96	E
Lateral spinal A	A18	40	0.99	0.99- 0.99	E	0.98	0.98- 0.99	E	0.99	0.98- 0.99	E
Lumbar lordosis A	A19	41	0.92	0.87- 0.95	G-E	0.88	0.81- 0.92	G-E	0.87	0.79- 0.91	G-E
Lateral lumbar A	A20	42	0.96	0.90- 0.98	E	0.95	0.93- 0.97	E	0.95	0.81- 0.97	G-E
Pelvic tilt A	A21	43	0.99	0.99- 0.99	E	0.99	0.99- 0.99	E	0.99	0.99- 0.99	E
Trunk sway A	A22	44	0.98	0.96- 0.99	E	0.96	0.94- 0.98	E	0.98	0.96- 0.99	E
Lateral trunk A	A23	45	0.96	0.93- 0.98	E	0.92	0.87- 0.95	G-E	0.97	0.93- 0.99	E
Lateral hip A	A24	46	0.97	0.95- 0.98	E	0.91	0.85- 0.94	G-E	0.97	0.96- 0.98	E
Hip–plumb line D	D15	47	0.99	0.98- 0.99	E	0.98	0.97- 0.99	E	0.99	0.98- 0.99	E
Lateral knee A	A25	48	0.97	0.95- 0.98	E	0.89	0.83- 0.93	G-E	0.95	0.92- 0.97	E
Knee -plumb line D	D16	49	0.98	0.97- 0.99	E	0.97	0.95- 0.98	E	0.96	0.94- 0.97	E
Lateral ankle A	A26	50	0.97	0.91- 0.98	E	0.97	0.95- 0.98	E	0.97	0.96- 0.98	E

Body sway A	A27	51	0.99	0.99- 0.99	E	0.99	0.98- 0.99	E	0.99	0.98- 0.99	E
Inferior angle - midline D	D17	52	0.99	0.98- 0.99	E	0.96	0.93- 0.97	E	0.99	0.98- 0.99	E
Inferior angle - midline D	D17-	53	0.98	0.97- 0.99	E	0.95	0.92- 0.97	E	0.99	0.98- 0.99	E
Inferior angle –T2 D	D18	54	0.99	0.98- 0.99	E	0.98	0.97- 0.99	E	0.99	0.98- 0.99	E
Inferior angle –T2 D	D18-	55	0.99	0.98- 0.99	E	0.98	0.97- 0.99	E	0.99	0.98- 0.99	E
Scapular tilt A	A28	56	0.90	0.83- 0.94	G-E	0.82	0.71- 0.88	M-G	0.84	0.74- 0.90	M-G
Thoracic spine alignment A	A29	57	0.79	0.53- 0.90	M-G	0.76	0.48- 0.89	P-G	0.69	0.34- 0.86	P-G
Elbow – trunk D	D19	58	0.99	0.99- 0.99	E	0.99	0.98- 0.99	E	0.99	0.98- 0.99	E
Elbow – trunk D	D19-	59	0.99	0.99- 0.99	E	0.99	0.98- 0.99	E	0.99	0.99- 0.99	E
Elbow trunk difference	D20	60	0.99	0.98- 0.99	E	0.98	0.96- 0.99	E	0.96	0.95- 0.98	E
Coronal spinal balance	D21	61	0.97	0.96- 0.98	E	0.97	0.95- 0.98	E	0.98	0.96- 0.98	E
Trunk balance	D22	62	0.91	0.86- 0.94	G-E	0.86	0.78- 0.91	G-E	0.95	0.92- 0.97	E
Lumbar spine alignment A	A30	63	0.69	0.50- 0.80	M-G	0.74	0.59- 0.84	M-G	0.68	0.48- 0.80	P-G
Pelvic lateral tilt A	A31	64	0.95	0.92- 0.97	E	0.97	0.95- 0.98	E	0.83	0.73- 0.89	M-G
Popliteal tilt angle	A32	65	0.79	0.65- 0.87	M-G	0.73	0.57- 0.83	M-G	0.61	0.37- 0.76	P-G
Rear foot angle right	A33	66	0.72	0.56- 0.83	M-G	0.44	0.10- 0.65	P-M	0.33	-0.06- 0.58	P-M
Rear foot angle left	A33-	67	0.73	0.57- 0.83	M-G	0.54	0.27- 0.71	P-M	0.53	0.25- 0.70	P-M

A: Angle, D: Distance, E: Excellent, G: Good, M: Moderate, P: Poor.
*$P < 0.05$.

Table 3 Analysis of the difference and association between photogrammetry and standard values

	n	Differences[a]	*P* value[b] ()	R^2	*P* value[c]
Distance (cm)	100	0.003 ± 2.19	0.98	1.00	0.000
Angle (degree)	81	0.02 ± 0.32	0.43	1.00	0.000

[a] Data are presented as mean ± SD.
[b] Paired *t* test.
[c] Regression.

cobb angle with the standard method.[30] Wilczyński et al have compared photogrammetry and radiology for spinal curvature diagnosis and they have found that there is a significant but low correlation between them.[31] Döhnert and Tomasi found that photogrammetry would not be useful for screening and diagnoses of mild scoliosis.[32]

Each parameter of posture assessment could be evaluated with its standard method of diagnosis.

Although there are different gold standard methods like X-ray, goniometry, inclinometer, etc to diagnose postural abnormalities, the aim of this study was not to compare all these with photogrammetry but it was to investigate how measurements are accurate. Therefore, we defined fixed points on the grid wall with known distances and angles and compared the value of each parameter with those obtained by photogrammetry. Schwertner et al had used similar way to verify the validity of SPGAP (posture evaluation rotating platform system).[33] They compared the values obtained through SPGAP system measurement of an object with its known dimensions. Ruivo et al used the metal pieces and goniometer as the reference values for assessing the validity of SAPO software.[34] Ferreira et al also had used an object with known distances and angles to investigate the validity of SAPO software.[19] They found that the mean difference for angle and distance measurement were 0.11 degree and 1.8 mm, respectively. We found that the mean difference for angle and distance measurement were 0.02 degree and 0.03 mm, respectively. There was no statistically significant difference ($P > 0.05$) and the correlation between measurements was almost complete ($R^2 = 1$). The magnification error of measurements was 0.02 which is inevitable in two dimensional analyses. So, it could be said that the body vision is a reliable and valid tool for analysis of postural parameters.

Standing posture is not static and may change during time.[35] Sacco et al found that photogrammetry is not suitable for follow up purposes because the intra-subject reliability of rear foot angle measurement is low when analyzing the subjects with one-week interval. [36] In this study, we did not examine intra-subject reliability which is necessary to be evaluated in future studies. The experience of examiner whom marks the anatomical points, as well as the computer experience of examiners might affect the results and have to be investigate.[19,37]

Conclusion

It could be claimed that the use of body vision system is a reliable and valid tool for measuring postural parameters. Although the measures are reliable and valid, the utility of these analyses should be investigated in follow up studies.

Study Highlights

What is current knowledge?

- Body vision is a novel method which examines postural indices through photogrammetric essentials. Nevertheless, its reliability and validity has not been appraised till now.

What is new here?

- TThe body vision system is a valid and reliable tool for measuring postural parameters.

Conflict of Interest
Authors declare no conflict of interest in this study.

Ethic Approval
This research was approved by regional ethic committee of Tabriz University of Medical Sciences (IR.TBZMED.REC.1395.1174).

Authors' Contribution
YS and NAF contributed to conception and design of the study and literature review. MA, AE and HH collected the data and contributed to data interpretation and drafting the manuscript. NAF and ND. drafted the first manuscript. All authors reviewed and approved the final version of the article.

Acknowledgments
We are thankful to all of the participants who helped us to conduct this project. The authors would like to thank the team of the Physical Medicine and Rehabilitation Research Center of Tabriz University of Medical Sciences for their support with this study.

Funding
This study has been funded by Physical Medicine and Rehabilitation Research Center of Tabriz University of Medical Sciences, Iran.

References
1. Senthil P, Subramanian S, Senthilselvam P, Sivakumar P, Radhakrishanan, Sarala R. Inter-rater reliability of Posture Pro 8 software analysis in upper body dysfunction: a prospective study. J Clin Diagn Res. 2018;12(2):YC1-YC3. doi: 10.7860/jcdr/2018/31038.11095.
2. Macedo Ribeiro AF, Bergmann A, Lemos T, Pacheco AG, Mello Russo M, Santos de Oliveira LA, et al. Reference values for human posture measurements based on computerized photogrammetry: a systematic review. J Manipulative Physiol Ther. 2017;40(3):156-68. doi: 10.1016/j.jmpt.2016.12.001.
3. Agustsson A, Gislason MK, Ingvarsson P, Rodby-Bousquet E, Sveinsson T. Validity and reliability of an iPad with a three-dimensional camera for posture imaging. Gait Posture. 2019;68:357-62. doi: 10.1016/j.gaitpost.2018.12.018.
4. Stolinski L, Kozinoga M, Czaprowski D, Tyrakowski M, Cerny P, Suzuki N, et al. Two-dimensional digital photography for child body posture evaluation: standardized technique, reliable parameters and normative data for age 7-10 years. Scoliosis Spinal Disord. 2017;12:38. doi: 10.1186/s13013-017-0146-7.
5. Alexandre AS, Sperandio EF, Yi LC, Davidson J, Poletto PR, Gotfryd AO, et al. Photogrammetry: a proposal of objective assessment of chest wall in adolescent idiopathic scoliosis. Rev Paul Pediatr. 2019;37(2):225-33. doi: 10.1590/1984-0462/;2019;37;2;00001.
6. Furlanetto TS, Sedrez JA, Candotti CT, Loss JF. Photogrammetry as a tool for the postural evaluation of the spine: a systematic review. World J Orthop. 2016;7(2):136-48. doi: 10.5312/wjo.v7.i2.136.
7. Milanesi JM, Berwig LC, Busanello-Stella AR, Trevisan ME, da Silva AMT, Corrêa ECR. Nasal patency and craniocervical posture in scholar children. Fisioter Pesqui. 2017;24(3):327-33. doi: 10.1590/1809-2950/17648424032017.
8. Ruivo RM, Pezarat-Correia P, Carita AI. Cervical and shoulder postural assessment of adolescents between 15 and 17 years old and association with upper quadrant pain. Braz J Phys Ther. 2014;18(4):364-71. doi: 10.1590/bjpt-rbf.2014.0027.
9. Aroeira RM, de Las Casas EB, Pertence AE, Greco M, Tavares JM. Non-invasive methods of computer vision in the posture evaluation of adolescent idiopathic scoliosis. J Bodyw Mov Ther. 2016;20(4):832-43. doi: 10.1016/j.jbmt.2016.02.004.
10. Singla D, Veqar Z. Methods of postural assessment used for sports persons. J Clin Diagn Res. 2014;8(4):LE01-4. doi: 10.7860/jcdr/2014/6836.4266.
11. Koo TK, Li MY. A guideline of selecting and reporting intraclass correlation coefficients for reliability research. J Chiropr Med. 2016;15(2):155-63. doi: 10.1016/j.jcm.2016.02.012.
12. Souza JA, Pasinato F, Basso D, Corrêa ECR, da Silva AMT. Biophotogrammetry: reliability of measurements obtained with a posture assessment software (SAPO). Rev Bras Cineantropom Desempenho Hum. 2011;13(4):299-305. doi: 10.1590/s1980-00372011000400009.
13. Santos MM, Silva MPC, Sanada LS, Alves CRJ. Photogrammetric postural analysis on healthy seven to ten-year-old children: interrater reliability. Rev Bras Fisioter. 2009;13(4):350-5. doi: 10.1590/s1413-35552009005000047.
14. Hazar Z, Karabicak GO, Tiftikci U. Reliability of photographic posture analysis of adolescents. J Phys Ther Sci. 2015;27(10):3123-6. doi: 10.1589/jpts.27.3123.
15. Helmya NA, El-Sayyadb MM, Kattabeib OM. Intra-rater and inter-rater reliability of Surgimap Spine software for measuring spinal postural angles from digital photographs. Bulletin of Faculty of Physical Therapy. 2015;20(2):193-9. doi: 10.4103/1110-6611.174719.
16. Muniandy Y, Singh DKA, Mani S, Omar B. Intra and inter-rater reliability of web plot digitizer software in quantifying head posture angles. Indian J Public Health Res Dev. 2019;10(7):745-50. doi: 10.5958/0976-5506.2019.01664.4.
17. Szucs KA, Brown EVD. Rater reliability and construct validity of a mobile application for posture analysis. J Phys Ther Sci. 2018;30(1):31-6. doi: 10.1589/jpts.30.31.
18. Salahzadeh Z, Maroufi N, Ahmadi A, Behtash H, Razmjoo A, Gohari M, et al. Assessment of forward head posture in females: observational and photogrammetry methods. J Back Musculoskelet Rehabil. 2014;27(2):131-9. doi: 10.3233/bmr-130426.
19. Ferreira EA, Duarte M, Maldonado EP, Burke TN, Marques AP. Postural assessment software (PAS/SAPO): validation and reliabiliy. Clinics (Sao Paulo). 2010;65(7):675-81. doi: 10.1590/s1807-59322010000700005.
20. Hébert-Losier K, Abd Rahman F. Reliability of postural measures in elite badminton players using Posture Pro 8. Physiother Theory Pract. 2018;34(6):483-94. doi: 10.1080/09593985.2017.1420117.
21. do Rosário JL. Photographic analysis of human posture: a literature review. J Bodyw Mov Ther. 2014;18(1):56-61. doi: 10.1016/j.jbmt.2013.05.008.
22. Antoniolli A, Candotti CT, Gelain GM, Schmit EFD, Ducatti LMA, de Oliveira Melo M, et al. Influence of feet position on static postural assessment by means of photogrammetry: a comparative study. Eur J Physiother. 2018;20(3):166-71.

doi: 10.1080/21679169.2018.1435719.

23. Walicka-Cupryś K, Wyszyńska J, Podgórska-Bednarz J, Drzał-Grabiec J. Concurrent validity of photogrammetric and inclinometric techniques based on assessment of anteroposterior spinal curvatures. Eur Spine J. 2018;27(2):497-507. doi: 10.1007/s00586-017-5409-8.
24. Ludwig O, Hammes A, Kelm J, Schmitt E. Assessment of the posture of adolescents in everyday clinical practice: intra-rater and inter-rater reliability and validity of a posture index. J Bodyw Mov Ther. 2016;20(4):761-6. doi: 10.1016/j.jbmt.2016.04.004.
25. Marques AP, Marcolan JNO, Prado JNN, Burke TN, Ferreira EAG. Inter-and intra-rater reliability of computerized photogrammetry and universal goniometer in the measurement of hip flexion and abduction. Fisioter Pesqui. 2017;24(1):22-8. doi: 10.1590/1809-2950/15886624012017.
26. Drzał-Grabiec J, Truszczyńska A, Tarnowski A, Płaszewski M. Comparison of parameters characterizing lumbar lordosis in radiograph and photogrammetric examination of adults. J Manipulative Physiol Ther. 2015;38(3):225-31. doi: 10.1016/j.jmpt.2015.01.001.
27. Saad KR, Colombo AS, João SM. Reliability and validity of the photogrammetry for scoliosis evaluation: a cross-sectional prospective study. J Manipulative Physiol Ther. 2009;32(6):423-30. doi: 10.1016/j.jmpt.2009.06.003.
28. de Albuquerque P, de Alencar GG, de Oliveira DA, de Siqueira GR. Concordance and reliability of photogrammetric protocols for measuring the cervical lordosis angle: a systematic review of the literature. J Manipulative Physiol Ther. 2018;41(1):71-80. doi: 10.1016/j.jmpt.2017.08.004.
29. Furlanetto TS, Candotti CT, Comerlato T, Loss JF. Validating a postural evaluation method developed using a Digital Image-based Postural Assessment (DIPA) software. Comput Methods Programs Biomed. 2012;108(1):203-12. doi: 10.1016/j.cmpb.2012.03.012.
30. Marchetti BV, Candotti CT, Raupp EG, Oliveira EBC, Furlanetto TS, Loss JF. Accuracy of a radiological evaluation method for thoracic and lumbar spinal curvatures using spinous processes. J Manipulative Physiol Ther. 2017;40(9):700-7. doi: 10.1016/j.jmpt.2017.07.013.
31. Wilczyński J, Habik N, Bieniek K, Janecka S, Karolak P, Kabała M, et al. Comparison of spatial photogrammetry and digital radiology in the diagnosis of spinal curvature. Mod Appl Sci. 2008;12(10):178-85. doi: 10.5539/mas.v12n10p178.
32. Döhnert MB, Tomasi E. Validity of computed photogrammetry for detecting idiopathic scoliosis in adolescents. Rev Bras Fisioter. 2008;12(4):290-7. doi: 10.1590/s1413-35552008000400007.
33. Schwertner DS, Oliveira R, Mazo GZ, Gioda FR, Kelber CR, Swarowsky A. Body surface posture evaluation: construction, validation and protocol of the SPGAP system (Posture evaluation rotating platform system). BMC Musculoskelet Disord. 2016;17:204. doi: 10.1186/s12891-016-1057-0.
34. Ruivo RM, Pezarat-Correia P, Carita AI, Vaz JR. Reliability and validity of angular measures through the software for postural assessment. Postural Assessment Software. Rehabilitación. 2013;47(4):223-8. doi: 10.1016/j.rh.2013.07.002.
35. Candotti CT, Gelain GM, Antoniolli A, Araújo LM, Vieira A, Loss JF. Repeatability and reproducibility of postural variables by photogrammetry. J Manipulative Physiol Ther. 2019;42(5):372-8. doi: 10.1016/j.jmpt.2018.10.006.
36. Sacco IC, Picon AP, Ribeiro AP, Sartor CD, Camargo-Junior F, Macedo DO, et al. Effect of image resolution manipulation in rearfoot angle measurements obtained with photogrammetry. Braz J Med Biol Res. 2012;45(9):806-10. doi: 10.1590/s0100-879x2012007500113.
37. da Silva Almeida I, Barreto LP, de Sousa Andrade L, Sousa CV, Mota YL. Reliability of measurements derived from the palpation method of a software for postural evaluation: does clinical experience matter? Rev Bras Cineantropom Desempenho Hum. 2018;20(6):515-24. doi: 10.5007/1980-0037.2018v20n6p515.