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Corresponding Author
Ingrid Ratcliffe
Ratcliffe@worldonline.co.za

Intra-Rater Reliability of the Posture Analysis Tool kit

Ronette Hough, B OT, M OT (UFS)
Lecturer, Department of Occupational Therapy, Faculty of Health Sciences, University of the Free State, Bloemfontein, South Africa

Riette Nel, M Med Sc (UFS)
Lecturer, Department of Biostatistics, Faculty of Health Sciences, University of the Free State, Bloemfontein, South Africa

ABSTRACT

Background: *Health care professionals mainly assess posture through qualitative observation of the relationship between a plumb line and specified anatomical landmarks. However, quantitative assessments of spinal alignment are mostly done by biophotogrammetry and are limited to laboratory environments. The Posture Analysis Toolkit (PAT), a photogrammetric measurement instrument was developed in 2009 to assess standing posture.* **Aim**: *The aim of this study was to test the intra-rater reliability of the Posture Analysis Toolkit.* **Methodology:** *A prospective, cross-sectional study design was conducted. Fourteen participants were required to do three measurements of the posture of a single subject using the PAT. Photographs of the anterior and left lateral upright standing posture were taken once, and imported three times for computerised analysis. Reliability was determined using descriptive statistics per session, confidence interval for the median difference between sessions, 95% limits of agreement and Spearman correlations.* **Results:** *In this study the intra-rater reliability of PAT between sessions was good.* **Conclusion:** *The Posture Analysis Toolkit was tested and proved to be reliable for use as an instrument for the assessment of standing postural alignment. Recommendations are suggested for the development of the PAT.*

Key words: posture assessment, biophotogrammetry, reliability, postural assessment toolkit

INTRODUCTION

Spinal posture is considered a prominent factor in the development and prevalence of low back pain[1,2,3]. Assessment and modification of postural alignment have been associated with improved clinical outcomes[4], energy efficiency and mechanical advantage during a person's participation in activity[5a]. Health care workers make use of a variety of methods to assess body alignment and postural imbalances[1,6,7]. These methods range from simple visual observation in clinical practice[8], to more complex laboratory-based motion analysis systems[9,10,11].

A number of computerised postural analysis systems has been developed that involve digitising an image of a client's upright standing posture to evaluate postural asymmetries[12,13]. Unfortunately, many of these systems are complex and time-consuming and cannot be easily used outside the laboratory setting. Furthermore, a significant limitation of these traditional laboratory-based motion analysis systems is that they cannot provide instantaneous postural feedback.

In 2008 Hermens and Vollenbroek-Hutton[14] advocated the use of portable, minimally invasive methods of analysing posture in "real world" settings to provide a quantitative measurement of posture in the workplace. Numerous devices have been developed to analyse spinal posture outside the laboratory, such as Biotoniz, ChiroVision, and Posture Pro[15], but many have proven to be too large and invasive, and lack empirical data to support their use. In 2009 the Postural Analysis Toolkit (PAT)[16,17], a novel wireless method of measuring postural alignment, was developed for use in studies to establish the Accuracy of the Plumbline Method[16], and body alignment[17]. In both these studies the PAT method demonstrated potential clinical utility, with data accessible for immediate analysis and presentation.

Whereas many laboratory-based methods of analysing posture have been shown to be both reliable and valid[18] the PAT has not been subjected to scientific validation in this regard. With increasing pressure for accountability and ethical practice in health service delivery, methods for assessment of posture are under continuous investigation to contribute to valid and reliable assessment practices.

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Atkinson and Nevill[19] suggest that reliability should be tested, first in any new measurement tool, since the instrument will never be valid if it is not adequately consistent in the provision of values from repeated measurements. The aim of this study was therefore to establish the intra-tater reliability of the PAT.

LITERATURE REVIEW

Ferreira et al[20] indicated that several independent companies have developed postural assessment software, which often consists of digital markers for photographic images and tools for measuring a number of variables. These computer based assessment software include, amongst others, the Postural Assessment Software (PAS)[20] which is a widely used option for the assessment of posture. Despite the success of computer based software in the scientific community[21] it should be emphasised that photogrammetry provides a two dimensional quantification of the body and that true postural changes may be hidden by the plane evaluated[22]. Existing software focuses on different aspects of posture of which dynamic posture is a prominent feature. The Multimedia Video Task Anlaysis[23] (MVTA) has been proven to be reliable in occupational studies to analyse postures and repetition during *work tasks*[24]. The BodyGuard™ 1, a monitoring device that monitors spinal alignment in real time also proved to be reliable during usual *dynamic tasks* such as sitting and forward bending.

The PAT was developed to assist in the assessment of *static* posture from digitalised photographs[16,17], and consists of software that requires the assessor to indicate with a mouse click on the anatomical landmarks indicated on the photo in the programme. (See *Figure 1*). After all the landmarks have been indicated, the assessor saves the application, and the deviation distances are then exported to Microsoft Excel® from PAT. The results are calibrated in EXCEL®. A calibration length of 1000 millimetres was entered so that all deviations could be converted into millimetres.

The success of technology that assists in the observational assessment of spinal alignment requires sufficient repeatability of postural assessments to ensure that ensuing/consequent changes are attributable to postural intervention strategies and not to any naturally occurring variability in posture. The Consensus Based Standards group for the selection of health status Measurement Instruments [25](COSMIN group), regard reliability as a key measurement property of a measurement instrument and refers to consistency as a prominent feature of reliable measurements. In addition, it also highlights the absence of measurement error as an important aspect of reliability. The COSMIN[25] group further agrees on a property of reliability to be the amount of measurement error that has been deemed acceptable for the effective clinical use of a measurement tool. In addition Scholtes[26] suggests that reliability estimates the extent to which scores for research participants who have not changed are the same for repeated measurements under the following conditions of measurement[26]:

- Using different sets of items from the same measurement instrument (internal-consistency)
- Across time (test-retest)
- By different raters on the same occasion (inter-rater)
- By the same person on different occasions (intra-rater)

To estimate reliability test-retest is the more conservative method. The three main components of this method are to firstly use the measurement instrument on two separate times for each subject, secondly to compute measurements between the two separate measurements, and thirdly to assume that there is no change in the underlying trait to be measured between test 1 and test 2. Scholtes, Terwee and Poolman[26] also suggest that different sets of items from the same measurement instrument (internal-consistency) be used across time (test-retest), by different persons on the same occasion, and by the same person on different occasions to establish reliability.

METHODOLOGY

The aim of the study was to establish the intra-rater reliability of the PAT (Posture Analysis Toolkit).

Study design

A prospective, cross-sectional study design was conducted after obtaining ethical clearance from the Ethics Committee of the Faculty of Health Sciences at the University of the Free State (ECUFS 20\2010).

Population and inclusion criteria

Fifteen final year students from the department of Occupational Therapy at the University of the Free State were recruited to participate as assessors in the study. According to Walter, Eliasziw and Donner[28] a sample of 14.4 (approximated to 15) participants was required considering that three repetitions were done and compared to give a reliability 0.8.

Participants who had successfully completed the accredited assessment module of posture and who had evaluated at least two patients with postural problems in clinical practice prior to the study were included in the study as assessors.

Procedure

Both intra- and inter-rater reliability depend primarily on the good training of the raters[29]. The training took place at a computer laboratory within the Faculty of Health Sciences during the first half of the morning. The assessors were trained to perform posture analysis by using the PAT which consisted of verbal instruction, and a Power Point® presentation supported by practical demonstration of the method.

The practical demonstration was presented as follows: The assessor trainees observed the experienced assessor-trainer perform the procedure of taking the digital photographs; loading the photographs to the computer; activating the programme; doing the assessment of posture and exporting the results to an EXCEL® file. Opportunity was given for trainees to ask questions in order to clarify issues, following which the trainee-assessors had an opportunity to practise the procedure. After the demonstration and practice session all the trainee assessors indicated that they felt competent to start with the measurement procedure. (From here they are referred to as assessor(s)).

During the second half of the morning the procedure progressed as follows: Each assessor took two photographs of the same normal healthy volunteer, aged between 18-30 years. One photograph was taken of the anterior view, and one photograph was taken of the left lateral view of the standing volunteer.

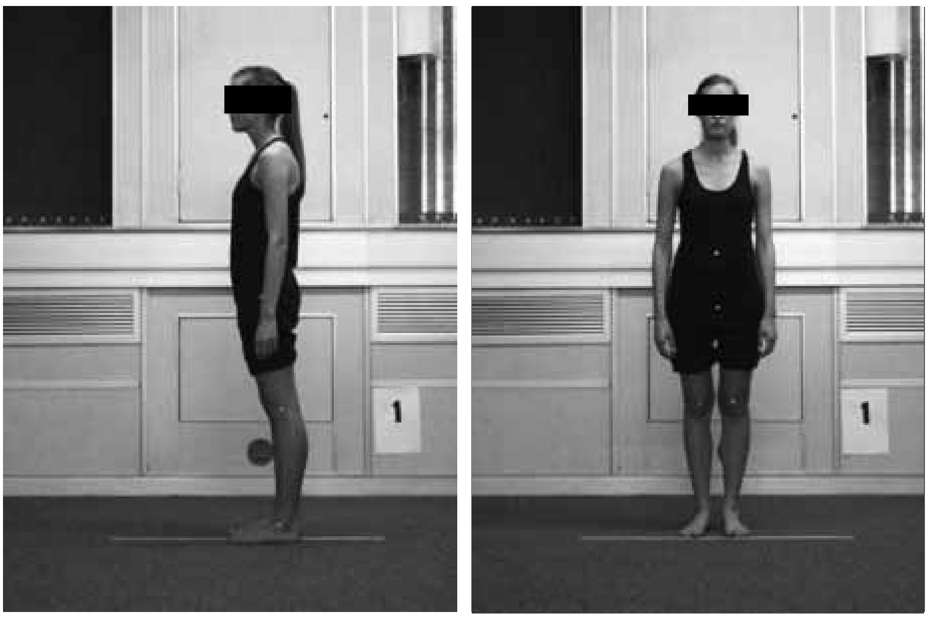

Figure 1: Anterior and lateral left view of volunteer

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A digital camera was set up 5000mm from the volunteer, on a tripod set at a height of half the length of the volunteer (±750mm). The following anatomical landmarks were indicated on the body of the volunteer by means of coloured stickers[5b]:

- Anterior position: mid-medial malleoli, mid-knee, mid-pubis, navel, sternum and nose.
- Left lateral position: anterior to lateral malleolus, anterior mid-knee, greater trochanter, mid-acromion and mid-ear lobe.

The research assistant lined up the volunteer, placed the markers and camera before every student took their photos and focused the camera on the central portion of the body, to avoid any distortions. The volunteer was de-identified on the photos by blocking out parts of the face. See *Figure 1*. Exactly the same set-up was used for each assessor and all they had to do was to stand in front of the camera and click the button to take the photo.

After each assessor had taken the 2 photos, they individually loaded the photos onto a computer. Thereafter, the assessors completed questionnaires regarding (i) background information, and (ii) the participants' experience of posture assessment with PAT. After the questionnaires were completed, the assessors then loaded the anterior and left-lateral photographs. The anterior view photograph was first loaded into the program. The assessor then clicked on the appropriate anatomical landmarks, and the location of each landmark was entered into the computer. This process started off with the plumb line as basis (the mid lateral maleoli), then working upward through all the mentioned anatomical landmarks. The lateral-left photograph was then loaded and the same procedure was followed. After all the anatomical landmarks were entered (for both photographs), a report was generated for the specific assessor by PAT for each of the 2 methods.

During the afternoon session the loading of photos, taken previously, and entering of data and the completion of questionnaires were repeated twice by the trainee. In these afternoon sessions the photo taken by each assessor during the morning session was re-used to take measurements with PAT.

After the three repetitions of measurement the participants were asked to complete the second and third questionnaire regarding difficulties experienced during the measurements. The information pertaining to body alignment as measured by each assessor in each of the 3 respective measurement sessions were exported from PAT to an EXCEL® file.

Possible measurement error was limited as each assessor's computer was blocked from the view of the assessor next to them. During the measurement process no opportunity existed for one assessor to copy from the other.

Prior to the study a pilot study was conducted with five Physiotherapy final year students who went through the same training process. This pilot study was carried out to determine whether there were any problems using the computer programme, the training programme and the questionnaires. The results of the pilot study were excluded from the main study.

Data Analysis

Descriptive statistics, namely frequencies and percentages for categorical data and medians and percentiles for continuous data were calculated: firstly per measurement session, and secondly per assessor. The results were compared by means of 95% confidence intervals for measurement sessions and assessors. Repeatability or the estimation of the agreement between two measurements was done by means of the Bland-Altman analysis[30].

RESULTS

Participants in the study were female with a median age of 22 (range 21 to 23). Approximately a third (35.7%) of participants carried out regular posture assessments prior to the study, on a regular basis in clinical settings. Nine participants did not assess posture on a regular basis. The median number of posture assessments was four, with a minimum of two, and a maximum of seven assessments. One participant was excluded as she did not meet the minimum requirement of two assessments. The results therefore pertain to 14 participants. All participants found it easy to load photos onto the computer. All participants were of the opinion that this manner of posture assessment was more reliable than the visual analysis using the plumb line method. No problems were experienced during the three sessions regarding the taking of the photo, loading the photo and entering the data onto PAT. The participants' only recommendation was that PAT should indicate when it was saving the data, this adjustment has been made to the programme.

The PAT measurements reflect the deviation from the plumb line in millimetres. No participants had any problems regarding the measurements for any of the three sessions.

In *Table I* the measurements for PAT Anterior and Lateral position are given per session. As indicated the median measurement seemed not to vary i.e. naval at session 1 = -1.69 and the same of session 2, Session 3=-1.08.

Table I: PAT measurements Anterior and Lateral positions (n=14) per session (in millimetres from plumbline)

	Minimum	Median	Maximum
Session 1	**Anterior**		
Mid-medial malleoli	0	0	0
Mid-knee	-3.99	-1.23	2.15
Mid-pubis	-0.92	4.15	8.92
Naval	-7.70	-1.69	3.99
Sternum	-5.85	0.72	8.92
Nose	-8.31	-1.69	13.23
Session 2			
Mid-medial malleoli	0	0	0
Mid-knee	-3.69	-1.60	7.07
Mid-pubis	-0.92	3.84	12.61
Naval	-7.70	-1.69	8.3
Sternum	-5.85	0.57	13.22
Nose	-8.01	-2.16	16.91
Session 3			
Mid-medial malleoli	0	0	0
Mid-knee	-3.39	-0.62	2.18
Mid-pubis	-1.85	4.45	7.66
Naval	-9.26	-1.08	2.76
Sternum	-6.79	1.38	8.27
Nose	-6.79	-1.23	11.33
Session 1	**Lateral**		
Lateral malleolus	0	0	0
Anterior mid-knee	0.29	8.62	13.56
Greater trochanter	-85.59	-60.02	-2.71
Mid-acromion	-9.25	-0.63	10.46
Mid-ear lobe	-81.36	-58.48	-2.98
Session 2			
Lateral malleolus	0	0	0
Anterior mid-knee	7.37	8.61	13.55
Greater trochanter	-66.58	-60.9	-51.72
Mid-acromion	-14.74	-2.16	11.08
Mid-ear lobe	-71.87	-60.47	-45.57
Session 3			
Lateral malleolus	0	0	0
Anterior mid-knee	3.69	8.63	12.94
Greater trochanter	-66.38	-60.81	-52.99
Mid-acromion	-15.37	-1.23	9.86
Mid-ear lobe	-73.76	-59.87	-46.21

In *Table II* the differences between the sessions are given for the anterior position and the lateral left position with the 95% confidence interval for the median difference for paired data.

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Table II: Differences between sessions for the anterior and lateral positions

	Minimum	Median	Maximum	95% Confidence interval for the median difference
Session 1 vs Session 2				
Anterior				
Mid-medial malleoli	0	0	0	
Mid-knee	-4.92	0	2.46	[-1.54 ; 0.91]
Mid-pubis	-3.68	-0.0000006	2.45	[-1.54 ; 0.61]
Naval	-4.30	0	2.46	[-0.92 ; 0.32]
Sternum	-4.29	0	1.84	[-0.31 ; 1.22]
Nose	-3.68	0	1.85	[-1.54 ; 0.62]
Lateral				
Lateral malleolus	0	0	0	
Anterior mid-knee	-7.69	0	4.27	[-0.64 ; 0.64]
Greater trochanter	-23.02	0	63.63	[-1.16 ; 2.46]
Mid-acromion	-3.06	0.31	14.09	[-1.23 ; 1.85]
Mid-ear lobe	-21.88	0.01	68.88	[-0.55 ; 0.74]
Session 1 vs Session 3				
Anterior				
Mid-medial malleoli	0	0	0	
Mid-knee	-3.84	0.46	1.85	[-2.15 ; 1.54]
Mid-pubis	-2.76	0.62	2.15	[-1.54 ; 1.83]
Naval	-2.77	-0.46	1.84	[-1.83 ; 1.54]
Sternum	-3.38	0.31	1.54	[-1.85 ; 0.94]
Nose	-2.77	-0.15	2.15	[-1.81 ; 0.91]
Lateral				
Lateral malleolus	0	0	0	
Anterior mid-knee	-7.69	-0.01	4.29	[-0.59 ; 0.62]
Greater trochanter	-24.33	0.04	63.67	[-1.64 ; 1.19]
Mid-acromion	-1.23	0.61	14.72	[-0.60 ; 1.23]
Mid-ear lobe	-22.57	0.64	70.77	[-0.58 ; 1.81]
Session 2 vs Session3				
Anterior				
Mid-medial malleoli	0	0	0	
Mid-knee	-3.84	-0.000003	6.77	[-0.92 ; 0.93]
Mid-pubis	-1.23	0.16	5.56	[-0.62 ; 1.23]
Naval	-1.87	-0.31	5.54	[-1.24 ; 1.54]
Sternum	-1.85	-0.61	4.95	[-1.84 ; 0.92]
Lateral				
Nose	-1.88	-0.61	5.58	[-1.23 ; 0.94]
Lateral malleolus	0	0	0	
Anterior mid-knee	-1.84	0	3.71	[-1.23 ; 0.61]
Greater trochanter	-1.88	-0.34	3.62	[-1.32 ; 1.31]
Mid-acromion	-1.23	0.31	2.46	[-0.62 ; 1.23]
Mid-ear lobe	-0.69	0.31	3.61	[-0.65 ; 1.29]

Table III Bland–Altman analysis for the anterior and lateral positions comparing sessions

	95% limits of agreement between sessions
Session 1 vs Session 2	
Anterior	
Mid-knee	-3.23 ; 3.63
Mid-pubis	-2.59 ; 3.21
Naval	-2.75 ; 3.44
Sternum	-2.85 ; 3.20
Nose	-2.49 ; 3.11
Lateral	
Anterior mid-knee	-4.82 ; 5.31
Greater trochanter	-40.01 ; 34.60
Mid-acromion	-9.27 ; 7.02
Mid-ear lobe	-42.94 ; 36.01
Session 1 vs Session 3	
Anterior	
Mid-knee	-3.47 ; 3.49
Mid-pubis	-3.28 ; 2.82
Naval	-2.67 ; 3.15
Sternum	-2.70 ; 3.32
Nose	-2.66 ; 3.22
Lateral	
Anterior mid-knee	-4.98 ; 5.21
Greater trochanter	-40.18 ; 34.68
Mid-acromion	-9.25 ; 6.39
Mid-ear lobe	-44.4 ; 36.49
Session 2 vs Session3	
Anterior	
Mid-knee	-4.72 ; 4.34
Mid-pubis	-4.07 ; 2.99
Naval	-3.93 ; 3.71
Sternum	-3.51 ; 3.78
Nose	-3.89 ; 3.84
Lateral	
Anterior mid-knee	-2.75 ; 2.48
Greater trochanter	-3.09 ; 3.01
Mid-acromion	-2.51 ; 1.89
Mid-ear lobe	-2.95 ; 1.98

The sessions did not differ significantly from each other, as also indicated before in *Table I*. Even though sessions 2 vs 3 seem to differ more than 1 vs 2 and 1 vs 3, the confidence intervals were not statistically significant. Even though the *lateral position* varied less than the *anterior position* values they were not statistically significant. This indicates that PAT's measurements did not differ from session to session.

In Table III the 95% limits of agreement are given for the comparisons between sessions for both the anterior and lateral positions.

The limits of agreement indicate a variation of approximately within -3 to 3mm's which is considered clinically insignificant. No differences between sessions were observed for the anterior and the lateral photo between sessions 1 and 3**.** The lateral measurements for session one seem to differ from those of session 2 and 3, though not statistically significant (*Table II*). As in *Table III*, *Table IV* also indicates good reliability reaffirmed by the Spearman correlation in *Table IV*.

The closer the correlation is to 1, the stronger is the relationship. A poor correlation was only observed at session 1 vs 2 for the greater trochanter and mid-ear lobe anatomical landmarks and at session 1 vs 3 for the midknee, greater trochanter and mid-ear lobe anatomical landmarks, otherwise strong relationships existed between the measurements taken at each session. Most of the p-values in *Table IV* are significant indicating this was not a chance finding.

DISCUSSION

Health care workers commonly make use of the qualitative visual assessment method for the assessment of body alignment and postural imbalances. Lunes and colleagues[31] demonstrated that the agreement of data for comparison between visual assessment and computerised photogrammetry postural assessment is poor. In addition, the use of photography as measurement of spinal alignment is further recommended for its simplicity, low cost, and for its possibility of creating a database to document postural performance[32]. Dart[33] and colleagues regard reliability of spinal alignment measurement as critical to ensure that the presence or absence of an association between spinal alignment and NSCLBP can be accurately estimated.

The COSMIN[25] group developed a 4-point scale consensus-based model to evaluate the methodological quality of the relative measures of a reliability measuring instrument. When the PAT is evaluated for reliability according to the design requirements of the relative measures of this scale, PAT scores *excellent* on the 4-point scale, ranging from excellent to poor, with reference to 9 of the 10 design requirements. The exception was the size of the sample included in the analysis. It *firstly* indicates that the measurement conditions for all three sessions were similar regarding the type of administration, environment and instructions given to assessors. *Secondly*, it indicates that the components of the PAT i.e. the volunteer (photo subject), assessors and camera setup were stable in the process of the photographs being taken, and *thirdly*,

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Table IV: Lateral left and Anterior position

	Spearman correlation	p-value
Session 1 vs Session 2		
Lateral		
Anterior mid-knee	0.86	<0.01*
Greater trochanter	0.53	0.05
Mid-acromion	0.88	<0.01*
Mid-ear lobe	0.50	0.07
Anterior		
Mid-knee	0.71	<0.01*
Mid-pubis	0.89	<0.01*
Naval	0.93	<0.01*
Sternum	0.96	<0.01*
Nose	0.85	<0.01*
Session 1 vs Session 3		
Lateral		
Anterior mid-knee	0.93	<0.01*
Greater trochanter	0.54	0.05
Mid-acromion	0.90	<0.01*
Mid-ear lobe	0.51	0.06
Anterior		
Mid-knee	0.48	0.08
Mid-pubis	0.83	<0.01*
Naval	0.91	<0.01*
Sternum	0.87	<0.01*
Nose	0.82	<0.01*
Session 2 vs Session 3		
Lateral		
Anterior mid-knee	0.89	<0.01*
Greater trochanter	0.94	<0.01*
Mid-acromion	0.98	<0.01*
Mid-ear lobe	0.99	<0.01*
Anterior		
Mid-knee	0.78	<0.01*
Mid-pubis	0.92	<0.01*
Naval	0.96	<0.01*
Sternum	0.89	<0.01*
Nose	0.89	<0.01*

* Statistical significant

that the time interval between sessions was stated. *Fourthly*, at least two measurements were done, (3 measurements were done in PAT) and *fifthly* the administrations were done independently by the assessors. Sixthly, the design and execution of the study were adequately described with necessary detail and approved by an accredited ethics committee. Eight and nine refers to the percentage of the missing items and how the missing items were handled. In this study there were no missing items as the assessors completed all measurements. According to the 4-point scale nine of the ten above-mentioned criteria were met with *excellent* performance. Lastly the sample size of the study was the only exception which was considered small (<14) and is rated on the 4-point scale as *poor* according to the COSMIN[25] group. However, as mentioned earlier the authors expected a high reliability of 0.8 and therefore required an estimated sample size of only 14.4 assessors as indicated by Walter et al[28]. Therefore the authors of this article view the sample size as good.

The above mentioned provides information on the compliancy regarding the design requirements of the measuring instrument as suggested by the COSMIN[25] consensus based model. When the PAT is evaluated for reliability according to statistical methods, the COSMIN[25] group suggest that firstly, for continuous scores the Spearman correlation should be used. In this study it was calculated and no systematic change occurred for a classification of good in the model. Secondly, as there are only continuous data measurements for the PAT the rest of the criteria regarding ordinal scores do not apply.

In addition to the above methodological measures of quality, O'Sullivan, Galeotti, Danearts[1] suggest that intra-rater reliability of the device is important if it is to be used as an outcome measure, while inter-rater reliability is important if different assessors are to measure consistently. In this study only the intra-rater reliability of the PAT between sessions was studied and found to be consistent as indicated in *Tables I* (Descriptive statistics per session), *II* (confidence interval for the median difference between sessions), *III* (95% limits of agreement) and reaffirmed in *Table IV* by the Spearman correlation. Thus in this study intra-rater reliability of the PAT was relatively good (*Table II*).

The intra-rater variation across all sessions was high for the anterior view based on the small variation of the limits of agreement (*Table III*); a similar finding was also made by Dunk et al[15] who attributed variation to the many inherent factors contributing to the measured postures. There was some variation for the lateral view for session one but the variation was high for the rest of the sessions. The Spearman correlations (*Table IV*) reaffirm the high reliability of PAT.

After comparing the performance of PAT with leading researchers' criteria for testing of reliability instruments the results from the current study indicate the PAT as reliable for assessing the spinal alignment of the saggital and coronal plane.

CONCLUSIONS

In this study, the Posture Analysis Toolkit, a photogrammetric measurement instrument, was tested and proved to be reliable for use as an instrument for the assessment of standing postural alignment. Firstly, it is recommended that the application of PAT be compared to the findings of the generation of technological assessment instruments to determine spinal posture, and secondly to be tested for spinal alignment in positions other than standing, and lastly that the instrument be developed for measurement of dynamic posture in occupational settings.

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Corresponding Author

Mrs Ronette Hough

houghpa@ufs.ac.za

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