



Part I: Validity and reliability of a Photographic Method for Postural Assessment (P-MPA)

*Petronella Aletta Hough, BOT (UFS), MOT (UFS) <https://orcid.org/0000-0001-9931-6360>

Lecturer, Department of Occupational Therapy, Faculty of Health Sciences, University of the Free State, Bloemfontein

Mariette Nel, BA (UFS), BA Hons (UFS), M Med Sc in Biostatistics <https://orcid.org/0000-0002-3889-0438>

Lecturer, Department of Biostatistics, School of Medicine, University of the Free State

ABSTRACT

Introduction: Good postural alignment is positively associated with safe, mechanically effective and meaningful engagement in occupations. Health care professionals assess posture in clinical settings by using a variety of methods ranging from simple visual observation, to more complex quantitative assessments of postural alignment, which are costly and mostly done in laboratory environments. The need exists for a cost effective and user-friendly method for the assessment of posture in clinical settings and research studies.

Objectives: The aim of this study was to develop a Photographic Method of Postural Assessment (P-MPA) that quantitatively measures postural alignment, and to determine the validity and reliability of the P-MPA.

Methods: A graph, representing graphic postural alignment, was used consisting of a vertical line that represents the five levels of anatomical landmarks, with a horizontal line crossing the vertical line at each of the five levels. A total of 20 points were randomly plotted on the five horizontal lines. The graph was photographed using a smartphone, and A4 sized photographs were printed. Fifty participants measured and noted the distance deviations between the points on the horizontal lines and the vertical line. The actual deviation from the vertical line was calculated using a ratio of measured to real distance.

Results: The distance deviation between measured and actual distances was statistically significant for certain anatomical landmarks as indicated by 95% Confidence Intervals and Limits of Agreement. With respect to the anatomical landmarks and respective points, no clinically significant differences were observed, as a difference of less than 10mm was found.

Recommendations: It is recommended that the P-MPA be used, as a user-friendly and cost-effective method, for measuring postural alignment in clinical settings, and, that it be further developed and investigated as measurement tool for both single and multiple-joint research studies during activity performance.

Key words: Posture assessment, validity, reliability

INTRODUCTION

Good postural alignment is positively associated with safe¹, mechanically effective and meaningful engagement in occupations². Health care professionals assess posture in clinical settings by using a variety of methods^{3,4,5} which range from simple visual observation in clinical practice⁶, to more complex quantitative assessments of postural alignment^{7,8,9}. Many of these systems however proved to be time-consuming, complex and are difficult to use outside the laboratory environment, such as in the context of community and hospital settings.

With increasing pressure for accountability on quality practices as well as ethical standards in health service delivery, methods for assessment of posture are under continuous investigation to contribute to valid and reliable assessment practices¹⁰. Rosario¹¹ presented categories of methods of postural assessments from a study sample of 452 articles describing related technologies of Biomechanical assessment of human posture. These categories are visual observation, goniometry, photographic, radiographs, electromagnetic tracking, as well as the plumb line method. Singla and Vegar¹² and Rosario¹¹ both found that visual observation is the most generally used method to assess posture in clinical practice. Limitations of the visual observation method are that quantitative data cannot be obtained, and minor postural alterations cannot be detected. In addition, poor interrater agreement of the visual observation method discourage the use of this method for clinical and scientific research purposes. The "gold standard" radiographic method however is costly and risks exposure towards harmful

radiations, which promotes the use of non-invasive methods for the measurement of postural variables. Singla and Vegar¹² argues that the advancement of photographic method and its use as a method for postural evaluation is indisputable. This method has been compared with the visual observation method, goniometry and radiography and Singla and Vigar¹² and Rosario¹¹ recommend the use of the photogrammetric method for future studies that focus on posture evaluation.

Consistent with contemporary validity and reliability theories, the performance of a new instrument needs to be evaluated in terms of accuracy, correctness or conformity as it relates to the true context¹³ and value that is being measured¹⁴, as well as the consistency reflected in the measurements using the same instrument^{15,16}.

The objectives of the current study were therefore to: (i) develop a Photographic Method of Postural Assessment (P-MPA) that quantitatively measures postural alignment, (ii) test the P-MPA in terms of the accuracy of measurements between anatomical landmarks and the line of gravity, representing validity, and (iii) test the P-MPA in terms of reproducibility, representing reliability¹⁵.

Two of the 3 types of validity as suggested by The Consensus Based Standards group for the selection of health status Measurement Instruments (COSMIN group)¹⁷ were considered in the study of the P-MPA namely content validity which includes face validity, and construct validity which includes structural validity.

The COSMIN group¹⁸ regards 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 group further agrees on a property of reliability to be the amount of measurement error deemed acceptable for the effective clinical use of a measurement tool.

METHODOLOGY

A cross sectional study was conducted after obtaining ethical clearance from the Health Sciences Research Ethics Committee of the Faculty of Health Sciences at the University of the Free State (HSREC 153/2016 (UFS-HSD2016/1263).

The **development** of Photographic Method of Postural Assessment (P-MPA) comprised four steps. **Step 1:** A graph with measurements 1600x500x2mm was used as a graphic representation of postural alignment (See *Figure 1a*).

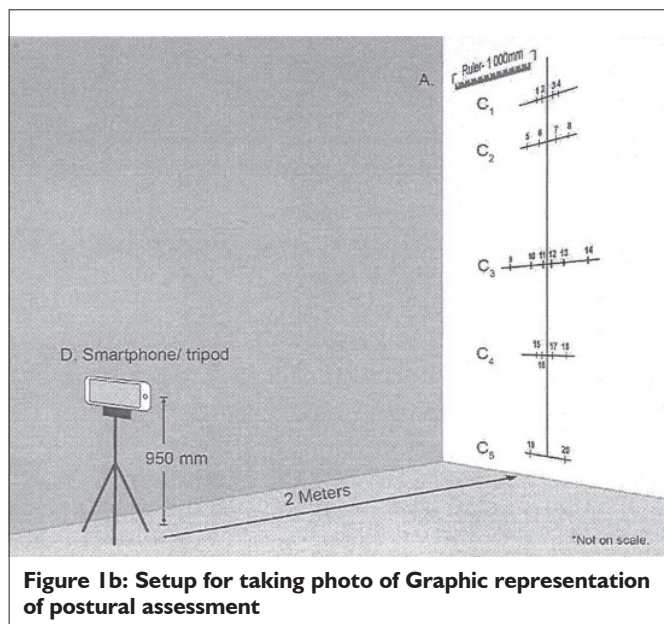
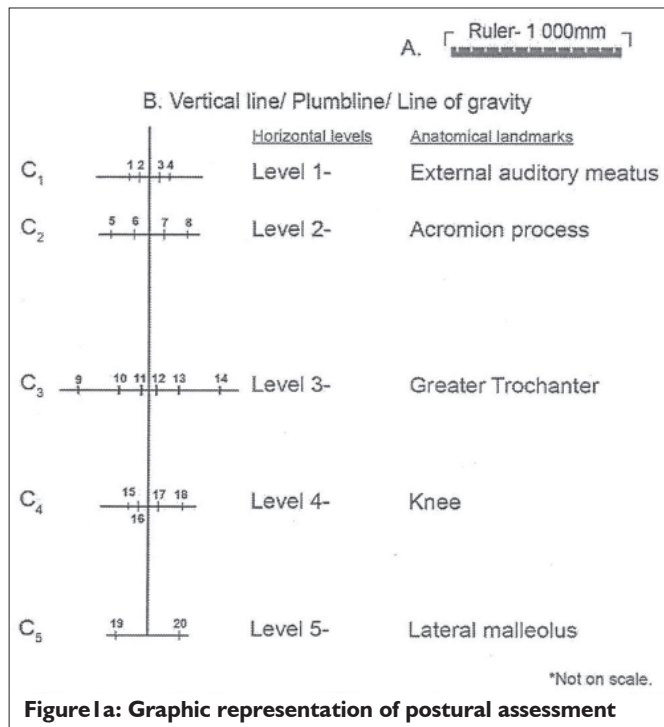


Figure 1: Photographic Method of Postural Assessment (P-MPA)

On the graph, a ruler (A) was positioned indicating a real distance of 1000mm. A vertical line (B) represents the line of gravity (plumb line) during posture assessment, and five horizontal lines (C1-5) that cut the vertical line, representing the levels of the anatomical landmarks¹⁹ namely lateral malleolus, greater trochanter, knee, acromion process and external auditory meatus. A total of 20 points were randomly plotted on the five horizontal lines, representing random possible deviations from the plumb line. The graph was mounted on a wall. **Step 2:** Two photographs were taken of the graph by using a smartphone(D) (Samsung, S6, 16MP, f/2.2, 31mm, OIS, autofocus) positioned at a right angle on a tripod at a distance of 2 meters from the graph, at the height of 950mm (*Figure 1b*). **Step 3:** Two A4 printed photographs were handed to each of the 50 participants who measured the distance deviation of each of the 20 points with respect to the plumb line. These measurements were documented and transferred to an excel spreadsheet. **Step 4:** The actual (real) distance on photos was established by calculating the ratio of *measured/real distance x distance from plumb line*. (see *Table I* on page 43 column: actual distances in mm's)

Procedure: On the first day steps 1 and 2 were performed by the researchers, namely graph was mounted, photographed, and A4 copies were printed. On the second day (step 3), measurements were done on the photographs. Fifty participants were each issued with two A-4 sized photographs of the graph and a 300mm ruler with mm increments. Participants were requested to (i) measure the distance in millimetres between each of the 20 points plotted on the five horizontal lines and the plumb line, and (ii) to note the measurements on a data form. After all the measurements were noted, the measurements were transferred from the data forms to an EXCELL spreadsheet by the researchers. For analysis purposes (step 4) the ratio of *measured/real distance x distance from the plumb line* was applied to all measurements.

Data were analysed using descriptive statistics namely medians and ranges for continuous data and frequencies and percentages for categorical data. Validity and reliability were described by means of 95% confidence intervals (CI) for the median difference for paired data, 95% limits of agreements²⁰.

RESULTS

Fifty university students from the department of Occupational Therapy gave informed consent to participate in the study. The median age was 20.1 years, ranging from 18.7 to 25.7 years. Most (90%) were in their second year of study. The actual and measured distances are shown in *Table I* on page 44.

As depicted in *Table I*, results pertaining to content validity indicate that the distance deviation between measured and actual distances for both photos were statistically significant (95% CI) for landmark 1: point 2, point 3 and point 4, landmark 2: point 5, point 8, landmark 3: point 14, and landmark 4: point 18. Statistically significant differences were also found for photo 2 at the following points, landmark 3: point 9 [-6.7;-6], landmark 5: point 19 [-3.3;-3.3] and point 20 [-3.3;-3.3]. Although statistically significant, no clinically significant differences were observed with respect to landmarks 1-5 and the respective points mentioned above. As noted in *Table I* the P-MPA limits of agreement vary mostly *within* 10mm for both photos, which indicates a high level of accuracy of the results obtained by measurements of the 20 points on the 5 horizontal landmarks in support of strong content validity.

For the purposes of this study, clinical significance was seen as 10mm (1cm) deviation from the plumb line. Clinical significance (or relevance) is based on clinical expertise²¹ therefore given the researcher's clinical experience regarding posture assessment the posture deviation from the plumb line within 1cm is viewed as clinically the same.

The reliability of the P-MPA results is given in *Table II* on page 44. To determine reliability, the differences between the two photos with reference to the distance measured and actual distance, were compared.

Table I: Distance deviation between measured and actual in mm (n=50)

| Variable | Anatomical landmarks | Actual distance in mm's | Measured distance in mm's on photo (range) | Median difference in mm's (range) | 95% CI for the median difference for paired data | 95% Limits of agreement |
|-----------------|------------------------------------|-------------------------|--|-----------------------------------|--|-------------------------|
| Photo 1 | 1: External auditory meatus | | | | | |
| Point 1 | | 40 | 40 (33.3-40.7) | 0 (0; 6.7) | 0 ; 0 | -2.4 ; 2.9 |
| Point 2 | | 21 | 20.0 (20-26.7) | 1 (-5.7; 1.0) | 1 ; 1* | -2.6 ; 3.8 |
| Point 3 | | 30.5 | 30 (26.7-33.3) | 0.5 (-2.8; 3.8) | 0.5 ; 0.5* | -2.2 ; 4.1 |
| Point 4 | | 61 | 60 (58.3-60.0) | 1.0 (1.0; 1.0) | 1 ; 1* | 1 ; 1 |
| | 2: Acromion | | | | | |
| Point 5 (n=45) | | 106 | 106.7 (106.7-113.3) | -0.7 (-0.7; 2.7) | -0.7 ; -0.7* | -1.9 ; 1.0 |
| Point 6 (n=49) | | 50 | 50 (46.7-53.3) | 2.0 (-3.3; 3.3) | 0 ; 3.3 | -1.8 ; 5.1 |
| Point 7 | | 50 | 50 (46.7-53.3) | 0 (-3.3; 3.3) | 0 ; 0 | -2.9 ; 3.6 |
| Point 8 (n=47) | | 106 | 106.7 (103.3-106.7) | -0.7 (-6.0; 2.7) | -0.7 ; -0.7* | -3.2 ; 3.4 |
| | 3: Greater trochanter | | | | | |
| Point 9 | | 140 | 146.7 (142.0-146.7) | 0 (-0.7; 0) | 0 ; 0 | -0.2 ; 0.2 |
| Point 10 (n=49) | | 70 | 71.7 (66.7-73.3) | 0 (-3.3; 3.3) | 0 ; 3.3 | -2.3 ; 4.8 |
| Point 11 | | 20 | 20 (13.3-30.0) | 0 (-6.7; 0) | 0 ; 0 | -2.3 ; 1.9 |
| Point 12 | | 10 | 10 (6.7-13.3) | 0 (-3.3; 3.3) | 0 ; 0 | -2.5 ; 2.7 |
| Point 13 | | 70 | 70 (66.7-73.3) | 0 (-6.7; 3.3) | 0 ; 0 | -3.7 ; 4.3 |
| Point 14 (n=49) | | 105 | 106.7 (106.7-106.7) | -1.7 (-1.7; 1.7) | -1.7 ; -0.3* | -8.7 ; 8.6 |
| | 4: Mid knee | | | | | |
| Point 15 | | 50 | 53.3 (40-66.7) | 0 (-3.3; 10.0) | 0 ; 0 | -3.4 ; 4.9 |
| Point 16 | | 10 | 10 (6.7-13.3) | 0 (-3.3; 3.3) | 0 ; 0 | -2.9 ; 3.6 |
| Point 17 | | 40 | 40 (40-42) | 0 (0; 0) | 0 ; 0 | 0 ; 0 |
| Point 18 (n=49) | | 85 | 86.7 (86.7-90) | -1.7 (-1.7; 5.0) | -1.7 ; -1.7* | -3.6 ; 0.7 |
| | 5: Lateral malleolus | | | | | |
| Point 19 | | 60 | 63.3 (60-66.7) | 0 (-1.3; 0) | 0 ; 0 | -0.5 ; 0.4 |
| Point 20 | | 60 | 63.3 (60-63.3) | 0 (-1.3; 0) | 0 ; 0 | -0.4 ; 0.4 |
| | | | | | | |
| Photo 2 | 1: External auditory meatus | | | | | |
| Point 1 | | 40 | 40 (33.3-40.7) | 0 (-0.7; 0.7) | 0 ; 0 | -1.8 ; 2.0 |
| Point 2 | | 21 | 20.0 (20-26.7) | 1.0 (-5.7; 1.0) | 1 ; 1* | -1.0 ; 2.8 |
| Point 3 | | 30.5 | 30 (26.7-33.3) | 0.5 (-2.8; 3.8) | 0.5 ; 0.5* | -1.5 ; 3.3 |
| Point 4 | | 61 | 60 (58.3-60.0) | 1.0 (1.0; 2.7) | 1 ; 1* | 0.5 ; 1.6 |
| | 2: Acromion | | | | | |
| Point 5 | | 106 | 106.7 (106.7-113.3) | -0.7 (-7.3; -0.7) | -0.7 ; -0.7* | -2.7 ; 1.1 |
| Point 6 | | 50 | 50 (46.7-53.3) | 0 (-3.3; 3.3) | 0 ; 0 | -2.6 ; 2.5 |
| Point 7 | | 50 | 50 (46.7-53.3) | 0 (-3.3; 3.3) | 0 ; 0 | -1.9 ; 2.2 |
| Point 8 | | 106 | 106.7 (103.3-106.7) | -0.7 (-0.7; 32.7) | -0.7 ; -0.7* | -12.1 ; 14.2 |
| | 3: Greater trochanter | | | | | |
| Point 9 | | 140 | 146.7 (142.0-146.7) | -6.7 (-6.7; -2.0) | -6.7 ; -6* | -8.6 ; -2.6 |
| Point 10 | | 70 | 71.7 (66.7-73.3) | -1.7 (-3.3; 3.3) | -3.3 ; 0 | -5.1 ; 1.9 |
| Point 11 | | 20 | 20 (13.3-30.0) | 0 (-10.0; 6.7) | 0 ; 0 | -3.5 ; 3.4 |
| Point 12 | | 10 | 10 (6.7-13.3) | 0 (-20.0; 3.3) | 0 ; 0 | -6.4 ; 5.9 |
| Point 13 | | 70 | 70 (66.7-73.3) | 0 (-3.3; 3.3) | 0 ; 0 | -3.8 ; 2.5 |
| Point 14 | | 105 | 106.7 (106.7-106.7) | -1.7 (-1.7; -1.7) | -1.7 ; -1.7* | -1.7 ; -1.7 |
| | 4: Mid knee | | | | | |
| Point 15 | | 50 | 53.3 (40-66.7) | -3.3 (-16.7; 10.0) | -3.3 ; 3.3 | -9.2 ; 3.8 |

... table continued on page 45

... table continued from page 44

| | | | | | | |
|----------|-----------------------------|----|----------------|-------------------|--------------|--------------|
| Point 16 | | 10 | 10 (6.7-13.3) | 0 (-3.3; 3.3) | 0 ; 0 | -2.4 ; 3.4 |
| Point 17 | | 40 | 40 (40-42) | 0 (-2.0; 0) | 0 ; 0 | -1.0 ; 0.8 |
| Point 18 | | 85 | 86.7 (86.7-90) | -1.7 (-5.0; 31.7) | -1.7 ; -1.7* | -14.3 ; 12.8 |
| | 5: Lateral malleolus | | | | | |
| Point 19 | | 60 | 63.3 (60-66.7) | -3.3 (-6.7; 0) | -3.3 ; -3.3* | -6.1 ; 0.1 |
| Point 20 | | 60 | 63.3 (60-63.3) | -3.3 (-3.3; 0) | -3.3 ; -3.3* | -5.2 ; 0.3 |

* Statistical significant difference

Table II: Differences between photos regarding the distance measured and actual distance in mm (n=50)

| Variable | Anatomical landmarks | Median difference in mm's (range) | 95% CI for the median difference for paired data | 95% limits of agreement |
|----------|------------------------------------|-----------------------------------|--|-------------------------|
| | 1: External auditory meatus | | | |
| Point 1 | | 0 (0; 6.7) | 0 ; 0 | -3.1 ; 3.9 |
| Point 2 | | 0 (-6.7; 0) | 0 ; 0 | -2.9 ; 2.5 |
| Point 3 | | 0 (-6.7; 3.3) | 0 ; 0 | -5.1 ; 3.6 |
| Point 4 | | 0 (-1.7; 0) | 0 ; 0 | 0 ; 0 |
| | 2: Acromion | | | |
| Point 5 | | 0 (0; 53.3) | 0 ; 0 | -1.2 ; 1.7 |
| Point 6 | | 1.3 (-3.3; 13.3) | 0 ; 3.3 | -2.7 ; 4.3 |
| Point 7 | | 0 (-6.7; 6.7) | 0 ; 0 | -3.9 ; 4.9 |
| Point 8 | | 0 (-33.3; 33.3) | 0 ; 0 | -3.1 ; 4.1 |
| | 3: Greater trochanter | | | |
| Point 9 | | 6.7 (2; 33.3) | 6 ; 6.7* | -1.1 ; 5.6 |
| Point 10 | | 3.3 (-30; 6.7) | 2 ; 3.3* | -1.6 ; 7.8 |
| Point 11 | | 0 (-6.7; 10) | 0 ; 0 | -1.0 ; 0.9 |
| Point 12 | | 0 (-3.3; 20) | 0 ; 0 | -3.3 ; 4.5 |
| Point 13 | | 0 (-6.7; 6.7) | 0 ; 0.7 | -3.5 ; 8.4 |
| Point 14 | | 0 (0; 30) | 0 ; 1.3 | -1.8 ; 4.4 |
| | 4: Mid knee | | | |
| Point 15 | | 3.3 (-6.7; 16.7) | 3.3 ; 3.3* | -5.9 ; 7.8 |
| Point 16 | | 0 (-6.7; 3.3) | 0 ; 0 | -1.9 ; 2.5 |
| Point 17 | | 0 (0; 2) | 0 ; 0 | -0.6 ; 0.8 |
| Point 18 | | 0 (-66.7; 6.7) | 0 ; 0 | -1.9 ; 2.5 |
| | 5: Lateral malleolus | | | |
| Point 19 | | 3.3 (0; 6.7) | 3.3 ; 3.3* | -1.6 ; 5.8 |
| Point 20 | | 3.3 (0; 3.3) | 3.3 ; 3.3* | -1.3 ; 5.5 |

* Statistical significant difference

Although statistically significant differences (95% confidence interval for the difference) were found when the two photos were compared (vary within 7mm), no clinically significant differences were found as it fell within 10 mm.

In addition to the confidence interval difference, the limits of agreement indicate that the measurement methods are similar as the agreement deviates within 10mm, which has the clinical implication that the measurements do not differ from the actual values.

DISCUSSION

With the need for evidence to advance quality health care service delivery, researchers need to provide research results that are clinically relevant and have an impact on decision making in order to enhance evidence-based practice.

Graphical representation of body measurement of the whole body allows for the "derivative" measurements in research²². The

P-MPA is similar to the 'moiré' projection technique²², of a spatial object with limited depth, leading to the formation of a 'moiré' topography on the object surface.

Consistent with contemporary calls for validity and reliability^{13,14}, results from the current study reflect *content validity* of the P-MPA, which was further evaluated for *construct validity*, and reported in terms of accuracy. This current study also reports on the intra-rater reliability in terms of consistency reflected in the measurements of deviations from the plumb line.

In order to establish *content validity*²³ the graph used in the current study represented the five anatomical landmarks which is depicted by means of horizontal lines, and 20 points plotted on the horizontal lines indicating the possible range in distance deviation from the plumb line. Consistent with the plumb line observational method of assessment of posture¹⁹ these five horizontal lines were representative of the anatomical landmarks used in the assessment

of posture namely lateral malleolus, knee, greater trochanter, acromion and external auditory meatus. *Face validity* was reflected by the representation of the constructs of the anatomical landmarks on the graph, which reflected the dimensions of a person of 1.6m in height as well as the range in distances of the 20 points plotted on the horizontal lines. *Construct validity* was ensured by using a ratio to calculate the actual distances between the anatomical landmarks and the points on the horizontal lines in relation to the plumb line.

Similar to the research performed by authors Grosso, Negrini, Boniolo and Negrini²³ a clinically significant difference in the current study was set at 10mm to compensate for physiologic responses in the short term. From a practice perspective, a clinically significant difference value of 10mm from the reference point was considered to accommodate for minor postural re-adjustments that a person makes after a position had been assumed, as is often seen in clinical practice in preparation for postural assessment. No other laboratory studies, with similar objectives, were found that specify a clinical value for comparison.

Contrary to the design of other studies, the advantage of this study was that the actual deviation from the plumb line was a constant and known measure to compare to, which contributes to construct validity. In comparison to evidence from existing studies^{10,24,25} the P-MPA is a valid instrument to measure posture, considering that the measured distances (in *Table II* on page 45) deviate within 10mm from the actual values.

In line with the Cosmin's theory of reliability, the P-MPA has good reproducibility as indicated by the 95% confidence intervals and limits of agreement (in *Table II*) and can therefore be repeatedly used by different users as no clinically significant differences were found between measurements, as performed by the 50 participants. The high level of accuracy of the P-MPA has been demonstrated, and results on reliability reflect both accuracy and repeatability, which according to Altman²⁰, justifies good agreement.

The estimated limits of agreement indicate how large disagreements between methods measurements will be on 95% of occasions. As seen in the results of this study, the measurements do not differ clinically significantly which confirms the P-MPA to be a reliable inter-rater measurement instrument to use.

The statistical significant distance deviations between measured and actual distances observed at the extremities of the anatomical landmarks could be due to measurement error of the camera lens. This was also noted by Strzecha et al²⁶, with the analysis of photogrammetric systems that showed that none of these systems features options of automated adjustment of the camera height, which were not equipped in distance sensors (rangefinders). Distance sensors allow for precision measurement of the distance of a selected body part of a patient from the camera lens. However, in the current study, differences between measured and actual values are clinically insignificant and the P-MPA can, therefore, be used as a measurement tool for the assessment of posture.

Finally, contrary to the subjective nature of qualitative reporting when using the plumb line method of posture assessment, results from this study indicate that the P-MPA is valid and reliable as a quantitative method for the assessment of posture.

CONCLUSION

Results from this study show that the method of postural assessment (P-MPA) can be used as a valid (face, content and construct validity) and reliable method in a clinical context for the assessment of postural alignment.

RECOMMENDATION

It is recommended that the P-MPA be used, as a user-friendly and cost-effective method, for measuring postural alignment in both clinical settings and research studies. The authors recommend that the P-MPA be investigated further regarding its reproducibility; firstly comparing different postural alignments from different patients measured by different therapists within the clinical context,

and secondly, determine the lack of camera lens range-finding function by using more cameras and that the photos be measured more than once by the same therapists. Lastly, we recommend that the P-MPA be further developed and investigated as a measurement tool in both single and multiple-joint research studies such as in the alignment of hand and wrist joints during activity performance.

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□

Corresponding Author

***P A Hough**

houghpa@ufs.ac.za