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A computer vision-based mobile tool for assessing human posture: A validation study

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ABSTRACT

Background and Objective: Non-invasive methods for postural assessment are tools used for tracking and monitoring the progression of postural deviations. Different computer-based methods have been used to assess human posture, including mobile applications based on images and sensors. However, such solutions still require manual identification of anatomical points. This study aims to present and validate the *NLMeasurer*, a mobile application for postural assessment. This application takes advantage of the PoseNet, a solution based on computer vision and machine learning used to estimate human pose and identify anatomical points. From the identified points, *NLMeasurer* calculates postural measures. Methods: Twenty participants were photographed in front view while using surface markers over anatomical landmarks. Then, the surface markers were removed, and new photos were taken. The photos were analyzed by two examiners, and six postural measurements were computed with *NLMeasurer* and a validated biophotogrammetry software. One-sample *t*-test and Bland Altman procedure were used to assess agreement between the methods, and Intraclass Correlation Coefficient (ICC) was used to assess inter- and intra-rater reliability. Results: Postural measurements calculated using the *NLMeasurer* were in agreement with the biophotogrammetry software. Furthermore, there was good inter- and intra-rater reliability for most photos without surface markers. Conclusions: *NLMeasurer* demonstrated to be a valid tool method to assess postural measurements in the frontal view. The use of surface markers on specific anatomical landmarks (i.e., ears, iliac spines and ankles) can facilitate the digital identification of these landmarks and improve the reliability of the postural measurements performed with *NLMeasurer*.

1. Introduction

Bilateral symmetry in morphological features in humans [1] contributes to postural stability. Although small asymmetries do not represent bodily impairments, postural misalignments are often associated with the presence of musculoskeletal pain and impaired movement [2]. Moreover, depending on the severity of the postural misalignment, pain and movement disorders can decrease the performance of individuals in their daily activities [3].

The influence of body posture on human health makes postural assessment part of physical examination performed in medicine. This allows health professionals to develop therapeutic programs for patients according to the severity of their postural misalignments and their functioning disabilities [2]. Palpation associated to visual inspection is used for postural assessment, a process in which the examiner, using his/her hands, touches the patient and visually searches for body asymmetries. It is a cost-free method that does not require the use of equipments, and is therefore routinely used by professionals [4].

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Fig. 1. *NLMeasurer* screenshots: (a) new image capture screen with x, y and z axes at the top of the screen, so indicating that the mobile device is aligned; (b) floating buttons with functions available in *NLMeasurer*; (c) determination of the reference segment size; and (d) digital markers positioned on the anatomical landmarks.

Another method used to assess postural alterations, especially spinal misalignments, is the calculation of the Cobb angle on X-ray images. However, in this case, patients are repeatedly exposed to radiation [5]. To avoid negative impact of X-ray examinations, non-invasive methods have been developed, such as manual tools [6] and computer-based solutions [7].

Among non-invasive methods, computer-based solutions such as biophotogrammetry (i.e., a method for quantifying postural assessment by measuring linear distances and angles using digital photographs [8,9]), have been widely explored. Examples of biophotogrammetry software solutions are Biotonix [10,11], Posture Assessment Software (in Portuguese, *Software de Avaliação Postural - SAPO*) [12], Digital Image-based Postural Assessment Software (DIPA) [13], and Posture Pro [14]. Due to advances in computing power of smartphones, mobile applications for postural assessment have been proposed for health professionals [15]. Regarding image-based mobile applications, PostureScreen Mobile (PSM) was a pioneer mobile application for biophotogrammetry, which has been studied by several researchers [2,16–18]. PSM is a mobile application that already integrates human body image capture using the smartphone and an interface that allows the evaluator to manually mark specific anatomical landmarks on photos using a zoom-in tool and the touch screen function.

Although biophotogrammetry software has represented an important advance in the postural assessment process, desktop solutions still need manual identification of anatomical landmarks, which requires the examiner to place reflective markers on them, so results may be biased by his/her ability to recognize such anatomical landmarks. Moreover, both current desktop and mobile solutions studied in the literature have not a feature responsible for the automatic detection of anatomical landmarks, which can provide agility in the evaluation process and reduce the occurrence of human error in placing markers.

In this study, we propose *NLMeasurer for Postural Assessment*, a mobile application based on computer vision that enables the automatic identification of anatomical landmarks and, from them, the recognition of body alignment angles. The objectives of this study are: (1) to present the *NLMeasurer* for postural assessment in the frontal view; and (2) to validate *NLMeasurer* as a postural assessment tool. For this purpose, *NLMeasurer* is compared to the *SAPO*, a validated software [12], in measurements performed with and without using surface markers on the body (i.e., external markers positioned on the anatomical landmarks of the individual's body). To the best of our knowledge, this is the first study to explore automatic detection of anatomical landmarks for postural assessment.

The remaining of this paper is organized as follows. Section 2 describes the *NLMeasurer* and experimental protocol. Section 3 presents the results, while we discuss them in Section 4. Finally, in Section 5, we derive our conclusions.

2. Methodology

2.1. NLMeasurer for postural assessment

NLMeasurer is a mobile application for health professionals capable of recording individual evaluations from the automatic identification of anatomical landmarks and the determination of anthropometric measures and body alignment angles in frontal view body images. *NLMeasurer* is an application based on image analysis, then it requires capturing a photo. For this purpose, the application monitors the device position using accelerometers (i.e., by using an embedded inertial sensor) that provide the angles for x, y, and z axes (shown at the top of the screen in Fig. 1a), and allows the photo to be taken only from the proper perspective. When the text turns green the smartphone is correctly aligned, while in red the device is in unsuitable position for the photo since perspective effects can introduce systematic errors in determining the measurements.

NLMeasurer was developed using IONIC Framework [19] and taking advantage of the PoseNet API [20]. PoseNet is a computer vision model running on TensorFlow.js [21] library for ML in JavaScript. This includes the method *estimateSinglePose*, which *NLMeasurer* uses to estimate the human pose from an image using anatomical landmarks as reference. The captured image is processed by the PoseNet that returns a JSON object containing: (i) a vector with 17 key points (i.e., anatomical landmarks) - each one of them with a position (x, y) and the name of the identified key points related to body parts (Table 1), (ii) the score rate values for each key point, varying between 0.0 and 1.0, which represent confidence scores associated to each inference made by the model, and (iii) the mean score for all key points.

PoseNet offers several parameters that can be combined. The performance of the *NLMeasurer* to identify the anatomical landmarks has been tested with 72 different combinations of these parameters to evaluate the feasibility of using the PoseNet to identify

Table 1
Anatomical Landmarks identified and Postural Measurements (PM) performed using *NLMeasurer*.

Anatomical Landmarks	PM
Nose, Eyes (2), Ears (2), Shoulders (2), Elbows (2), Wrists (2), Hips (2), Knee (2) and Ankles (2)	Head Tilt, Shoulder Tilt, Hip Tilt, Ankle Tilt, Right knee angle and Left knee angle,

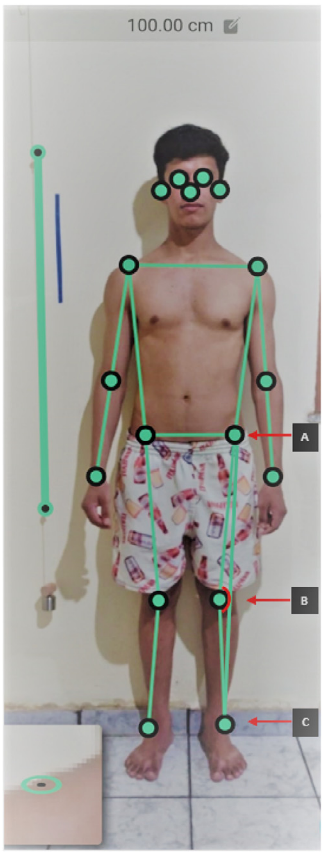

Fig. 2. Knee angle (∠*ABC*) defined by: (A) the anterior superior iliac spine - left ($ASIS_L$); (B) the left knee; and (C) the left ankle.

anatomical landmarks [22]. Among the 72 combinations of parameters tested, the one with the best performance is used in *NLMeasurer* for the implementation of the postural assessment function.

NLMeasurer computes PMs based on the Euclidean distance and the law of cosines, which is used to find angles in non-right triangles. To calculate PMs, coordinates (x, y) of 2 points (A, B) representing parallel anatomical landmarks are used. A third point (C) is formed from the coordinates A(y) and B(x), then forming C(x, y). By using Euclidean distance, *NLMeasurer* identifies the distances d(AB), d(BC) and d(AC). When finding the values of the distances between the points, a triangle is formed. The law of cosines is then applied, and the resulting value is applied to Eq. (1) to calculate the tilt angle of the body segments.

$$angle = \cos\theta^{-1} + 180/\pi \tag{1}$$

In Eq. (1), $\cos\theta$ is the value previously found by the law of cosines, and its inverse represents the intended angle. The *angle* variable corresponds to the tilt angle of the body segments. For example, these calculations are used to identify the knee angle (∠*ABC*), as shown in Fig. 2.

2.2. Sample

A sample of 20 individuals (five men) participated in this study: age varying between 12 and 66 years (35.1±17.5), height of 1.60±0.1cm, and body mass index of 25.6±4.0kg/m^2. These participants were recruited in Sobral, a Brazilian city. Subjects with history of diseases that could compromise balance and standing position and who refused to be photographed according to the experimental protocol were not included. Ethical approval was obtained from the institutional review board of the Federal University of Piauí (number 2.927.518). All participants, or their legal guardians, signed the informed consent form.

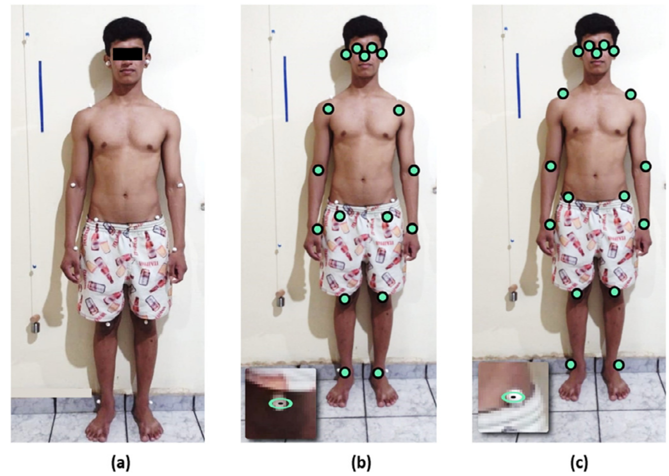

Fig. 3. (a) Surface marker placement; (b) Position of surface markers and digital markers automatically identified; and (c) Position of digital markers on surface markers.

2.3. Data collection

Anatomical landmarks were identified on the participant's body through palpation by a single physiotherapist evaluator. Reflective surface markers (i.e., styrofoam balls with 15 mm circumference) were placed on the participant's body while he/she remained standing in front of a wall. A 1-meter plumb line marked with two styrofoam balls was used for vertical calibration. The evaluator positioned herself 2 m in front of the participant, took the photo with a smartphone running the *NLMeasurer* application - Android 10, Qualcomm Snapdragon 662 (2.0 GHz Octa-Core)/Adreno 610 processor, 4.0 GB RAM, and 48 MP camera. Then, the evaluator removed the surface markers from the participant's body and registered a new photo for evaluation. All photos were taken in front view and saved in the *NLMeasurer* library.

2.4. Data analysis

First, the photos with surface markers were analyzed with *NLMeasurer* (Fig. 3a). In this step, the evaluator selected the function to identify anatomical landmarks, and the 17 markers (Table 1) were automatically identified on the photo (Fig. 3b). When necessary, the digital markers were moved manually by the evaluator (Fig. 3c). After confirming anatomical landmarks, the evaluator selected the postural assessment function to calculate posture measurements (Table 1) and present them in a PDF report. Results were recorded in a spreadsheet for later comparison with *SAPO* (version 0.69). The same photo analysis was performed by a

Table 2
Results of postural measurements by *NLMeasurer* and *SAPO* with individuals using surface markers.

PM	NLMeasurer Mean±SD	SAPO Mean±SD	Z-Value & *p*-value	Spearman's Correlation (r) & *p*-value
Head tilt	3.77±2.92	3.47±2.67	-0.747; p=0.455	0.749; p<0.001
Shoulder tilt	2.18±1.56	2.11±1.64	-0.803; p=0.422	0.679; p=0.001
Hip tilt	1.58±0.86	1.38±1.06	-0.896; p=0.370	0.606; p=0.005
Ankle tilt	1.67±0.98	1.95±1.06	-1.307; p=0.191	0.608; p=0.004
Right knee tilt	163.93±4.03	163.92±3.8	0.747; p=0.455	0.888; p<0.001
Left knee tilt	165.94±3.56	166.09±3.68	0.971; p=0.332	0.932; p<0.001

Table 3
Results of postural measurements by two evaluators making use of *NLMeasurer* with subjects using surface markers.

PM	First Evaluator Mean±SD	Second Evaluator Mean±SD	ICC	*p*-value
Head tilt	3.77±2.92	3.45±2.85	0.848	p<0.0001
Shoulder tilt	2.18±1.56	2.25±1.55	0.815	p=0.0002
Hip tilt	1.58±0.86	1.35±1.18	0.749	p=0.0013
Ankle	1.67±0.98	1.65±1.35	0.867	p<0.0001
Right knee tilt	163.92±4.03	164±3.86	0.975	p<0.0001
Left knee tilt	166.03±3.64	166.1±3.86	0.880	p<0.0001

second evaluator and data recorded in another spreadsheet. Fifteen days after the end of the first analysis, the first evaluator repeated the analysis with *NLMasurer* in the photos without surface markers.

Fifteen days after the analyses with *NLMeasurer*, the photos with surface markers were exported to a desktop computer and analyzed using *SAPO*, in which the same six postural measurements were calculated (Table 1). Results were recorded in a third spreadsheet for later comparison. This step was performed to validate *NLMeasurer*.

2.5. Statistical analysis

Statistical analysis was conducted using IBM SPSS 20.0 (IBM Corp., Armonk, NY). Spearman's and Pearson's correlation [23] was applied to quantify the correlation between *NLMeasuer* and *SAPO*. However, a strong correlation may not present strong agreement. Based on this, the statistical procedure Bland Altman [24] with a Wilcoxon and one-sample *t*-test with data from the first evaluator were used to verify the agreement between both software tools. Both parametric and non-parametric tests were considered for use based on the basic assumptions for choosing statistical tests, including data normality. To assess agreement between evaluator, the Intraclass Correlation Coefficient (ICC) [25] was performed for inter- and intra-rater reliability. P-values less than 0.05 were considered statistically significant.

3. Results

There was a positive correlation from moderate to strong between *NLMeasurer* and *SAPO*, and the Wilcoxon test showed that there was no significant difference between them (Table 2). Bland Altman plots (Fig. 4) also showed that the mean difference values between postural measurements identified using *NLMeasurer* and *SAPO* were not significant in any of the evaluated segments. Moreover, no proportion bias was identified, that is, values did not tend to deviate from the mean (p>0.05).

Table 3 shows comparisons between two evaluators for postural measurements performed with *NLMeasurer*. The results do not demonstrate a significant statistical difference between them, and indicate an excellent inter-evaluator reliability for all measured angles.

Table 4 shows a comparison of the results obtained by the same evaluator (the first evaluator) in two moments at a 15-day interval. The results demonstrate similarity between the two moments, then showing that there was no significant difference in measurements by *NLMeasurer* between the first and second evaluations (i.e., there was excellent intra-rater reliability.)

When analyzing photos in which the subjects were not using surface markers, Pearson correlation demonstrated that there was a moderate positive correlation between *NLMeasurer* and *SAPO* measurements, except for hip (r=-0.046; p=0.846) and ankle (r=0.142; p=0.551) tilts. One-sample *t*-test showed that the mean of postural measurements evaluated with *NLMeasurer* was not significantly different from the measurements performed using *SAPO* (p>0.05) (Table 5).

Bland Altman plots (Fig. 5) also showed that mean differences between the postural measurements evaluated with *NLMeasurer* and *SAPO* in the subjects without using surface markers were not significant in any of the evaluated segments (p>0.05). Moreover, no proportion bias was identified (i.e., values did not tend to deviate from the mean), so demonstrating the agreement between *NLMeasurer* and *SAPO* for all postural measurements, similarly what occurred in the analysis of the photos in which participants were using surface markers.

The ICC test demonstrated a reasonable and excellent inter-evaluator reliability (Table 6), except for head and ankle tilts (poor correlation).

Table 7 shows a comparison of the results obtained by the same evaluator (i.e., the first one) in two moments in a 15-day interval. Results demonstrated similarity between the two days, then showing no significant difference in measurements by *NLMeasurer* between the first and second assessments (i.e., there was good or excellent intra-rater reliability), except for ankle tilts.

4. Discussion

NLMeasurer allows for marking automatically 17 anatomical landmarks in the frontal view of the human body, which are identified by a machine learning-based computer vision solution. The evaluator checks if they are correctly positioned and makes the necessary adjustments, moving the digital markers manually, directly on the device screen. In addition, *NLMeasurer* automatically calculates postural measurements and generates a posture assessment report. Analysis of these postural measurements demonstrated validity of the *NLMeasurer* for evaluating postural alignment in the frontal view, when comparing it with *SAPO*, using photos with and without surface markers.

There is no significant difference between *NLMeasurer* and *SAPO* for postural measurements performed using photos with surface

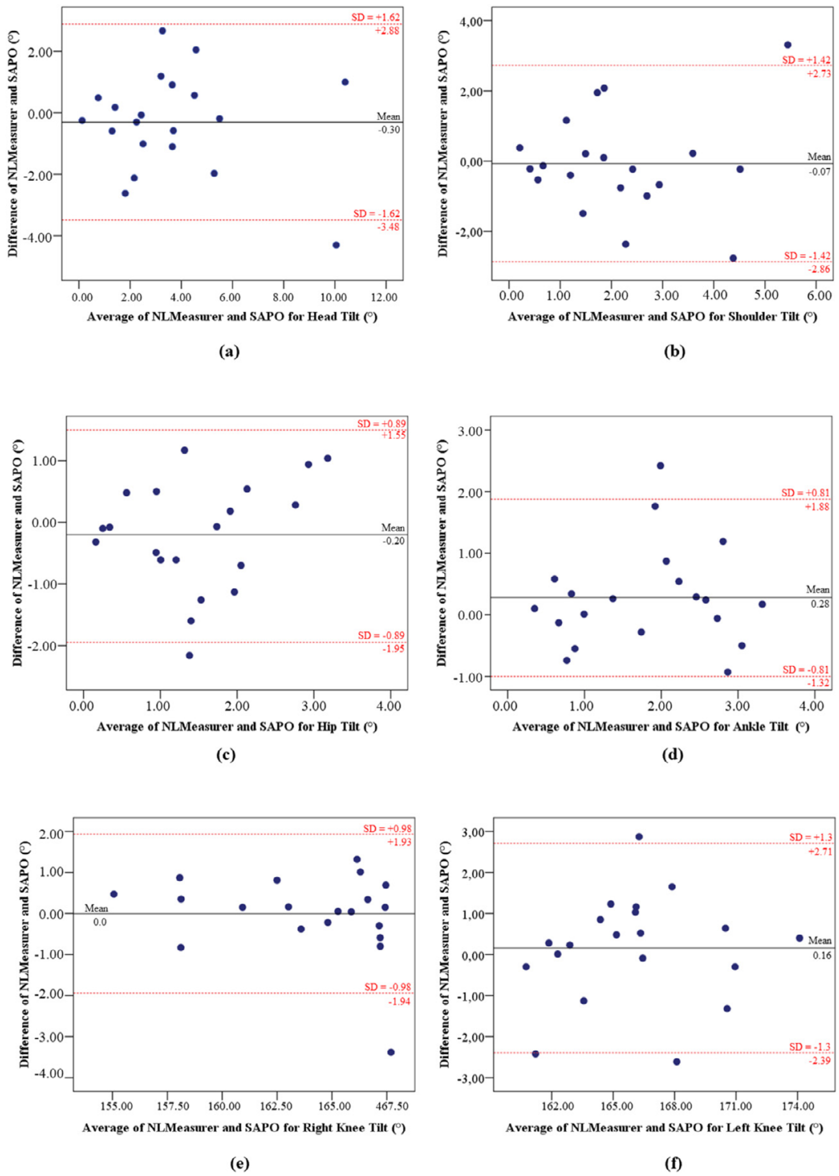

Fig. 4. Bland Altman Plot showing differences between *NLMeasurer* and *SAPO* with individuals using surface markers for: (a) head tilt, (b) shoulder tilt, (c) hip tilt, (d) ankle tilt, (e) right knee tilt, and (f) left knee tilt. The centered gray lines show mean difference, and the 2 outer dotted lines represent 95% confidence interval (CI).

Table 4
Results of postural measurements by the first evaluator making use of *NLMeasurer* in two moments, and with subjects using surface markers.

PM	First Evaluator Mean±SD	Second Evaluator Mean±SD	ICC	*p*-value
Head tilt	3.77±2.92	3.95±3.34	0.950	$p<0.001$
Shoulder tilt	2.18±1.56	2.20±1.63	0.916	$p<0.001$
Hip tilt	1.58±0.86	1.46±1.15	0.880	$p<0.001$
Ankle tilt	1.67±0.98	1.52±1.20	0.937	$p<0.001$
Right knee tilt	163.92±4.03	163.79±4.14	0.980	$p<0.001$
Left knee tilt	166.04±3.64	166.95±4.23	0.856	$p<0.001$

Table 5
Results of postural measurements when using *NLMeasurer* and *SAPO* with subjects without making use of surface markers.

PM	NLMeasurer Mean±SD	SAPO Mean±SD	*t*-test and *p*-value	Correlation (r) and *p*-value
Head tilt	4.07±2.58	3.47±2.67	$t(19)=1.474$ ($p=0.157$)	0.758 ($p=0.001$)
Shoulder tilt	1.79±1.67	2.11±1.64	$t(19)=0.883$ ($p=0.388$)	0.513 ($p=0.021$)
Hip tilt	1.36±0.98	1.38±1.06	$t(19)=0.075$ ($p=0.941$)	-0.046 ($p=0.846$)
Ankle tilt	1.52±0.81	1.95±1.06	$t(19)=1.544$ ($p=0.139$)	0.142 ($p=0.551$)
Right knee tilt	165.12±3.46	163.92±3.8	$t(19)=1.844$ ($p=0.081$)	0.685 ($p=0.001$)
Left knee tilt	167.27±3.36	166.09±3.68	$t(19)=1.825$ ($p=0.084$)	0.669 ($p=0.001$)

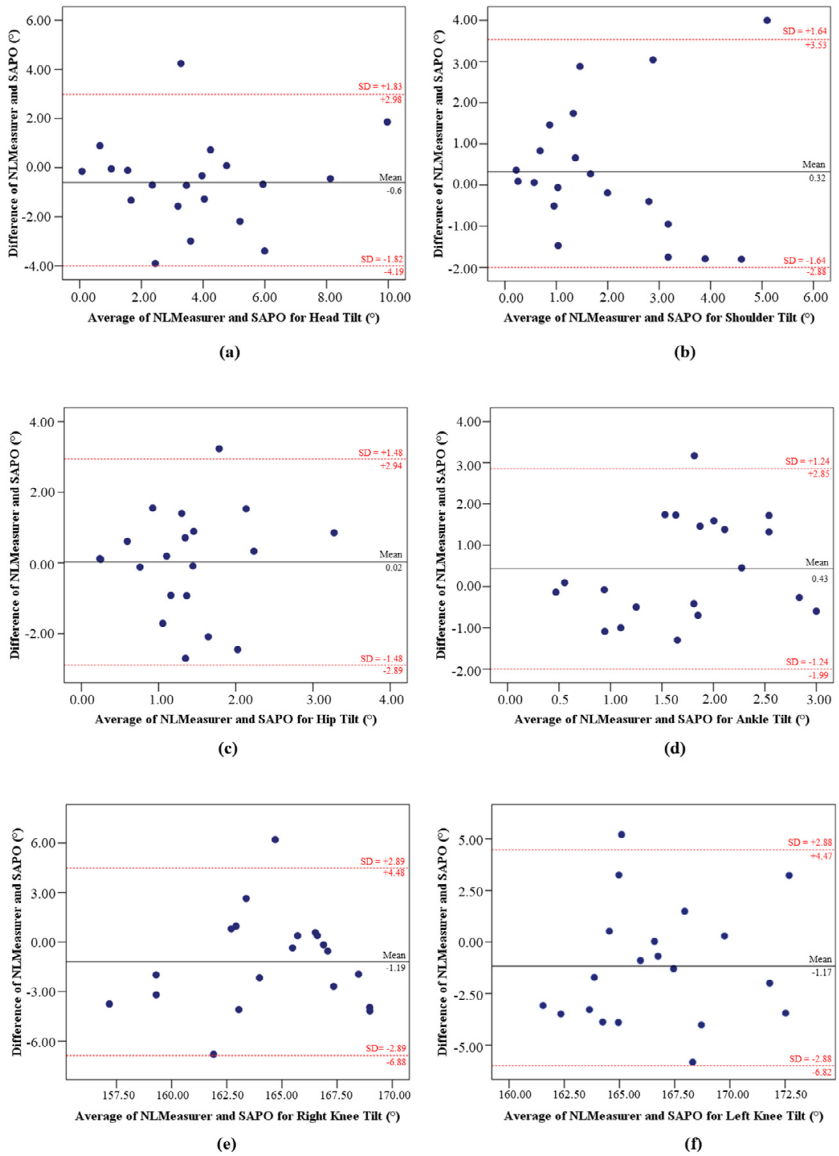

Fig. 5. Bland Altman plots showing differences between *NLMeasurer* and *SAPO* without making use of surface markers, for (a) head tilt, (b) shoulder tilt, (c) hip tilt, (d) ankle tilt, (e) right knee tilt, and (f) left knee tilt. The centered gray lines show the mean difference, and the 2 outer dotted lines represent 95% CI.

Table 6
Results of postural measurements by two evaluators making use of *NLMeasurer* with subjects without using surface markers.

PM	First Evaluator Mean±SD	Second Evaluator Mean±SD	ICC	*p*-value
Head tilt	4,1±2.58	2.8±2.1	0.420	p=0.097
Shoulder tilt	1.79±1.67	1.56±1.33	0.816	p<0.0001
Hip tilt	1.36±0.98	1.27±0.93	0.670	p=0.012
Ankle tilt	1.52±0.81	1.82±1.68	0.037	p=0.469
Right knee tilt	165.12±3.46	168,33±3.69	0.643	p=0.001
Left knee tilt	167.62±3.21	168.83±3.54	0.595	p=0.023

Table 7
Results of postural measurements by the same evaluator making use of *NLMeasurer* in two moments, with subjects without using surface markers.

PM	First Day Mean±SD	Second Day Mean±SD	ICC	*p*-value
Head tilt	4.07±2.58	3.88±2.73	0.950	p<0.0001
Shoulder tilt	1.79±1.67	1.85±1.46	0.859	p<0.0001
Hip tilt	1.36±0.98	1.45±1.08	0.708	p=0.006
Ankle tilt	1.52±0.81	1.29±0.75	-0.267	p=0.692
Right knee tilt	165.12±3.46	166.46±3.84	0.747	p=0.001
Left knee tilt	167.62±3.21	168.94±2.36	0.785	p<0.0001

markers and, for this reason, we assume that calculations implemented to identify body alignment angles are valid. Moreover, the agreement between *NLMeasurer* and *SAPO*, when analyzing photos without surface markers (Fig. 5), indicates that *NLMeasurer* is also a valid tool for performing postural assessment in the frontal view without surface markers. This means that manual adjustments to correct the position of the digital markers on the device's screen did not compromise the performance of the *NLMeasurer* to calculate postural measurements. However, we should pay attention to some data to ensure the proper use of this application in clinical practice. Intra and inter-rater reliability indicate that *NLMeasurer* is an application with good clinical reproducibility, except for head and ankle tilt measurements. Therefore, it can be used by different professionals and by the same ones in different moments, without compromising results.

The correct identification of anatomical landmarks directly influences the results of postural measurements [26], but this identification may be influenced by the amount of tissue adjacent to the anatomical landmarks and by the evaluator's experience [27]. Therefore, *NLMeasurer* using surface markers joins several non-invasive postural assessment tools that can be used to monitor clinical evolution of patients during treatment, not only manual assessment tools such as arcomenter [28], Debrunner Kyphometer [29], scoliomenter [30], Digital Inclinometer [31], but also computer-based tools such as *SAPO* [12] (see additional information in [15]). Despite the advantage of the *NLMeasurer* being a portable tool, the use of surface markers in the initial data collection/analysis of this study does not reduce the palpation, patient exposure, and the time spent to place markers, which is needed in biophotogrammetric assessments [32].

On the other hand, the automatic process for identifying anatomical landmarks and presenting the digital markers on the device's screen may be a way to decrease palpation errors, since the PoseNet draws digital markers over actual anatomical landmarks during the photo analysis. The use of the zoom feature helps evaluators to reposition digital markers, but the non-reproducibility of the head and ankle measurements suggests that manually moving the digital markers directly on the device screen may negatively influence the results, that is, it contributes to the low reliability of postural measures of head and ankles [18].

The zoom feature may degrade image quality when enlarged by blurring it [33], in a way that makes it difficult to visualize anatomical landmarks. To tackle this problem, we tested different combinations of parameters of the PoseNet, including two different image resolutions and the one with the best results (i.e., 720x1440) tested in the feasibility study [22] was used in the *NLMeasurer* development. Another parameter that can affect the results is the image perspective, that is, the dimension of objects and the spatial relationship between them in the image [34]. To minimize possible negative effects caused by the perspective on the results, two precautions were taken: (i) the distance between evaluator and participants was fixed, which were positioned at a point in front of a wall; and (ii) evaluators only took photographs when the smartphone alignment axes were green (Fig. 1a), so indicating that the device was aligned. However, as the device was in the hands of the evaluator, it is not possible to confirm that there were no small upward, downward or rotational variations. Likewise, there may also have been small oscillations of the patient's body, which may not be controlled by evaluators.

Another point to be considered is the negative influence of the type of clothing worn by participants. Long clothes, which do not allow visualizing the body segments (e.g., shoulder, iliac spine or knee) may increase the chances of error in the digital identification of anatomical landmarks by the *NLMeasurer*. The human body is a sophisticated structure [35] and, even more prominent regions (e.g., ear, ankle), may be difficult to identify depending on other characteristics of the patient. For example, the feet may be rotated, adducted or abducted, and this anatomical position cannot be corrected by evaluators, as it is inherent to each individual. This may have contributed to the low intra- and inter-evaluator reliability found in this study for head and ankle tilt measurements.

NLMeasurer is the first mobile application studied in the literature that takes advantage of a machine learning-based computer vision solution originally used to estimate human pose, and employ it for postural assessment [15]. However, caution is needed when using it without placing surface markers on the patient's body, given the unreliability of the measures for two segments (ear and ankle). To reduce the chance of wrong measures, we recommend that professionals keep using surface markers for the head, hip and ankle segments. Although there was no difference for hip measurements, we recommend the use of markers to increase the reliability of the results, when this region is covered by clothes, which makes it difficult to locate iliac spines.

NLMeasurer can be useful to assist professionals in monitoring patients in the short and long term. Although *NLMeasurer* does not replace X-ray examinations, it enables to monitor the clinical evolution of patients and, especially for those undergoing long-term treatment, it can be a useful tool to avoid repeated exposure to radiation [36]. Moreover, one of the main differences from *NLMeasurer* to other postural analysis systems is providing more agility in the evaluation process, reducing the palpation to place markers and, consequently, it can reduce the patient exposure time.

Despite the promising results regarding the use of the *NLMeasurer*, it is necessary to highlight some limitations inherent to this study. First, only six postural measures were analyzed in the present study, all of them in the frontal view. Furthermore, the study did not standardize which type of upper body clothing women should wear. Some of them wore shorter shirts, while others wore longer shirts. We believe that this may have contributed to the low reliability of some measures. For further investigation, evaluating the results by participant groups, considering demographic aspects, may help to better understand if there is influence of the type of clothing on the results. Therefore, future research will consider the demographic profile of the participants, that is, evaluating the influence of age, height, weight and gender on the performance of the *NLMeasurer*. Also, in future studies, *NLMeasurer* performance will be investigated regarding the assessment time, the number of manual adjustments of digital markers required from the evaluators, and characteristics of the clothing worn by participants, considering subjects wearing short and long clothes. This performance should be evaluated in a system usability and user experience study, which will require a larger number of evaluators.

5. Conclusion

This study aimed to present and validate the *NLMeasurer* for postural assessment in the frontal view. *NLMeasurer* takes advantage of the PoseNet, a machine learning-based computer vision solution used to estimate human pose, and available features provided in current mobile devices. The results indicate that *NLMeasurer* is a valid solution for postural analysis, which was demonstrated by the agreement found between *NLMeasurer* and *SAPO*, and it can be used to obtain reproducible measurements (inter- and intra-evaluator). However, in the analysis of the photos in which participants had not surface markers, professionals need to be careful. Preferably, they have to use surface markers on the ear, iliac spines and ankle regions, to facilitate the identification of anatomical landmarks and, consequently, the calculation of postural measurements.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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