Journal of Rehabilitation Sciences and Research

Journal Home Page: jrsr.sums.ac.ir

Original Article

Assessment of Knee Angular Deformities: Correlation between Photogrammetric, Clinical, and Radiographic Methods

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ARTICLE INFO

Article History:
Received: 10/05/2023
Revised: 02/02/2024
Accepted: 19/05/2024

Keywords:
Photogrammetry
Genu Varum
Genu Valgum
Knee
Tibiofemoral Joint

Please cite this article as:
Rashedi N, Eftekharsadat B, Dolatkhah N, Soleymanpour J, Salekzamani Y, Babaie S. Assessment of Knee Angular Deformities: Correlation between Photogrammetric, Clinical, and Radiographic Methods. JRSR. 2025;12(4):71-80. doi: 10.30476/jrsr.2024.98852.1371

ABSTRACT

Background: Photogrammetry is a safe and non-invasive technique for evaluating posture in clinical settings. Body Vision is a novel system that employs photogrammetric principles to assess postural parameters. This study aimed to determine the relationship between clinical, photogrammetric, and radiological techniques in detecting knee angular deformities.

Methods: This cross-sectional study was performed on 53 volunteers of both genders, encompassing a total of 106 lower limbs with complaints of knee pain or knee deformity. Sampling was conducted in a non-random and accessible manner based on predefined inclusion and exclusion criteria. All participants had previously obtained full-length radiographs of their lower limbs. The clinical evaluation included measurements of the anatomical axis, Q angle, and intermalleolar and intercondylar distances. These parameters were also assessed using the Body Vision photogrammetric system while the patient was in a standing position. Data from all three methods were compared using the measured angles and distances.

Results: The evaluations indicated a strong correlation between the photogrammetric and radiological methods regarding the anatomical axis of the lower limb ($r = 0.939$, $p < 0.001$). A high correlation was also observed between the clinical and photogrammetric methods for the intermalleolar distance ($r = 0.948$, $p < 0.001$) and intercondylar distance ($r = 0.927$, $p < 0.001$). For the Q angle, a high but relatively lower correlation was found between the clinical and photogrammetric methods ($r = 0.834$, $p < 0.001$). However, a moderate correlation was detected between the clinical measurement of the anatomical axis and both the photogrammetric ($r = 0.70$) and radiological ($r = 0.62$) methods.

Conclusion: This study demonstrated a strong correlation between the photogrammetric technique and the gold standard radiological method, indicating that photogrammetry can serve as a viable alternative for evaluating knee angular deviations.

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Introduction

Alignment of the hip, knee, and ankle is a key factor in weight distribution at the knee joint [1]. The mechanical axis of the lower limb, or the weight-bearing axis, is defined as a line extending from the center of the femoral head to the ankle center, passing directly through the center of the knee [2]. In cases of abnormal limb alignment, mechanical axis deviation is observed during weight-bearing, presenting as genu varum or genu valgum—deformities that can lead to postural control issues in the standing position. Varus deformity causes the knee center to deviate laterally, whereas valgus deformity results in medial knee deviation [3] (Figure 1).

Assessment of knee alignment is essential for detecting arthritic conditions affecting the knee join [4], as well as for guiding both surgical procedures and conservative management. A deviation of more than 5 degrees in either the varum or valgus position is associated with a significant loss of function over time compared to knees with less deviation [5]. Furthermore, alterations in lower limb biomechanics increase athletes' risk of anterior cruciate ligament (ACL) injuries and are associated with patellofemoral pain [6].

Whole-leg radiography in the weight-bearing position is considered the gold standard method for assessing lower limb alignment, as it allows reliable determination of the mechanical (hip–knee–ankle) and anatomical (femorotibial) angles [5]. However, its routine use is limited due to high costs and radiation exposure. Furthermore, abnormal limb rotation or malrotation during imaging can compromise the accuracy of radiographic measurements [7,8]. Consequently, identifying other reliable methods for quantitative postural assessment is essential for confirming diagnoses and monitoring the effects of conservative management.

Several studies have examined alternative evaluation methods, including clinical measurements using a goniometer and photogrammetry [9,10]. Photogrammetry is a non-invasive technique widely used for postural evaluation in clinical practice [11]. Its ability to capture subtle postural changes quickly and accurately has made it an attractive option for specialists in the field. Moreover, photogrammetry can help reduce radiation exposure and serve as a feasible diagnostic tool [12]. However, its effectiveness depends heavily on both the image-capturing process and the precision of mathematical measurements. Unlike qualitative clinical assessments, photogrammetry can detect subtle postural deviations, thereby reducing measurement variability among different evaluators [12-14].

Numerous studies have evaluated the reliability of photogrammetry for measuring various body angles. Carvalho et al. assessed the reliability and reproducibility of goniometric and photogrammetric methods in measuring hand joint movements, including thumb abduction, proximal interphalangeal flexion of the index finger, and thumb metacarpophalangeal flexion. Their results demonstrated that both goniometry and photogrammetry are reliable and reproducible techniques for assessing different hand joint angles [15]. Similarly, Sacco et al. investigated the reliability of computerized photogrammetry compared to goniometry for four lower limb angles—tibiotarsal, knee flexion–extension, quadriceps (Q), and subtalar—and found that photogrammetry demonstrated high reliability in healthy young individuals for all angles except the Q angle [16].

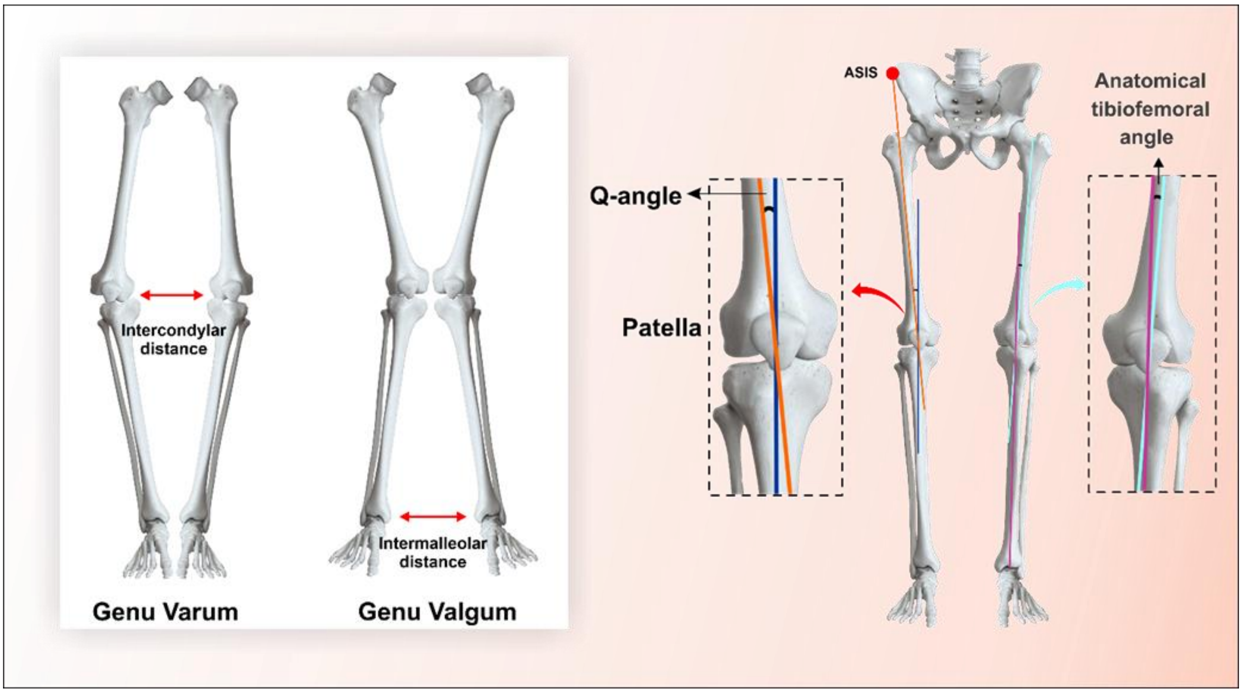


Figure 1: Schematic Illustrations of Genu Varum and Genu Valgum Deformities, Anatomical Tibiofemoral Angle, Q Angle, Intercondylar, and Intermaleolar Distances.

In a more recent study, Salekzamani et al. used the Body Vision System to evaluate postural indices via photogrammetry, confirming the method's reliability and validity [10]. They reported no statistically significant differences between distances and angles recognized on a grid wall and those obtained from photogrammetry. Despite these promising findings and numerous studies supporting the reliability and reproducibility of photogrammetry for measuring various angles [10, 16], further investigation is needed to validate this cost-effective and safe method for diverse postural parameters when compared to the well-established gold-standard radiological techniques.

Therefore, the present study aimed to investigate the correlation between clinical, photogrammetric, and radiological methods in assessing knee angular deformities.

Subjects and Methods

This cross-sectional study was conducted on 53 volunteers of both genders, comprising a total of 106 lower limbs, who were referred to the outpatient clinic between January 2019 and December 2019 with complaints of knee pain or knee deformity. Sampling was conducted in a non-random, convenience-based manner, adhering to predefined inclusion and exclusion criteria. Each participant signed an informed consent form before participation. The study was approved by the Ethics Committee of Tabriz University of Medical Sciences (IR.TBZMED.REC.1398.443).

The inclusion criteria were: age between 18 and 75 years, presence of knee angle deviation identified on physical examination, and availability of full-length lower extremity radiographs obtained within the last six months.

Exclusion criteria included: history of lower limb fracture or balance disorders; prior hip or knee joint replacement; history of lower limb surgery; hip obliquity; knee joint dislocation; body mass index (BMI) below 18.5; neurological or mental disorders; and congenital or acquired physical conditions that could interfere with interview procedures or posture assessment.

Before the examination, the height and weight of each patient were measured using digital scales (Seca, Germany) with an accuracy of 0.5 cm for height and 0.1 kg for weight. The body mass index (BMI) was then calculated as the weight in kilograms divided by the square of the height in meters (kg/m²). BMI values between 18.5–24.9 kg/m² were considered normal, 25–29.9 kg/m² overweight, and ≥30 kg/m² obese.

The same examiner performed two identical (duplicate) assessments, and the mean value was recorded for analysis. Full-length radiographs of the lower limbs were examined to determine mechanical and anatomical angles in a weight-bearing, standing position, with the patella facing anteriorly.

Photogrammetric evaluation was performed using the Body Vision System while patients stood upright, looking forward, in a weight-bearing position. The system was used to identify the anatomical tibiofemoral angle, Q angle, intercondylar distance, and intermalleolar distance.

To increase the accuracy of clinical and photogrammetric measurements, 10 anatomical landmarks were bilaterally identified with colored adhesive markers (1 cm diameter):

Greater trochanter, anterior superior iliac spine (ASIS), 10 cm above the tibial spines (mid-thigh region), 10 cm below the tibial spines (mid-leg region), center of the patella, tibial tuberosity, medial and lateral knee joint lines, medial (inner) epicondyle of the femur, medial (inner) and lateral (outer) malleolus.

Sample Size

The sample size was determined based on the study by Mündermann et al.[17], considering $\alpha = 0.05$, $\beta = 0.05$, and $r = 0.738$. The estimated sample size was calculated to be 45, which was then adjusted to 53 participants to account for a potential 20% drop-out rate.

Clinical Method (Goniometric Technique)

For clinical evaluation, the goniometric technique was used to measure angles, specifically the anatomical tibiofemoral and Q angles. Additionally, tape measurements were performed to document intercondylar and intermalleolar distances.

The anatomical tibiofemoral angle was defined as the angle between the anatomical axes of the femur and tibia. The anatomical axis of the femur was determined by drawing a line from the center of the tibial spines to a point 10 cm proximally, midway between the medial and lateral surfaces of the femur [18]. Similarly, the anatomical axis of the tibia was defined by a line from the midpoint of the tibial spines to a point 10 cm distally, midway between the medial and lateral tibial surfaces [18].

All patients were positioned in a standing posture with equal weight-bearing on both lower limbs, with knees fully extended, and arms resting freely at their sides. Using predetermined anatomical landmarks, the fulcrum of the goniometer was placed at the center of the patella, with the fixed arm aligned along the anatomical axis of the femur and the movable arm aligned along the anatomical axis of the tibia. The angle formed between these two lines was then measured.

Q angle was measured with a goniometer, by placing the fulcrum of the goniometer on the center of the patella, where its fixed armrests were placed on the line drawn from the center of the patella to the ASIS, and the movable arm was located from the center of the patella to the center of the tibial tuberosity [19].

To measure the intermalleolar and intercondylar distances, each patient was positioned standing with equal weight-bearing on both lower limbs. The lower limbs were then gently brought together until the knees and ankles made contact. When the medial malleoli contacted first, the alignment was classified as varus deformity; when the knees contacted first, it was classified as valgus deformity. If the knees and ankles made contact simultaneously, a neutral alignment was recorded.

Following previous studies, a standard measuring tape was used to determine the intercondylar distance in patients with varus deformity and the intermalleolar distance in patients with valgus deformity [5].

Computerized Photogrammetry Method

The Body Vision System consists of a 195 × 80 cm grid wall and a camera (Canon Zoom Lens EF-S 18–55 mm 1:3.5–5.6 IS II, 58 mm) positioned 390 cm from the grid wall at a height of 100 cm. The camera is connected to a computer, allowing the examiner to capture and store images within the system. Using the Body Vision software, various postural parameters, including angles and distances, were subsequently measured. This device was developed in Tabriz, Iran, by Tocea Tadbir Tavan Teb Company (Rehabsoon Co.), and its reliability and validity have been previously evaluated by Salekzamani et al.

[10].

Following clinical measurements, each patient was positioned in the Body Vision device’s setup in a standing posture. Images were captured in the frontal plane, after which the anatomical tibiofemoral angle, Q angle, intercondylar distance, and intermalleolar distance were calculated using the software.

Throughout the photogrammetric assessment, patients remained in a standing position with minimal clothing and their arms relaxed at their sides to ensure unobstructed landmark visibility and standardized posture.

Radiographic Method

In the radiographic method, weight-bearing, full-length, anteroposterior radiographs—with the patella facing anteriorly—were examined to determine both the mechanical and anatomical angles of the lower limb.

The intersection of the mechanical axes of the femur and tibia forms the mechanical angle. To determine the mechanical axis of the femur, a line was drawn from the center of the femoral head to the center of the femoral intercondylar notch. The tibial mechanical axis was drawn by connecting the center of the tibial spines to the center of the ankle joint, which corresponds to its anatomical axis [20].

The mechanical angle is considered the gold standard for evaluating lower limb alignment. An angle less than 180 degrees is classified as varus malalignment, while an angle greater than 180 degrees indicates valgus malalignment [21].

Statistical Analysis

Both descriptive and inferential statistical analyses were conducted to examine the collected data. In the descriptive analysis, the normality of data distribution was first assessed using histogram charts and the Shapiro–Wilk statistical test. Quantitative variables with a normal distribution were expressed as mean ± standard deviation (SD) along with their 95% confidence intervals.

For inferential analysis, the Pearson correlation coefficient was used to investigate the relationships among quantitative variables. A correlation coefficient (r) of ≥ 0.8 was interpreted as indicating a high correlation, whereas a coefficient between 0.6 and 0.8 was considered to represent a good to moderate correlation.

When a significant relationship was identified, linear regression analysis was performed to generate regression equations between the relevant quantitative variables. All statistical analyses were conducted using Stata software (Version 14.2; StataCorp, College Station, TX, USA), and a p-value < 0.05 was considered statistically significant.

Results

Demographic Characteristics

This study included 53 volunteers (representing 106 knee joints) with a mean age of 51.35 ± 15.03 years (range: 18–75 years) across both genders. The participants’ demographic characteristics are summarized in Table 1.

Table 1: Demographic Characteristics of the Participants

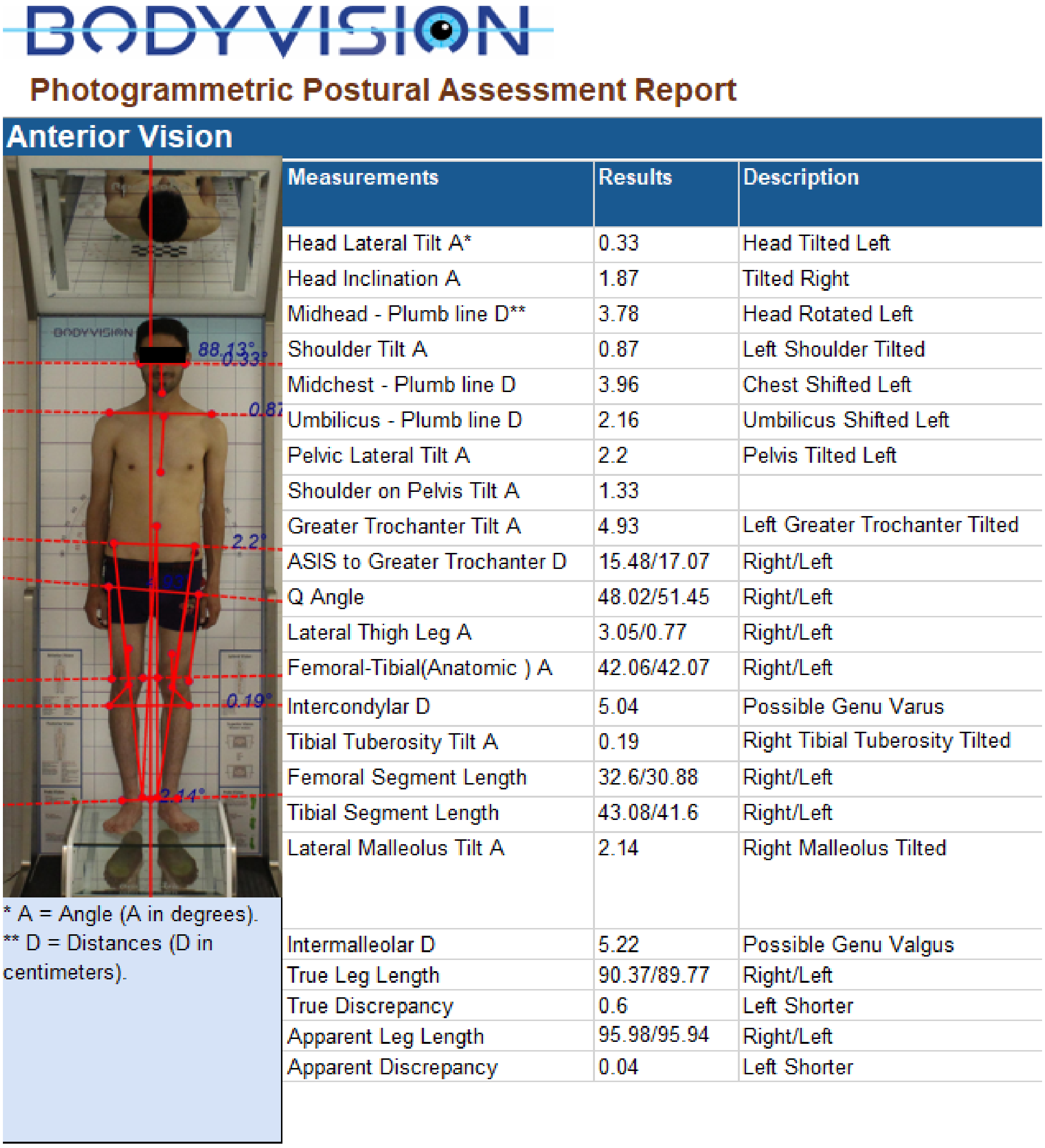
Variables		**N (%) / Mean±SD**
Gender	Male	13 (24.53%)
	Female	40 (75.47%)
Age (Years)		51.35 ± 15.03
Body Mass Index (kg/m^2)		28.86 ± 5.18

SD Standard Deviation

Alignment Results

This study determined four knee alignment indices—anatomical axis, Q angle, intermalleolar distance, and intercondylar distance—using both clinical and photogrammetric methods. Additionally, two alignment indices—the anatomical axis and mechanical axis—were evaluated through radiological assessment based on X-ray imaging.

The alignment results for 106 knee joints, obtained through these various measurement methods, are summarized in Table 2. The measurement of knee alignment parameters using the computerized photogrammetry method is illustrated in Figure 2.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Photogrammetric Postural Assessment Report

Anterior Vision

Measurements	Results	Description
Head Lateral Tilt A*	0.33	Head Tilted Left
Head Inclination A	1.87	Tilted Right
Midhead - Plumb line D**	3.78	Head Rotated Left
Shoulder Tilt A	0.87	Left Shoulder Tilted
Midchest - Plumb line D	3.96	Chest Shifted Left
Umbilicus - Plumb line D	2.16	Umbilicus Shifted Left
Pelvic Lateral Tilt A	2.2	Pelvis Tilted Left
Shoulder on Pelvis Tilt A	1.33	
Greater Trochanter Tilt A	4.93	Left Greater Trochanter Tilted
ASIS to Greater Trochanter D	15.48/17.07	Right/Left
Q Angle	48.02/51.45	Right/Left
Lateral Thigh Leg A	3.05/0.77	Right/Left
Femoral-Tibial(Anatomic) A	42.06/42.07	Right/Left
Intercondylar D	5.04	Possible Genu Varus
Tibial Tuberosity Tilt A	0.19	Right Tibial Tuberosity Tilted
Femoral Segment Length	32.6/30.88	Right/Left
Tibial Segment Length	43.08/41.6	Right/Left
Lateral Malleolus Tilt A	2.14	Right Malleolus Tilted
Intermalleolar D	5.22	Possible Genu Valgus
True Leg Length	90.37/89.77	Right/Left
True Discrepancy	0.6	Left Shorter
Apparent Leg Length	95.98/95.94	Right/Left
Apparent Discrepancy	0.04	Left Shorter

* A = Angle (A in degrees).
** D = Distances (D in centimeters).

Figure 2: Measurement of Knee Alignment Parameters Using the Computerized Photogrammetry Method

Table 2: Alignment Results Based on Various Measurement Methods

Characteristics	95% CI	Mean ± SD
Clinical Measurement		
Anatomical axis (°)	170.91 - 172.87	171.89 ± 5.08
Q-angle (°)	15.77 - 17.62	16.69 ± 4.80
Intermalleolar distance (cm)	1.38 - 3.62	2.50 ± 4.05
Intercondylar distance (cm)	4.70 - 6.82	5.76 ± 3.84
Photogrammetric Measurement		
Anatomical axis (°)	170.87 - 173.38	172.12 ± 6.51
Q-angle (°)	15.67 - 18.31	16.99 ± 6.85
Intermalleolar distance (cm)	2.86 - 5.48	4.17 ± 4.74
Intercondylar distance (cm)	5.69 - 7.82	6.75 ± 3.87
Radiological Measurement (X-ray)		
Anatomical axis (°)	171.08 - 173.93	172.50 ± 7.40
Mechanical axis (°)	169.77 - 172.43	171.10 ± 6.91

CI, Confidence Interval; SD, Standard Deviation

Anatomical Axis

The relationship between the obtained alignment results was examined using Pearson’s correlation test. For the anatomical axis, the strongest correlation was observed between the photogrammetric and radiological methods. Assessments between the clinical and photogrammetric methods and between the clinical and radiological methods demonstrated a moderate but significant correlation (Table 3).

The distribution of the anatomical axis values based on the photogrammetric and clinical methods is illustrated in Figure 3A. Linear regression analysis indicated a significant relationship between these two variables, expressed by the following formula:

Photogrammetric anatomical axis (degrees) = 0.901 × clinical anatomical axis (degrees) + 17.14.

Based on the findings, a significant correlation was identified between the photogrammetric anatomical axis and the radiological anatomical axis, expressed by the following regression formula:

Photogrammetric anatomical axis (degrees) = 0.824 × clinical anatomical axis (degrees) + 29.88

Furthermore, the results of the linear regression analysis demonstrating the correlation between the photogrammetric and radiological anatomical axes are illustrated in Figure 3B.

Correlation Between BMI and Anatomical Axis in Different Measurement Methods

Patients were categorized into three BMI groups: 13 patients (24.53%) with a BMI between 18.5–24.99, 17 patients (32.08%) with a BMI between 25–29.99, and 23 patients (43.40%) with a BMI above 30.

The Pearson correlation coefficient was used to evaluate the association between BMI and anatomical axis findings across different measurement methods.

For the clinical and photogrammetric methods, the highest correlation was observed in patients with a BMI between 18.5–24.99, whereas the lowest correlation was noted in patients with a BMI above 30.

In contrast, the photogrammetric and radiological methods demonstrated a high correlation across all three BMI categories (Table 4).

Q Angle

In the present study, a significant correlation was found between the photogrammetric and clinical methods for the Q angle (Table 3). Linear regression analysis yielded the following formula:

Photogrammetric Q angle (degrees) = 1.190 × clinical Q angle (degrees) - 2.89

The scatter plot and linear regression results illustrating this relationship are presented in Figure 3C.

Intermalleolar Distance

A significant correlation was also identified between the clinical and photogrammetric methods for intermalleolar distance (Table 3). Linear regression analysis produced the following formula:

Photogrammetric intermalleolar distance (cm) = 1.108 × clinical intermalleolar distance (cm) + 1.39

The scatter plot and linear regression results for this relationship are shown in Figure 3D.

Intercondylar Distance

A significant correlation was observed between the clinical and photogrammetric methods for measuring the intercondylar distance (Table 3). The linear regression formula describing this relationship is as follows (Figure 3E):

Photogrammetric intercondylar distance (cm) = 0.933 × clinical intercondylar distance (cm) + 1.37

Table 3: Correlation of Knee Alignment Results across Different Measurement Methods

Alignment Results	Measurement Method	Pearson’s r	*p*-value
Anatomical Axis	Clinical/photogrammetric	0.703	<0.001
	Clinical/radiological	0.625	<0.001
	Photogrammetric/radiological	0.936	<0.001
Q-angle	Clinical photogrammetric	0.834	<0.001
Intermalleolar Distance	Clinical/photogrammetric	0.948	<0.001
Intercondylar Distance	Clinical/photogrammetric	0.927	<0.001

Table 4: Correlation between the Anatomical Axis and Body Mass Index (BMI) Using Different Measuring Methods

Parameter	BMI	Measurement method	*p*- value	Pearson’s r
Anatomical Axis	18.5 -24.9	Clinical/photogrammetric	<0.001	0.833
	25-29.9	Clinical/photogrammetric	<0.001	0.744
	>30	Clinical/photogrammetric	<0.001	0.533
	18.5 -24.9	Photogrammetric/radiological	<0.001	0.954
	25-29.9	Photogrammetric/radiological	<0.001	0.932
	>30	Photogrammetric/radiological	<0.001	0.940

Body Mass Index (BMI)

Mechanical Axis

The results demonstrated a significant correlation between the mechanical axis and the clinical anatomical axis measured via radiological (X-ray) methods (Table 5). Furthermore, a strong and significant correlation was found between the mechanical axis and both the photogrammetric anatomical axis and the radiological anatomical axis.

Table 5: Correlation between the Mechanical Axis (Radiological Measurement) and Anatomical Axis Assessed by Different Measurement Methods.

Parameter	Measurement Method	*p*-value	Pearson's r
Mechanical Axis	Clinical	<0.001	0.625
	Photogrammetric	<0.001	0.923
	radiological (X-ray)	<0.001	0.967

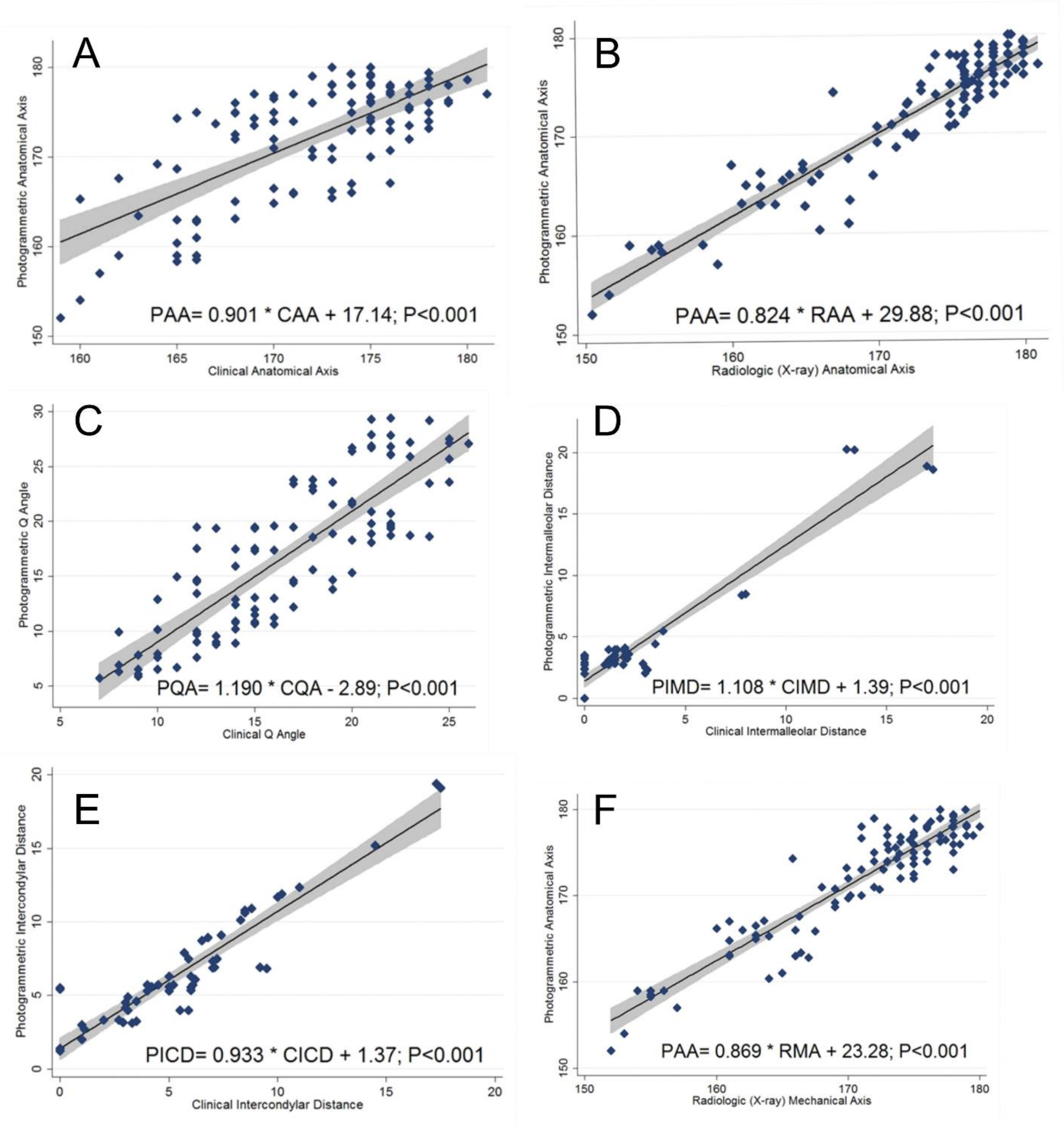

Figure 3: Scatter plots and linear regression analyses showing correlations between measurement methods: (A) photogrammetric anatomical axis (PAA) and clinical anatomical axis (CAA); (B) photogrammetric anatomical axis and radiological anatomical axis (RAA); (C) photogrammetric Q-angle (PQA) and clinical Q-angle (CQA); (D) photogrammetric intermalleolar distance (PIMD) and clinical intermalleolar distance (CIMD); (E) photogrammetric intercondylar distance (PICD) and clinical intercondylar distance (CICD); (F) photogrammetric anatomical axis and radiological mechanical axis (RMA).

PAA: Photogrammetric Anatomical Axis; RAA: Radiological Anatomical Axis; PQA: Photogrammetric Q angle; PIMD: Photogrammetric intermalleolar distance; PICD; Photogrammetric intercondylar distance; Radiological mechanical axis: RMA; Clinical intercondylar distance: CICD; Clinical Q angle: CQA

Linear regression analysis revealed a significant relationship between the photogrammetric anatomical axis and the radiological mechanical axis, expressed by the following formula (Figure 3F):

Photogrammetric anatomical axis (degrees) = 0.869 x radiological mechanical axis (degrees) + 23.28

Discussion

This study aimed to compare measurements of knee angular deviations using three methods—clinical (goniometric), photogrammetric, and radiographic—and to examine correlations among these techniques. The evaluation demonstrated a strong correlation between photogrammetric and radiological methods for assessing the anatomical axis of the lower limb. Additionally, high correlations were observed between clinical and photogrammetric methods for the Q angle, as well as intercondylar and intermalleolar distances. However, a moderate correlation was found between the anatomical axis measurements from the clinical method and those obtained via photogrammetric and radiological methods.

Accurate assessment of joint angles is essential for proper diagnosis and monitoring of treatment outcomes. While whole-leg radiography in a weight-bearing position is considered the gold standard for reliable determination of mechanical (hip-knee-ankle) and anatomical (femorotibial) angles [5]. In clinical practice, joint angles and ranges of motion are typically measured using a handheld goniometer [16]. The advantages of goniometry include low cost, accessibility, and simplicity; however, its accuracy heavily depends on the examiner's experience and skill [22].

Our findings are consistent with those of Navali et al., who reported a good correlation between mechanical axis measurements obtained by radiography and anatomical axis measurements obtained via goniometry [5]. Similarly, Hinman et al. demonstrated an acceptable correlation between anatomical and mechanical axes [23]. Conversely, Hinman et al. also reported no significant relationship between goniometric measurements of anatomical and mechanical axes in some cases, possibly due to variability in goniometer placement. Accurate positioning of the goniometer on bony landmarks, particularly using long-arm devices, may account for these discrepancies [23].

There are other various standardized techniques (*i.e.,* radiography, computerized photogrammetry, and other clinical methods) to calculate the knee angular deviations. Photogrammetry has recently emerged as a promising tool for quantitative postural assessment in clinical settings, providing a radiation-free method that evaluates posture in both sagittal and frontal planes through digital images [24]. Therefore, one of the important advantages of this method is the possibility of evaluating the whole body using several digital photographs, which does not expose the patient to radiation. Furthermore, comfortable use of the device and the related software offers the possibility of installing software on different operating systems and the ability to save data and analyze offline [24]. Various software options, such as SAPO and Surgimap, have demonstrated reliability in postural measurements [25, 26]. This study utilized the Body Vision System, a novel photogrammetry-based tool developed in Iran, which has shown valid and reliable results for postural assessment.

Based on previous studies regarding the validity of the Body Vision System in assessing postural parameters, the lower reliability observed for some measurements may be attributed to the reduced resolution of photographs at certain anatomical landmarks, such as the tibial tuberosity [10]. . Furthermore, in some cases, excessive obesity and a protruding abdomen obscure more proximal landmarks, such as the ASIS and enlarged trochanter, thereby complicating the evaluation process. Consequently, the clear and accurate identification of anatomical landmarks—and ensuring their full visibility in the captured photographs—are crucial for enhancing the accuracy and reliability of the photogrammetry technique, particularly in obese individuals.

This study demonstrated that the correlation between anatomical axis values obtained via the clinical method and those obtained via the photogrammetric method decreased as BMI increased. Specifically, for the anatomical axis, a strong correlation was observed between the clinical and photogrammetric methods in participants with a BMI of 18.5 to 24.9. In contrast, only a moderate correlation was found in participants with a BMI above 30. Conversely, unlike the pattern above, a strong correlation was observed between photogrammetric and radiological measurements of the anatomical axis across all BMI groups.

These findings suggest that anatomical axis data derived from the clinical method in obese individuals should be interpreted with caution. In contrast, the photogrammetric method appears more reliable compared to the gold-standard radiological method.

Another angular parameter investigated in this study was the quadriceps angle (Q-angle). Although Q-angle measurement is frequently used in clinical practice, few studies have examined the reliability of different methods for measuring this angle [16].

Our study indicated strong correlations in the measurement of the Q angle using the clinical and photogrammetric methods. Although an acceptable correlation was achieved between the clinical and photogrammetric methods for the Q angle, this correlation was weaker than the correlation observed for intercondylar and intermalleolar distances between the same two methods. This discrepancy may be attributed to the fact that, in Q-angle measurements, the anatomical reference points are located relatively far apart, and the muscle masses in these regions sometimes interfere with the accurate and proper placement of the goniometer arms in the standing position.

Previous studies have confirmed that multiple joint complexes—including the pelvic, hip, patellofemoral, and tibiofemoral joints—are involved in measuring this angle. Consequently, even minor changes in any of these joint complexes may influence the Q angle when measured using goniometric or photogrammetric methods. One critical factor for accurate Q-angle measurement is ensuring that patients are positioned consistently during assessment. In the standing position, contraction of the quadriceps muscle causes the patella to move laterally, thereby increasing the Q angle [27]. In the present study, the photogrammetric examination was conducted in a standing position; therefore, clinical measurements were also performed in the same position to ensure consistency.

However, as previously noted, the distance between anatomical landmarks posed limitations for the clinical method. The decreased correlation between clinical measurements of the anatomical axis and those obtained via photogrammetric and radiological methods may also be explained by the difficulty of positioning the goniometer arms over irregularities of the knee joint in obese patients or those with severe deformities. This suggests that data obtained using the clinical method for the anatomical axis in obese individuals should be interpreted cautiously.

In contrast, the photogrammetric approach demonstrated high reliability in obese individuals when compared to the gold-standard radiological method. Therefore, photogrammetry offers significant potential as a quantitative and precise tool for posture evaluation, while providing additional benefits such as objectivity, simplicity, and cost-effectiveness. Furthermore, when the examiner possesses sufficient proficiency and expertise and when anatomical landmarks are accurately identified, photogrammetry can serve as a viable alternative to radiographic assessment, effectively reducing patients’ exposure to X-ray radiation.

Among the limitations of the current study, it should be noted that, to avoid unnecessary radiation exposure, only patients who reported pain or knee deviation and had already undergone full-length lower limb radiography in the past few months were included. Furthermore, the mechanical and anatomical axes were assessed using a radiographic stereotype, which reflects a fixed position and may have introduced bias in establishing a strong relationship between the mechanical and anatomical axes via the radiographic method. However, to minimize radiation exposure, it was not feasible to request additional radiographs. Another limitation was the inability to compare Q-angle results obtained through the clinical and photogrammetric methods with those from the radiographic technique. Since, in most full-length lower limb radiographic images, the ASIS was not included as a reference point for Q-angle measurement, it was not possible to calculate this angle radiologically for comparison.

To address these limitations, future investigations are encouraged to evaluate a broader range of variables related to angle and distance measurements while utilizing a larger sample size.

Conclusions

The moderate correlation of the anatomical axis measured by the clinical method with the photogrammetric and radiological methods, along with the strong correlation of this parameter measured by the photogrammetric method with the gold standard (radiological) method, suggests the superiority of the photogrammetric method over the clinical method, particularly in individuals with excessive obesity in static lower extremity alignment. The present study demonstrates that photogrammetry can be used as an alternative method for evaluating knee angular deviations.

Acknowledgements

The authors would like to acknowledge Tabriz University of Medical Sciences.

Funding

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

Conflict of Interest: None declared.

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