ORIGINAL ARTICLE

Validating Fibula Length as a Reliable Estimator for Femoral Nail Length: A Comparative Analysis with the Standard AO Method

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ABSTRACT

INTRODUCTION: An appropriate femoral nail length is required to be measured preoperatively to ensure optimal surgical outcomes. Conventionally, measurements are obtained clinically or radiographically on the contralateral femur or by using forearm referencing. This study is aimed to determine whether fibula length can be used as an additional clinical method for estimating maximum femoral nail length. **MATERIALS AND METHOD:** This study involves measuring the femurs and fibulas of 140 patients using a standard tape measure. Femur length is measured adhering to the standard Arbeitsgemeinschaft für Osteosynthesefragen (AO) method, while fibula length was measured from the tip of the fibula head to the tip of the lateral malleolus. Pearson correlation coefficient (r) determines any correlation between the two measurements. **RESULTS:** The overall mean femoral length was 37.98cm (SD=2.72), with a range of 32.0 to 46.5 cm, and the mean fibula length was 37.72cm (SD=2.61), with a range of 32.4 to 47.0 cm. A robust and positive correlation (r=0.940, p<0.001) was observed between fibula length and femoral length. Age, body mass index, and gender did not affect this correlation. Both inter-observer and intra-observer reliabilities were high. A formula for estimating maximum femoral nail length was derived from the correlation graph: femoral nail length = 1 + (0.98 x fibula length). **CONCLUSION:** Fibula length demonstrates a strong correlation with femoral length, offering a reliable alternative clinical method for estimating femoral nail length. This method proves particularly useful in cases of bilateral femoral fractures with concurrent forearm fractures where forearm referencing method is impractical.

Keywords
Femoral length, fibula length, femoral shaft fracture, intramedullary nail

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INTRODUCTION

Femoral shaft fractures frequently present in emergency departments, often stemming from high-energy trauma such as road traffic accidents. The global incidence of these fractures range from 1.0 to 2.9 million annualy,[1-3] necessitating hospital admissions and operative intervention. Currently, the preferred surgical approach for femoral shaft fractures is intramedullary nailing, acknowledged as the gold standard.[4-6] Consequently, operation theatres are required to maintain a diverse inventory of nail sizes. However, the practicality of assuming the availability of all nail sizes during surgery is limited. Hence, it is essential for orthopaedic surgeons to preoperatively assess and determine the appropriate size and length of nails.

Polytrauma involving bilateral femoral fractures and bilateral upper limb fractures present significant challenges. Such injuries necessitate careful planning and precise management, highlighting the importance of accurately estimating femoral nail length. Studies indicate that polytrauma cases, while relatively uncommon, demand significant resources and advanced surgical techniques due to their complexity.[7-9] These findings reinforce the critical need for reliable methods to estimate femoral nail length. The conventional method for estimating femoral nail length involves

radiographic measurements of the intact contralateral femur.[10] Nevertheless, there are alternative clinical methods, recommended by Arbeitsgemeinschaft für Osteosynthesefragen (AO), for estimating femoral length that obviate the necessity for x-ray radiation. The AO Foundation, or the Association for the Study of Internal Fixation, is a medically guided, not-for-profit organization led by an international group of surgeons who specialize in the treatment of trauma and disorders of the musculoskeletal system. It is a globally recognized organization that focuses on improving patient outcomes in trauma and musculoskeletal disorders through research, education, and innovation.[10,11]

Additionally, recently studies propose an alternative method, measuring forearm length from the tip of the olecranon to the tip of the little finger, offering utility in bilateral femoral fractures or instances where patient characteristics impede palpation of the greater trochanter (GT).[10,12-15] Despite their efficacy, these clinical methods may prove insufficient in cases involving bilateral femoral fractures coinciding with bilateral upper limb fractures or in patients with known upper limb bone or joint deformities.

Considering these challenges, our study seeks to investigate the viability of fibula length as an alternative clinical method for estimating femoral nail length. This investigation is particularly relevant in scenarios where measuring the contralateral femur or utilizing the forearm referencing method is impractical.

MATERIALS AND METHODS

We conducted a cross-sectional study involving 140 participants recruited from the orthopaedic clinic and ward of a single tertiary trauma centre. Employing a systematic random sampling method, every third patient seen in the clinic or admitted to the ward was selected. Inclusion criteria encompassed individuals of both genders aged 18 to 60 years. Exclusion criteria comprised participants with lower limb deformities, limb length discrepancies, bone or joint pathologies, a history of lower limb fractures, and known skeletal diseases. The study received approval from the Human Research Ethics Committee of Hospital Universiti Sains Malaysia (USM/JEPeM/20120704).

The lower limbs of the participants were exposed, and the femoral and fibula lengths of each participant were measured by two independent observers (Observer A and Observer B) on separate occasions. Each measurement was taken three times by each observer using a standard, flexible 150-centimeter (cm) measuring tape (Seca) and recorded to the nearest 0.1 cm. The participants and observers were blinded to the measurements to ensure unbiased results. To minimize measurement bias, the observers initially measured using the inch side of the tape and then flipped it to record the measurement in cm. Participants were not informed of the specific measurements being taken.

Observers were unaware of each other's measurements and their own previous measurements for the same participant, ensuring objective and unbiased data collection. The femoral length was measured from the greater trochanter (GT) to the superior pole of the patella, following the standard AO method (Fig. 1A). The GT was identified as the most prominent bony landmark at the proximal lateral thigh, while the superior pole of the patella was identified as the most proximal tip of the patella in full knee extension. The fibula length was measured from the tip of the head of the fibula to the tip of the lateral malleolus (Fig. 1B). The tip of the fibula head was identified as the first prominent bony landmark below the knee joint line on the lateral aspect of the proximal leg, and the tip of the lateral malleolus was identified as the most distal tip on the lateral aspect of the leg.[16]

Figure 1: Measurement of the (A) femoral length from the GT to the superior pole of the patella, and (B) fibula length from the tip of the fibula head to the tip of the lateral malleolus.

Upon completion of data collection, all information was entered and analysed using SPSS version 26. Descriptive statistics summarized socio-demographic characteristics, presenting numerical data as mean (SD) or median (IQR) based on normality distribution and categorical data as frequency (percentage).

RESULTS

The demographic profile of the 140 participants is summarized in Table I. There were 107 males and 33 females. The mean age was 28.78 years (SD=8.61). Participants ranged from 18 to 57 years old, and the mean body mass index (BMI) was 23.68 (SD=4.49), with 54 participants having a BMI exceeding 25. Table II provides a summary of measurements conducted by Observers A and B, including the average measurements. The overall mean femoral length was 37.98cm (SD=2.72), with a range of 32.0 to 46.5 cm, and the mean fibula length was 37.72cm (SD=2.61), with a range of 32.4 to 47.0 cm. Correlation analyses are also presented in Table II, revealing a robust and positive correlation between the overall average measurements of the femur and fibula (r= 0.940, p< 0.001). Specifically, both Observer A (r=0.916, *p* <0.001) as well as Observer B (r=0.921, p<0.001) demonstrated a strong positive correlation between femur and fibula measurements. The linear correlation is visually depicted in Figure 2 and a formula for estimating maximum femoral nail length is derived from the correlation graph:

$$\mathbf{y} = 0.98 \times \mathbf{x},$$

where **y** is the femoral length or the maximum femoral nail length, and **x** is fibula length.

Table I: Demographic data of the participants (n = 140)

Variable		Mean (SD)	n (%)
Age (year)		28.79 (8.61)	
Gender	Female		33 (23.6)
	Male		107 (76.4)
Race	Malay		120 (85.7)
	Chinese		10 (7.1)
	Indian		10 (7.1)
Weight (kg)		66.24 (17.55)	
Height (cm)		165.98 (8.59)	
BMI		23.68 (4.49)	
	< 25		86 (61.4)
	25 and above		54 (38.6)

SD: standard deviation, BMI: body mass index

Table II: The mean of femur and fibula length taken by Observers A and B, the overall mean of both measurements, and the, correlations between the femur and fibula measurements

Variable (cm)	Mean (SD)	Correlation	p-value
Femur A	37.77 (2.79)	0.916	<0.001
Fibula A	37.79 (2.67)		
Femur B	38.19 (2.80)	0.921	<0.001
Fibula B	37.66 (2.62)		
Overall Femur	37.98 (2.72)	0.941	<0.001
Overall Fibula	37.72 (2.61)		

SD: standard deviation

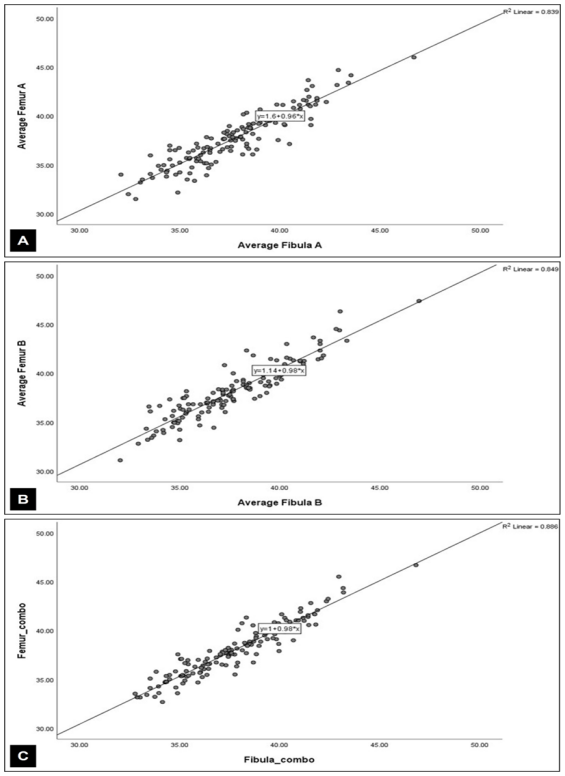

Figure 2: Linear correlations between femoral and fibula length measured by (A) Observer A, (B) Observer B, and (C) the overall average of both measurements.

Controlling for age, BMI, and gender, Table III illustrates a consistently strong and positive correlation between femur and fibula lengths measured by both observers (Observer A: r^A = 0.916-0.883, p<0.001; Observer B: r^B = 0.923-0.907, p<0.001). Notably zero-order correlations indicate that age, BMI, and gender exerted no influence on the relationship between femoral and fibula lengths.

Table III: The correlation of femur and fibula lengths with respect to the age, BMI, and gender.

		Age	BMI	Gender	
Variable	Correlation	Correlation	Correlation	Correlation	p-value
Femur A	0.916	0.916	0.914	0.883	<0.001
Fibula A					
Femur B	0.921	0.923	0.921	0.907	<0.001
Fibula B					

BMI: body mass index

Interclass correlation (ICC) analyses in Table IV affirm a high degree of reliability and consistency between Observers A and B for femoral and fibula lengths. The ICC values indicate good reproducibility and consistency between readings taken by the observers, both individually and collectively. Overall, this underscores the robustness and reliability of the femur and fibula measurements, confirming their consistency and strong correlation between observers.

Table IV: Interclass correlation coefficient (ICC) for inter-observer and intra-observer consistencies of the femoral and fibula lengths.

Variable	Interclass Correlation	95% (CI)		F-Stat	df1	df2	P-value
		Lower Bound	Upper Bound				
ICC for inter-observer consistency.							
Femur	0.938	0.906	0.958	17.505	139	139	<0.001
Fibula	0.972	0.961	0.980	36.287	139	139	<0.001
ICC for intra-observer consistency of the measurements recorded by Observer A and Observer B on the femur and fibula.							
Femur A	0.981	0.975	0.986	55.94	139	278	<0.001
Fibula A	0.996	0.994	0.997	224.12	139	278	<0.001
Femur B	0.987	0.983	0.990	76.36	139	278	<0.001
Fibula B	0.992	0.989	0.994	129.39	139	278	<0.001
ICC for intra-observer consistency between the femur and the fibula measurements of each observer.							
Femur and Fibula A	0.956	0.938	0.968	22.617	139	139	<0.001
Femur and Fibula B	0.958	0.941	0.970	23.768	139	139	<0.001

CI: confidence intervals, df: degrees of freedom

DISCUSSION

In the historical evolution of intramedullary fixation, Bircher introduced the initial form in 1886 with ivory pegs, a technique later refined by Gerhard Kuntscher during World War II, subsequently establishing itself as the gold standard for femoral shaft fracture fixation.[17-19] Intramedullary nailing aims to restore femoral length and provide an appropriately sized nail for stable fixation, avoiding complications such as knee joint perforation or peri-implant fractures resulting from excessively long or short nails.[9,12]

Traditionally, radiographic measurements of the intact femur from the greater trochanter (GT) to just above the distal femur's epiphyseal scar determine the ideal femoral nail length.[10,19,20] This represents the adequate longest femoral nail length that is required. However, this radiographic method necessitates x-ray radiation and accurate magnification, posing limitations.[12,14] Alternatively, AO has proposed clinical measurement methods, including measuring from the GT to the superior pole of the patella, or the lateral knee joint line minus 2 cm.[10,15,20] Despite these practices, clinical and radiographic methods prove ineffective in cases of bilateral comminuted femoral bone fractures.[12,20,21] Another clinical alternative involves measuring the forearm's length until the tip of the ipsilateral little finger, which has demonstrated a strong correlation with femoral length, serving as a viable alternative for estimating femoral nail length.[12-15] However, it is noteworthy that these methods necessitate intact, disease-free bilaterally forearms, hands, and fingers, devoid of joint pathologies, deformities, or malalignments, as the measurements span multiple joints and bones.

Karakas and Harma[21] previously attempted to estimate femoral medullary length, measured from the piriformis fossa to the intercondylar notch by integrating fibula length and femoral head diameter obtained through computed tomography (CT) scanning. However, due to the necessary distance requirement between the nail tip and the intercondylar notch, an adjustment involving subtracting the distance from the distal nail tip to the intercondylar notch was needed. This method, despite its potential, introduces a resource-intensive aspect by mandating the use of CT scanning for femoral nail length estimation.

To our knowledge, the utilization of clinical measurements of the fibula for estimating femoral nail length has not been investigated. Our rationale for choosing to correlate fibula length stems from its anatomical characteristics. Positioned as a long bone in the lateral aspect of the leg, just posterolateral to the tibia and below the knee joint, the fibula is distinguishable by a superficial styloid process at its proximal end, easily palpable from the lateral aspect of the fibula head. Distally, it terminates as the lateral malleolus.[16] This distinctive anatomy allows for a straightforward measurement of the fibula length, given its singular, palpable bone structure that does not transverse any joints. This approach contrasts with the method involving the measurement of the forearm plus the little finger, which entail multiple bones and joints. Similarly, the AO method, which relies on the palpation of the GT, poses challenges in obese patients.[13,15,22] Our decision to

focus on the fibula as a surrogate for femoral nail length estimation is grounded in its practical accessibility and simplicity, offering a viable alternative to existing methodologies.

In the present study involving 140 participants, we successfully established a robust and positive correlation between femoral length and the fibula length, unaffected by the participants' age, BMI, or gender. Moreover, our study demonstrated commendable inter-observer consistency in fibula measurements, highlighting the reliability of measuring fibula length. Additionally, a high level of agreement between observers on the femur and fibula length measurements further validated the method. The results of the study unveil a practical solution to the challenge of clinically estimating femoral nail length when traditional methods like contralateral femur and forearm referencing are impractical. Our findings indicate that measuring fibula length offers a reliable and straightforward method for estimating femoral nail length. This method reduces the reliance on radiographic measurements, lowers costs, and is particularly valuable in resource-limited settings or complex clinical scenarios, such as bilateral comminuted femoral fractures with concurrent bilateral forearm fractures. The proposed formula for estimating femoral nail length offers a straightforward and effective alternative.

Beyond addressing this clinical conundrum, the findings also suggest potential implications for incorporating fibula measurements in anthropometry studies focusing on human anatomy within the local population.

This study marks the inaugural comparison of fibula length to femoral length for estimating the optimal femoral nail length. Nonetheless, it is crucial to acknowledge certain limitations within this study, including its relatively modest sample size comprising 140 patients, primarily of a singular ethnicity and male gender. Despite these constraints, the findings presented herein serve as a robust foundation, laying the groundwork for subsequent investigations in diverse populations. Further studies exploring this methodology in varied demographic groups are warranted to enhance the generalizability and broaden the understanding of its applicability.

CONCLUSION

Measuring fibula length proves to be a reliable and straightforward method, demonstrating a strong correlation with femoral length, unaffected by variables such as age, BMI, or gender. The derived formula provides a simple an accurate means of estimating the maximum femoral nail length without resorting to unnecessary x-ray radiation. This method is particularly advantageous in situations where palpating the greater trochanter poses challenges or in cases involving bilateral comminuted femoral fractures with concurrent bilateral forearm fractures. The study establishes the effectiveness and practicality of using fibula length as a dependable alternative in various clinical scenarios.

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