



Variation in femoral length across different age groups and its correlation with walking patterns: A cross-sectional observational study.

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Abstract

Background:

Femoral length plays a vital role in determining lower limb biomechanics and walking efficiency. Variations in femoral length across different age groups may influence gait parameters such as step length and walking speed. This study aimed to investigate femoral length variations with age and examine their correlation with walking patterns.

Methods:

A cross-sectional observational study was conducted on 50 participants, divided into five equal age groups: 10–19, 20–29, 30–39, 40–49, and ≥ 50 years. Femoral length was measured using standardized anthropometric techniques. Gait parameters, including step length and walking speed, were recorded using a motion analysis setup. Descriptive statistics, ANOVA, and Pearson correlation analysis were employed to analyze the data.

Results:

The mean femoral length was highest in the 20–29 age group (45.1 ± 2.1 cm) and lowest in the 10–19 group (41.8 ± 2.4 cm). Walking parameters showed similar trends, with peak step length (72.4 ± 4.8 cm) and walking speed (1.51 ± 0.14 m/s) observed in the 20–29 group. A moderate positive correlation was found between femoral length and step length ($r = 0.62$, $p < 0.001$), as well as between femoral length and walking speed ($r = 0.58$, $p < 0.001$).

Conclusion:

Femoral length significantly varies across age groups and is positively correlated with walking efficiency. These findings underscore the importance of femoral length in gait biomechanics and may have implications in orthopedic assessment, rehabilitation, and prosthetic design.

Recommendations:

Incorporate femoral length assessment in gait evaluations to optimize rehabilitation strategies, prosthetic fitting, and age-specific orthopedic interventions.

Keywords: Femoral length, age groups, step length, walking speed, gait analysis, biomechanics, anthropometry

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Introduction

The femur, the longest and strongest bone in the human body, plays a vital role in maintaining upright posture and facilitating bipedal locomotion. Its anatomical dimensions, particularly femoral length, have a significant impact on gait biomechanics, walking efficiency, and lower limb function [1,2]. Variations in femoral structure, especially with aging,

can influence muscle mass, bone mineral density, and joint mechanics, thereby affecting gait parameters such as step length and walking speed [1,3,6].

Age-related changes in bone loading and sarcopenia contribute to alterations in walking stability and performance, underscoring the need for age-specific evaluations of gait [1,6]. While leg length discrepancies and structural abnormalities have been linked to gait asymmetry



and reduced stability [2,4], the relationship between normal femoral length variations across age groups and dynamic walking parameters remains underexplored.

Moreover, novel gait analysis tools, including metrics such as the Walking Orientation Randomness Metric (WORM), have highlighted the importance of assessing subtle gait changes to predict fall risk and mobility impairments [5]. Despite advancements in gait assessment technologies, limited data exist on how femoral length correlates with spatiotemporal parameters across the lifespan. Addressing this gap is crucial for enhancing rehabilitation strategies, optimizing prosthetic design, and understanding both developmental and degenerative influences on locomotor function.

This study was undertaken to address this gap by systematically evaluating the variation in femoral length across different age groups and analyzing its correlation with walking parameters. By exploring this relationship, we aim to contribute to a more comprehensive understanding of lower limb biomechanics and age-related changes in gait, which may assist clinicians, physiotherapists, and biomedical engineers in optimizing therapeutic interventions and device design.

Methodology

Study Design and Setting:

This cross-sectional observational study was carried out at the Neelima Institute of Medical Sciences, Hyderabad, Telangana, between May 2024 and February 2025. The work was undertaken through collaboration between the Departments of Orthopaedics and Anatomy. The institute is a tertiary care teaching hospital that houses multiple clinical and non-clinical departments, including Orthopaedics, General Medicine, General Surgery, Pediatrics, Obstetrics and Gynaecology, Radiology, Anatomy, Physiology, and Community Medicine. It provides both inpatient and outpatient services, advanced diagnostic facilities, rehabilitation care, and medical education. For this study, gait assessments were performed using the calibrated gait analysis walkway system within the Department of Orthopaedics, ensuring uniform and controlled measurement conditions.

Study Population:

A total of 50 healthy individuals were recruited and categorized into five age-based groups: 10–19, 20–29, 30–39, 40–49, and ≥ 50 years, with 10 participants in each group. Participants were selected using a convenience sampling method.

Sample Size Determination:

The sample size of 50 participants was determined based on feasibility and previous literature on gait and anthropometric studies in similar settings. Considering the exploratory nature of this study, a minimum of 10 participants per age stratum was deemed adequate to allow for comparative analysis across five predefined age groups (10–19, 20–29, 30–39, 40–49, and ≥ 50 years). This stratified distribution was chosen to ensure adequate representation of developmental and aging phases. Although no formal power calculation was performed due to the observational design, the sample was sufficient to detect moderate correlations ($r > 0.5$) with statistical significance at $\alpha = 0.05$ and power of 80%, as supported by prior gait studies.

Inclusion Criteria:

Healthy individuals aged 10 years and above.

Willingness to participate and provide informed consent.

Exclusion Criteria:

Individuals with any history of lower limb fracture, congenital deformity, or musculoskeletal disorders.

Subjects with neurological or systemic conditions affecting gait.

Bias and Its Management:

Several strategies were implemented to minimize bias in the study:

Selection Bias:

To reduce selection bias, participants were recruited from different hospital units and the community outpatient clinics, ensuring representation across age groups. Inclusion and exclusion criteria were strictly applied to maintain homogeneity.

Measurement Bias:

Femoral length was measured by a single trained investigator using standardized anthropometric techniques to avoid inter-observer variability. Each measurement was repeated twice, and the average value was recorded.

Performance Bias:

Gait analysis was conducted under identical conditions for all participants (barefoot walking at a comfortable pace on the same walkway), minimizing variability due to environment or footwear.



Confounding Bias:

Potential confounders such as lower limb deformities, systemic illnesses, or neurological conditions were excluded by design to ensure that only healthy individuals were studied.

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Data Collection Procedures:

Femoral length was measured using an anthropometric rod from the greater trochanter to the lateral epicondyle of the femur with the subject in the anatomical position. All measurements were taken on the right side for standardization.

Gait parameters, including step length and walking speed, were assessed using a calibrated gait analysis walkway. Participants were instructed to walk barefoot at a comfortable pace, and each parameter was recorded over three trials to ensure accuracy.

Statistical Analysis:

Data were entered into Microsoft Excel and analyzed using SPSS software version 26. Descriptive statistics were used to present means and standard deviations. One-way

ANOVA was used to assess differences between age groups. Pearson correlation coefficients were calculated to evaluate the relationship between femoral length and walking parameters. A p-value < 0.05 was considered statistically significant.

Ethical Considerations:

The study protocol was approved by the Institutional Ethics Committee of Neelima Institute of Medical Sciences. Written informed consent was obtained from all participants or their guardians in the case of minors.

Results

Participant Screening and Recruitment:

A total of 58 individuals were initially approached for participation during the study period. Of these, 4 declined consent, and 2 did not meet the inclusion criteria due to prior lower limb fractures. Two more participants were excluded because of musculoskeletal conditions affecting gait. Finally, 50 healthy individuals satisfied the eligibility criteria and were included in the study. All 50 participants completed the assessments and were analyzed (Figure 1).

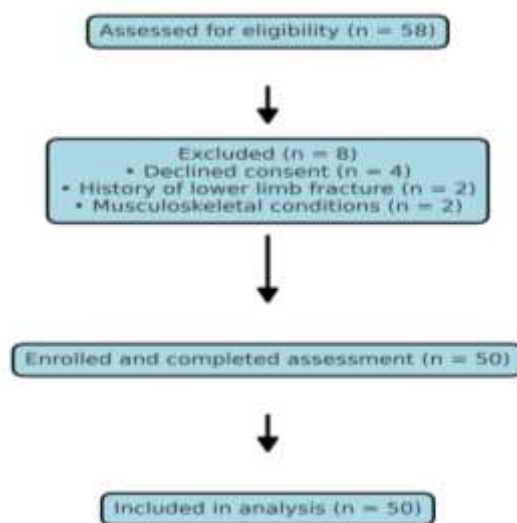


Figure 1: Participant Flow Diagram

A total of 50 participants were enrolled in the study and categorized into five age groups with an equal distribution of 10 individuals per group (Table 1).



Table 1: Demographic Distribution by Age Group

Age Group (Years)	Sample Size (n)
10–19	10
20–29	10
30–39	10
40–49	10
≥50	10
Total	50

The age groups included: 10–19 years, 20–29 years, 30–39 years, 40–49 years, and ≥50 years.

Femoral Length Variation:

The mean femoral length showed an age-dependent pattern. The highest mean femoral length was observed in the 20–29

years age group (45.1 ± 2.1 cm), followed closely by the 30–39 years group (44.7 ± 1.9 cm). A gradual decline was observed in older age groups, with the lowest mean femoral length noted in the 10–19 years group (41.8 ± 2.4 cm) and the ≥50 years group (42.1 ± 2.6 cm), as shown in **Table 2**.

Table 2: Femoral Length by Age Group

Age Group (Years)	Mean Femoral Length (cm)	Standard Deviation (SD)
10–19	41.8	2.4
20–29	45.1	2.1
30–39	44.7	1.9
40–49	43.2	2.2
≥50	42.1	2.6

Walking Parameters Across Age Groups:

Walking performance, assessed via step length and walking speed, demonstrated a trend consistent with femoral length variations. The 20–29 years group exhibited the longest step

length (72.4 ± 4.8 cm) and the highest walking speed (1.51 ± 0.14 m/s). These parameters gradually declined with increasing age. The ≥50 years group showed the shortest step length (63.5 ± 6.4 cm) and lowest walking speed (1.28 ± 0.15 m/s), as detailed in **Table 3**.

Table 3: Walking Parameters by Age Group

Age Group (Years)	Mean Step Length (cm)	Step Length SD	Mean Walking Speed (m/s)	Walking Speed SD
10–19	65.2	5.6	1.34	0.12
20–29	72.4	4.8	1.51	0.14
30–39	70.6	5.2	1.47	0.13
40–49	66.8	6.0	1.39	0.11
≥50	63.5	6.4	1.28	0.15

Correlation Analysis:

Pearson correlation analysis revealed a moderate positive correlation between femoral length and both step length ($r =$

0.62 , $p < 0.001$) and walking speed ($r = 0.58$, $p < 0.001$). These results indicate that individuals with greater femoral lengths tend to exhibit improved walking parameters (Table 4).

Table 4: Correlation Between Femoral Length and Walking Parameters

Variable Pair	Pearson Correlation Coefficient (r)	p-value
Femoral Length vs Step Length	0.62	< 0.001
Femoral Length vs Walking Speed	0.58	< 0.001



Discussion:

The highest mean femoral length was observed in the 20–29 years age group (45.1 ± 2.1 cm), followed closely by the 30–39 years group (44.7 ± 1.9 cm). In contrast, the 10–19 years and ≥ 50 years groups demonstrated lower values (41.8 ± 2.4 cm and 42.1 ± 2.6 cm, respectively). Correspondingly, step length and walking speed peaked in early adulthood and declined with advancing age, highlighting the influence of skeletal and muscular maturity on gait performance.

These findings align with established skeletal maturation patterns, where maximum bone length and density are typically achieved by the third decade of life [8]. The apparent decline in femoral length in older groups is unlikely to represent true shortening of the bone, but rather reflects postural changes associated with aging, including vertebral compression, pelvic tilt alterations, and musculoskeletal degeneration [7].

Walking parameters demonstrated moderate positive correlations with femoral length, reinforcing prior evidence that longer limb segments are associated with more efficient gait biomechanics [9]. The superior gait performance in the 20–29 years group reflects optimal musculoskeletal efficiency, whereas the decline in those aged ≥ 50 years likely results from sarcopenia, joint stiffness, and impaired balance—factors frequently encountered in elderly populations.

From a developmental perspective, lower limb length has been shown to play an important role in locomotor efficiency and overall health. Longer legs confer biomechanical advantages for stride length and energy conservation, which have evolutionary as well as clinical implications [10]. Similar relevance is noted in pediatric populations, where leg length and body composition strongly influence gait efficiency and physical performance [11].

Finally, the consistent correlations between femoral length, step length, and walking speed emphasize the role of variability in human movement. Controlled variability can represent adaptive strategies, but it may also serve as an early indicator of functional decline in aging or pathological conditions [12]. These findings support the integration of femoral length assessment into gait analysis to better identify mobility risks and optimize rehabilitation strategies.

Generalizability:

The findings of this study are generalizable to healthy individuals within the studied age range; however, variations in population demographics, lifestyle, and physical activity levels may limit broader applicability. Further research in diverse populations is recommended.

Conclusion:

This study demonstrates that femoral length varies significantly across age groups and has a positive correlation with walking parameters such as step length and walking speed. The 20–29 years age group exhibited the greatest femoral length and optimal gait characteristics, while individuals aged ≥ 50 years showed reduced femoral length and compromised walking performance. These findings highlight the biomechanical importance of femoral length in efficient locomotion. Understanding such age-related variations can aid in clinical assessments, rehabilitation planning, and the design of assistive devices and prosthetics. Further large-scale, longitudinal studies are warranted to explore gender differences and other influencing factors, like muscle strength and joint flexibility, on gait.

Limitations:

The relatively small sample size and the cross-sectional design limit causal interpretation. Additionally, gender differences and body mass index (BMI) were not accounted for, which could influence gait parameters and femoral length measurements. Future studies with larger, more diverse populations and longitudinal follow-up are recommended to validate these findings and explore additional biomechanical and physiological factors influencing gait.

Recommendations:

Based on the study findings, it is recommended that femoral length be routinely assessed in clinical evaluations of gait, particularly in populations with mobility issues. Understanding the variation of femoral length across age groups can aid in developing age-appropriate rehabilitation programs and optimizing physical therapy interventions. Prosthetic and orthotic designs should also consider femoral length to enhance comfort and walking efficiency. Additionally, femoral length measurements may serve as valuable predictors in the early identification of gait abnormalities, facilitating timely corrective measures. Future research should explore longitudinal changes and include diverse populations to strengthen the applicability of these findings in clinical practice.

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List of abbreviations:

ANOVA – Analysis of Variance

SD – Standard Deviation

SPSS – Statistical Package for the Social Sciences

WORM – Walking Orientation Randomness Metric

cm – Centimeter

m/s – Meters per second

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The study had no funding.

Conflict of interest:

The authors declare no conflict of interest.

Author contributions:

KZUH-Concept and design of the study, results interpretation, review of literature, and preparation of the first draft of the manuscript. Statistical analysis and interpretation, revision of manuscript. **SKK**-Concept and design of the study, results interpretation, review of literature, and preparing the first draft of the manuscript, revision of the manuscript. **SU**-Concept and design of the study, results interpretation, review of literature, and preparing the first draft of the manuscript. Statistical analysis and interpretation, revision of manuscript.

Data availability:

Data is available on request

Author Biography:

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References:

1. Fan Y, Zhang B, Huang G, Zhang G, Ding Z, Li Z, Sinclair J, Fan Y. Sarcopenia: Body Composition and Gait Analysis. *Front Aging Neurosci.* 2022 Jul 13;14:909551. Doi: 10.3389/fnagi.2022.909551. PMID: 35912078; PMCID: PMC9326397. <https://doi.org/10.3389/fnagi>
2. Azizan NA, Basaruddin KS, Salleh AF. The Effects of Leg Length Discrepancy on Stability and Kinematics-Kinetics Deviations: A Systematic Review. *Appl Bionics Biomech.* 2018 Jul 11;2018:5156348. Doi: 10.1155/2018/5156348. PMID: 30116295; PMCID: PMC6079584. <https://doi.org/10.1155/2018/5156348>
3. Paul SM, Gabor LR, Rudzinski S, Giovanni D, Boyce AM, Kelly MR, Collins MT. Disease severity and functional factors associated with walking performance in polyostotic fibrous dysplasia. *Bone.* 2014 Mar;60:41-7. doi: 10.1016/j.bone.2013.11.022. Epub 2013 Dec 4. PMID: 24316419; PMCID: PMC3985279. <https://doi.org/10.1016/j.bone.2013.11.022>
4. Khamis, S., Danino, B., Ovadia, D., & Carmeli, E. (2018). Correlation between Gait Asymmetry and Leg Length Discrepancy-What Is the Role of Clinical Abnormalities? *Applied Sciences*, 8(10), 1979. <https://doi.org/10.3390/app8101979>



5. Mobbs RJ, Natarajan P, Fonseka RD, Betteridge C, Ho D, Mobbs R, Sy L, Maharaj M. Walking orientation randomness metric (WORM) score: pilot study of a novel gait parameter to assess walking stability and discriminate fallers from non-fallers using wearable sensors. *BMC Musculoskelet Disord*. 2022 Mar 29;23(1):304. doi: 10.1186/s12891-022-05211-1. PMID: 35351090; PMCID: PMC8966274. <https://doi.org/10.1186/s12891-022-05211-1>
6. Anderson DE, Madigan ML. Effects of age-related differences in femoral loading and bone mineral density on strains in the proximal femur during controlled walking. *J Appl Biomech*. 2013 Oct;29(5):505-16. doi: 10.1123/jab.29.5.505. Epub 2012 Nov 21. PMID: 23185080; PMCID: PMC3796161. <https://doi.org/10.1123/jab.29.5.505>
7. Marshall LM, Zmuda JM, Chan BK, Barrett-Connor E, Cauley JA, Ensrud KE, Lang TF, Orwoll ES; Osteoporotic Fractures in Men (MrOS) Research Group. Race and ethnic variation in proximal femur structure and BMD among older men. *J Bone Miner Res*. 2008 Jan;23(1):121-30. doi: 10.1359/jbmr.070908. PMID: 17892375; PMCID: PMC2663587. <https://doi.org/10.1359/jbmr.070908>
8. Harvey NC, Mahon PA, Robinson SM, Nisbet CE, Javaid MK, Crozier SR, Inskip HM, Godfrey KM, Arden NK, Dennison EM, Cooper C; SWS Study Group. Different indices of fetal growth predict bone size and volumetric density at 4 years of age. *J Bone Miner Res*. 2010 Apr;25(4):920-7. doi: 10.1359/jbmr.091022. PMID: 20437610; PMCID: PMC3793299. <https://doi.org/10.1359/jbmr.091022>
9. Jiang C, Liu X, Su Q, Huang D, Tu X, Ke X, Lin Z. Gait kinematic and kinetic characteristics among older adults with varying degrees of frailty: a cross-sectional study. *Sci Rep*. 2025 Mar 29;15(1):10915. doi: 10.1038/s41598-025-95101-y. PMID: 40157994; PMCID: PMC11954902. <https://doi.org/10.1038/s41598-025-95101-y>
10. Bogin B, Varela-Silva MI. Leg length, body proportion, and health: a review with a note on beauty. *Int J Environ Res Public Health*. 2010 Mar;7(3):1047-75. doi: 10.3390/ijerph7031047. Epub 2010 Mar 11. PMID: 20617018; PMCID: PMC2872302. <https://doi.org/10.3390/ijerph7031047>
11. Popescu C, Matei D, Amzolini AM, Trăistaru MR. Comprehensive Gait Analysis and Kinetic Intervention for Overweight and Obese Children. *Children (Basel)*. 2025 Jan 23;12(2):122. doi: 10.3390/children12020122. PMID: 40003224; PMCID: PMC11854336. <https://doi.org/10.3390/children12020122>
12. Stergiou N, Decker LM. Human movement variability, nonlinear dynamics, and pathology: is there a connection? *Hum Mov Sci*. 2011 Oct;30(5):869-88. doi: 10.1016/j.humov.2011.06.002. Epub 2011 Jul 29. PMID: 21802756; PMCID: PMC3183280. <https://doi.org/10.1016/j.humov.2011.06.002>



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