

Original Research Article

Can height and weight of the patient predict the tibial footprint dimensions of anterior cruciate ligament on MRI: an observational study

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Received: 12 July 2025

Accepted: 06 August 2025

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ABSTRACT

Background: Anterior cruciate ligament (ACL) reconstruction techniques are increasingly individualized based on patient-specific anatomy. Preoperative knowledge of ACL dimensions guides surgical planning, particularly regarding single versus double-bundle reconstruction. This study aimed to evaluate ACL tibial footprint dimensions in a South Indian population and investigate their correlation with patient anthropometric measures.

Methods: This retrospective observational study analyzed MRI scans of 78 patients (41 males, 37 females) with intact ACL who presented with knee pain at a tertiary care teaching hospital in South India between January 2023 and April 2025. ACL tibial footprint length and width were measured on MRI. Correlation and regression analyses were performed to investigate relationships between ACL dimensions and patient height, weight, age and gender.

Results: The mean ACL tibial footprint length and width were 13.7 ± 1.8 mm and 11.5 ± 1.4 mm, respectively. Height demonstrated a strong positive correlation with ACL length ($r=0.68$, $p<0.001$) and a moderate correlation with ACL width ($r=0.52$, $p<0.001$). In multivariable analysis, height remained the strongest independent predictor of ACL length (standardized $\beta=0.53$, $p<0.001$), while weight ($\beta=0.04$, $p=0.687$) and age ($\beta=0.03$, $p=0.749$) showed no significant independent association. For every 1 cm increase in height, ACL length increased by 0.182 mm (95% CI: 0.140-0.224). Gender differences in ACL dimensions were significant but partially attributable to height differences. Overall, 60.3% of participants had ACL length <14 mm, with a significantly higher proportion among females (83.8%) compared to males (39.0%).

Conclusions: Height is a strong predictor of ACL tibial footprint dimensions in South Indian patients, explaining 46% of the variability in ACL footprint length. Patient height could serve as a simple clinical predictor of ACL footprint dimensions when advanced imaging is not readily available, potentially guiding surgical decision-making regarding reconstruction technique.

Keywords: Anterior cruciate ligament, ACL reconstruction, Anthropometry, Height, MRI, South Indian population, Surgical planning, Tibial footprint

INTRODUCTION

The anterior cruciate ligament (ACL) plays a pivotal role in knee joint stability by restricting excessive anterior tibial translation and rotational movements relative to the

femur.¹ As one of the primary stabilizers of the knee joint, the ACL consists of two functional bundles: the anteromedial bundle, which primarily restricts anterior tibial translation and the posterolateral bundle, which predominantly controls rotational stability.² ACL injuries

represent one of the most common ligamentous injuries of the knee, with an estimated incidence of 68.6 per 100,000 person-years.³ These injuries significantly impact patient quality of life and necessitate surgical intervention to restore knee stability and function. ACL reconstruction has evolved considerably over the past several decades, transitioning from non-anatomic techniques to approaches that more precisely restore the native ACL anatomy.⁴ Growing evidence suggests that double-bundle reconstruction may provide superior rotational stability and potentially lower re-rupture rates in certain patient populations.⁵

The concept of anatomic ACL reconstruction emphasizes restoring the native ligament's insertion sites, orientation and dimensions to optimize knee kinematics.⁶ This individualized approach considers patient-specific factors such as native ACL footprint dimensions, which vary considerably among individuals. The tibial footprint of the ACL serves as a critical reference point for tunnel placement during reconstruction and influences the selection of appropriate graft size and type.⁷ Accurate preoperative assessment of these dimensions facilitates surgical planning and may improve functional outcomes. Studies have demonstrated strong correlations between ACL footprint dimensions measured on MRI and actual anatomical measurements, validating its utility in surgical planning.⁸ According to established clinical decision algorithms, tibial footprint dimensions less than 14 mm may preclude double-bundle reconstruction due to spatial constraints, necessitating a single-bundle approach.^{4,6} Previous studies have explored correlations between patient height and ACL length, suggesting that taller individuals may have longer ACLs.⁹ However, the relationship between basic anthropometric measures and tibial footprint dimensions remains incompletely characterized, particularly in non-Western populations.

Most existing literature on ACL footprint morphology derives from Western populations, potentially limiting its applicability to other demographic groups. For instance, studies have suggested that East Asian populations may have smaller ACL dimensions compared to Western counterparts, which could impact graft selection and surgical technique.¹⁰ Establishing normative data for diverse populations is therefore essential for optimizing patient-specific approaches to ACL reconstruction. In this retrospective observational study, by analyzing the relationship between patient height, weight and ACL tibial footprint dimensions measured on MRI we aim to contribute to the growing body of knowledge on individualized approaches to ACL reconstruction while establishing normative data for an underrepresented population in the orthopaedic literature.

Aims and objectives

The primary aim of this study was to evaluate the dimensions of the ACL tibial footprint in a South Indian population using MRI. Secondary objective was to

investigate potential correlations between these tibial footprint dimensions to patient anthropometric parameters, (height and weight).

METHODS

Study design and setting

This was a retrospective observational study conducted at a tertiary care hospital in South India. Patient confidentiality was maintained throughout the study and all procedures were performed in accordance with the ethical standards of the institutional research committee.

Study population

The study population comprised patients who presented to our orthopaedic department with knee pain and subsequently underwent MRI evaluation between January 2023 and April 2025. We included patients aged between 18 and 45 years with intact ACL. The sample size required for the study was calculated to be 80 patients, based on an anticipated correlation coefficient of 0.3 between anthropometric measures and ACL dimensions, with 80% power and a 5% level of significance. All patients underwent a thorough clinical examination by a senior orthopaedic surgeon with 10 years of experience in sports medicine before being referred for MRI evaluation.

Patients with multi-ligament knee injuries, evidence of partial or complete ACL tears, open growth plates, degenerative changes of the knee joint (Kellgren-Lawrence grade ≥ 2), acute or chronic knee infections, fractures around the knee or previous history of knee surgery, patients with congenital anomalies of lower limb, inflammatory arthropathies were excluded from the study.

Data collection

Patient demographic data including age, gender, height (in centimeters) and weight (in kilograms) were retrieved from hospital electronic medical records. For patients who underwent bilateral knee MRI during the study period, only the right knee was included in the analysis to prevent potential statistical bias from paired observations.

MRI protocol

All MRI examinations were performed using a 3.0 Tesla MRI scanner (Siemens Magnetom Skyra, Erlangen, Germany) with a dedicated 15-channel knee coil. Patients were positioned supine with the knee in a neutral position (0-15 degrees of flexion). The standardized imaging protocol included proton density-weighted sequences in axial, sagittal and coronal planes, T2-weighted fat-suppressed sequences in all three planes and T1-weighted sequences in the sagittal plane. The following acquisition parameters were used: slice thickness of 3 mm, interslice gap of 0.3 mm, field of view of 160×160 mm and matrix

size of 384×384. The total acquisition time was approximately 25 minutes per knee.

Image analysis and measurements

All MRI scans were independently reviewed by two experienced musculoskeletal radiologists who were blinded to the patient's anthropometric data. The measurements were performed using the hospital's picture archiving and communication system

The length of the ACL tibial footprint was measured on the sagittal image that best demonstrated both the tibial and femoral attachments. It was defined as the maximum anteroposterior distance from the most anterior to the most posterior fibers of the ACL at its tibial attachment site. The width was measured as the maximum mediolateral distance between the most medial and most lateral fibers of the ACL on the oblique coronal image at its tibial insertion site.

Statistical analysis

Statistical analysis was performed using SPSS software version 26.0 (IBM Corp., Armonk, NY, USA). Normality of continuous variables was assessed using the Shapiro-Wilk test. Descriptive statistics were presented as mean±standard deviation for normally distributed variables and median with interquartile range for non-normally distributed variables. Categorical variables were expressed as frequencies and percentages.

The relationship between anthropometric measures (height and weight) and ACL tibial footprint dimensions (length and width) was evaluated using Pearson's correlation coefficient for normally distributed data and Spearman's rank correlation coefficient for non-normally distributed data. Simple linear regression models were developed to assess the predictive value of height and weight for ACL tibial footprint dimensions. Multiple linear regression analysis was performed to evaluate the combined effect of anthropometric variables on ACL dimensions, adjusting for potential confounders such as age and gender. Standardized beta coefficients were calculated to compare the relative strength of each predictor variable.

Intra-observer and inter-observer reliability were assessed using intraclass correlation coefficients (ICCs) with 95% confidence intervals. ICC values were interpreted as follows: <0.40 as poor reliability, 0.40-0.59 as fair reliability, 0.60-0.74 as good reliability and >0.75 as excellent reliability. Gender-based differences in ACL dimensions were analyzed using independent t-tests or Mann-Whitney U tests, as appropriate. A p value <0.05 was considered statistically significant for all analyses.

RESULTS

The present study involved a total of 78 participants with complete data available for analysis, after excluding two

cases with missing ACL dimension measurements. The demographic and anthropometric characteristics of the study population are presented in table 1. The mean age of participants was 28.6±6.2 years, with a slight male predominance (52.6%). The average height and weight of the study participants were 171.4±6.7 cm and 71.0±15.9 kg, respectively. Right knees were more frequently evaluated (61.5%) compared to left knees (38.5%).

The ACL tibial footprint dimensions in the overall study population and stratified by gender are presented in table 2. The mean ACL length was 13.7±1.8 mm and the mean ACL width was 11.5±1.4 mm. Significant gender differences were observed in both dimensions. Males had significantly larger ACL tibial footprint dimensions compared to females, with a mean length of 14.6±1.5 mm versus 12.6±1.3 mm ($p<0.001$) and a mean width of 12.4±1.3 mm versus 10.6±0.9 mm ($p<0.001$).

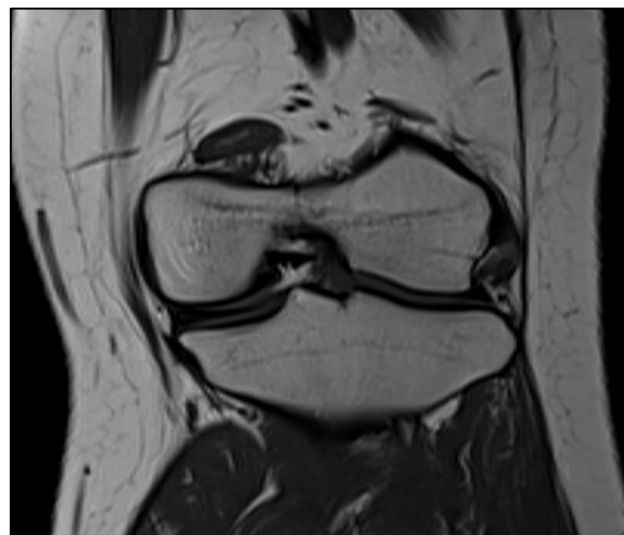


Figure 1: T1 coronal MRI of left knee. Measurement of width of ACL footprint.

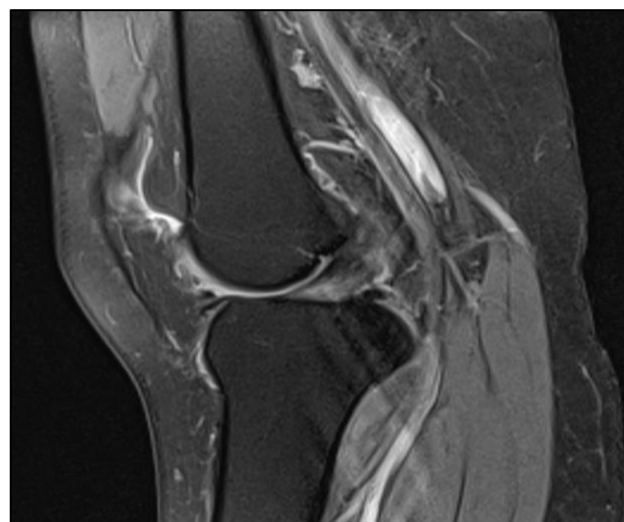


Figure 2: PD FS SAG MRI image of left knee measurement of the footprint length of ACL.

The correlation analysis between anthropometric measures and ACL dimensions revealed significant associations, as shown in Table 3. Height demonstrated a strong positive correlation with ACL footprint length ($r=0.68$, $p<0.001$) and a moderate correlation with ACL width ($r=0.52$, $p<0.001$). Weight showed a weak but statistically significant correlation with both ACL length ($r=0.31$, $p=0.006$) and ACL width ($r=0.25$, $p=0.027$). Age did not significantly correlate with either ACL length ($r=0.07$, $p=0.542$) or ACL width ($r=0.06$, $p=0.601$).

Simple linear regression analysis further quantified the relationships between anthropometric measures and ACL dimensions (Table 4). Height emerged as a significant predictor of both ACL length and width. For every 1 cm increase in height, ACL length increased by 0.182 mm (95% CI: 0.140 to 0.224, $p<0.001$), with height explaining 46% of the variability in ACL length ($R^2=0.46$). Similarly, for every 1 cm increase in height, ACL width increased by 0.109 mm (95% CI: 0.074 to 0.144, $p<0.001$), with height explaining 27% of the variability in ACL width ($R^2=0.27$). Weight showed statistically significant but weaker predictive value, explaining only 10% of the variability in ACL length ($R^2=0.10$) and 6% of the variability in ACL width ($R^2=0.06$).

Multiple linear regression analysis was conducted to evaluate the independent contribution of each predictor variable while controlling for potential confounders (Tables 5 and 6). For ACL length, the multivariable model including height, weight, age and gender explained 49% of the total variance (adjusted $R^2=0.46$, $p<0.001$). Height remained the strongest independent predictor of ACL length (standardized $\beta=0.53$, $p<0.001$), followed by gender (standardized $\beta=0.21$, $p=0.039$). After adjusting for other variables, weight (standardized $\beta=0.04$, $p=0.687$) and age (standardized $\beta=0.03$, $p=0.749$) were no longer significant predictors of ACL length.

Similarly, for ACL width, the multivariable model explained 34% of the total variance (adjusted $R^2=0.30$, $p<0.001$). Height (standardized $\beta=0.36$, $p=0.002$) and gender (standardized $\beta=0.28$, $p=0.012$) were significant

independent predictors of ACL width, while weight (standardized $\beta=0.03$, $p=0.762$) and age (standardized $\beta=0.02$, $p=0.849$) showed no significant association after adjusting for other variables.

To further explore the relationship between height and ACL dimensions, participants were categorized into three height groups: <165 cm, 165-175 cm and >175 cm (Table 7). A significant trend of increasing ACL dimensions with increasing height was observed. The mean ACL length increased from 11.9 ± 1.2 mm in the <165 cm group to 13.5 ± 1.3 mm in the 165-175 cm group and further to 15.5 ± 1.3 mm in the >175 cm group ($p<0.001$). Similarly, the mean ACL width increased progressively across the height categories (10.4 ± 0.8 mm, 11.4 ± 1.2 mm and 12.7 ± 1.4 mm, respectively; $p<0.001$).

When participants were categorized based on weight (<60 kg, 60-80 kg and >80 kg), a similar trend was observed (Table 8). The mean ACL length increased from 12.4 ± 1.5 mm in the <60 kg group to 13.7 ± 1.6 mm in the 60-80 kg group and further to 14.8 ± 1.6 mm in the >80 kg group ($p<0.001$). The mean ACL width also showed a progressive increase across weight categories (10.6 ± 1.0 mm, 11.5 ± 1.3 mm and 12.3 ± 1.5 mm, respectively; $p<0.001$). However, this association was likely confounded by height, as evidenced by the multivariable regression analysis where weight was no longer a significant predictor after adjusting for height and other variables.

Additionally, an analysis was performed to determine the proportion of patients with ACL tibial footprint length less than 14 mm. In the overall study population, 47 participants (60.3%) had an ACL length <14 mm. When stratified by gender, 16 males (39.0%) and 31 females (83.8%) had an ACL length <14 mm, indicating a significantly higher proportion among females ($p<0.001$).

Based on the simple linear regression equation (ACL length $=0.182\times\text{Height}-17.39$), a height of 172.5 cm would predict an ACL length of 14 mm.

Table 1: Demographic and anthropometric characteristics of study participants.

Characteristic	Value
Number of participants	78*
Age (years), mean$\pm$SD	28.6 $\pm$ 6.2
Gender, N (%)	
Male	41 (52.6%)
Female	37 (47.4%)
Height (cm), mean$\pm$SD	171.4 $\pm$ 6.7
Weight (kg), mean$\pm$SD	71.0 $\pm$ 15.9
Knee side, N (%)	
Right	48 (61.5%)
Left	30 (38.5%)

*Note: Two cases had missing ACL dimension data.

Table 2: ACL tibial footprint dimensions in the study population.

Measurement	Overall (n=78)	Males (n=41)	Females (n=37)	P value
ACL length (mm), mean±SD	13.7±1.8	14.6±1.5	12.6±1.3	<0.001
ACL width (mm), mean±SD	11.5±1.4	12.4±1.3	10.6±0.9	<0.001

Table 3: Correlation between Anthropometric Measures and ACL Dimensions.

Variables	Correlation Coefficient (r)	P value
Height vs ACL length	0.68	<0.001
Height vs ACL width	0.52	<0.001
Weight vs ACL length	0.31	0.006
Weight vs ACL width	0.25	0.027
Age vs ACL length	0.07	0.542
Age vs ACL width	0.06	0.601

Table 4: Simple linear regression analysis for predicting ACL dimensions.

Model	Regression coefficient (β)	95% CI	R ²	P value
Height predicting ACL length	0.182	0.140 to 0.224	0.46	<0.001
Height predicting ACL width	0.109	0.074 to 0.144	0.27	<0.001
Weight predicting ACL length	0.035	0.010 to 0.060	0.10	0.006
Weight predicting ACL width	0.022	0.003 to 0.042	0.06	0.027

Table 5: Multiple linear regression analysis for predicting ACL length.

Variable	Standardized coefficient (β)	95% CI	P value
Height	0.53	0.089 to 0.194	<0.001
Weight	0.04	-0.017 to 0.026	0.687
Age	0.03	-0.038 to 0.052	0.749
Gender (Male)	0.21	0.037 to 1.445	0.039

Table 6: Multiple linear regression analysis for predicting ACL width.

Variable	Standardized coefficient (β)	95% CI	P value
Height	0.36	0.027 to 0.112	0.002
Weight	0.03	-0.015 to 0.020	0.762
Age	0.02	-0.031 to 0.038	0.849
Gender (Male)	0.28	0.156 to 1.253	0.012

Model R² = 0.34, Adjusted R² = 0.30, p <0.001.

Table 7: ACL dimensions based on height categories.

Height category	N	ACL Length (mm), mean±SD	ACL Width (mm), mean±SD
<165 cm	16	11.9±1.2	10.4±0.8
165-175 cm	40	13.5±1.3	11.4±1.2
>175 cm	22	15.5±1.3	12.7±1.4
P value		<0.001	<0.001

Table 8: ACL dimensions based on weight categories.

Weight category	N	ACL Length (mm), mean±SD	ACL Width (mm), mean±SD
<60 kg	17	12.4±1.5	10.6±1.0
60-80 kg	39	13.7±1.6	11.5±1.3
>80 kg	22	14.8±1.6	12.3±1.5
p-value		<0.001	<0.001

DISCUSSION

The present study investigated the relationship between patient anthropometric measures and ACL tibial footprint dimensions in a South Indian population. Our findings revealed that height is a strong and independent predictor of ACL tibial footprint dimensions, particularly ACL length, while weight showed minimal independent association after adjusting for other factors.

Height demonstrated a strong positive correlation with ACL length ($r=0.68$, $p<0.001$) and a moderate correlation with ACL width ($r=0.52$, $p<0.001$). These findings align with those reported by Pontoh et al, who found a significant correlation between patient height and ACL length ($r=0.58$, $p<0.001$) in an Indonesian population.¹¹ Similarly, Treme et al, reported that taller patients had significantly longer ACL grafts ($r=0.35$, $p<0.001$), indirectly suggesting a relationship between height and native ACL dimensions.¹²

Our study demonstrated that for every 1 cm increase in height, ACL length increased by approximately 0.182 mm (95% CI: 0.140 to 0.224, $p<0.001$). This linear relationship is consistent with the findings of Brown et al, who reported that height was the strongest predictor of ACL length, with an increase of 0.2 mm in ACL length for every 1 cm increase in height ($p<0.001$).¹³ The slightly lower coefficient in our study might reflect population-specific variations, highlighting the importance of region-specific data for surgical planning.

The mean ACL tibial footprint length in our study was 13.7 ± 1.8 mm, which is comparable to the values reported in several cadaveric and imaging studies. Kopf et al reported a mean tibial insertion length of 14.9 ± 2.2 mm in their cadaveric study, while Kim et al, found a mean ACL tibial footprint length of 15.4 ± 2.1 mm on MRI measurements.^{14,15} The slightly smaller dimensions observed in our South Indian population are consistent with ethnic variations reported in the literature. Iriuchishima et al compared ACL dimensions between Caucasian and Japanese populations and found that Japanese specimens had significantly smaller tibial footprint dimensions (14.6 ± 1.7 mm vs. 17.6 ± 2.0 mm, $p<0.05$).¹⁶

Gender differences in ACL dimensions were prominent in our study, with males having significantly larger ACL tibial footprint dimensions compared to females (length: 14.6 ± 1.5 mm vs. 12.6 ± 1.3 mm, $p<0.001$, width: 12.4 ± 1.3 mm vs. 10.6 ± 0.9 mm, $p<0.001$). These findings corroborate those of Pujol et al who reported that females had significantly smaller ACL dimensions than males, with mean tibial insertion areas of 114.5 ± 17.9 mm² vs. 175.6 ± 41.2 mm², $p<0.001$.¹⁷ However, our multivariable analysis revealed that after adjusting for height, the independent effect of gender on ACL dimensions was reduced, suggesting that much of the gender difference could be attributed to height differences between males

and females. This observation is consistent with the findings of Chandrashekar et al who reported that gender differences in ACL size persisted even after normalizing for body weight but were attenuated after adjusting for height.¹⁸

The clinical significance of our findings lies in their potential application for preoperative planning in ACL reconstruction. According to van Eck et al, an ACL tibial footprint length less than 14 mm makes double-bundle reconstruction technically challenging and may necessitate a single-bundle approach.¹⁹ In our study population, 60.3% of participants had an ACL length <14 mm, with a significantly higher proportion among females (83.8%) compared to males (39.0%). This suggests that a substantial proportion of South Indian patients, particularly females, might have anatomical constraints for double-bundle reconstruction. Based on our regression model, patients shorter than 172.5 cm would be predicted to have an ACL length <14 mm, potentially guiding surgical decision-making when preoperative MRI is not available.

Weight showed a weak but statistically significant correlation with ACL dimensions in simple correlation analysis (length: $r=0.31$, $p=0.006$, width: $r=0.25$, $p=0.027$). However, after adjusting for height and other variables in multivariable analysis, weight was no longer a significant predictor. This finding differs somewhat from the results reported by Gupta et al who found significant correlations between body weight and ACL dimensions in a North Indian population ($r=0.41$, $p<0.001$ for tibial footprint width).²⁰ The discrepancy could be attributed to differences in study populations or methodological approaches, highlighting the need for region-specific data.

Age did not significantly correlate with ACL dimensions in our study (length: $r=0.07$, $p=0.542$; width: $r=0.06$, $p=0.601$). This is consistent with the findings of most previous studies, which have reported minimal or no association between age and ACL dimensions in adult populations. Ichiba et al found no significant correlation between age and ACL cross-sectional area in their MRI-based study of 103 patients.²¹

Our study has several strengths, including a balanced gender distribution, comprehensive analysis of multiple potential predictors and application of rigorous statistical methods. However, some limitations should be acknowledged. First, the cross-sectional design precludes establishment of causal relationships. Second, MRI measurements, while validated against anatomical measurements in previous studies, may have inherent measurement errors.

CONCLUSION

From this study we conclude that height is a strong and independent predictor of ACL tibial footprint dimension, particularly ACL length, while gender also shows

variability in dimensions, weight and age show minimal or no independent association after accounting for height and gender.

Funding: No funding sources

Conflict of interest: None declared

Ethical approval: The study was approved by the Institutional Ethics Committee

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Cite this article as: Panduranga BV, Mahendranath, Dyapur N, Janardhan S, Kumar R, Ganesan PVM. Can height and weight of the patient predict the tibial footprint dimensions of anterior cruciate ligament on MRI: an observational study. *Int J Res Orthop* 2025;11:1184-90.