

Anthropometric and Tendon Predictors of Hamstring Graft Diameter in Arthroscopic Anterior Cruciate Ligament Reconstruction: A Prospective Study

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ABSTRACT

Background: Hamstring graft diameter is a key determinant of successful anterior cruciate ligament (ACL) reconstruction, with smaller grafts associated with increased risks of graft failure and revision surgery. Identifying reliable preoperative predictors of graft diameter may facilitate surgical planning and optimize graft selection. This study evaluated the relationship between anthropometric variables, semitendinosus tendon length, and hamstring graft diameter in patients undergoing primary arthroscopic ACL reconstruction.

Methods: This prospective observational study included 31 consecutive patients who underwent primary arthroscopic ACL reconstruction using ipsilateral hamstring tendon autografts between May 2024 and October 2025 at a tertiary care centre. Preoperative anthropometric parameters, including height, weight, body mass index (BMI), and thigh circumference, were recorded. Intraoperatively, semitendinosus tendon length and quadrupled hamstring graft diameter were measured using standardized techniques. Pearson correlation analysis was performed to evaluate associations between anthropometric variables, tendon length, and graft diameter.

Results: The mean age of the participants was 32.9 ± 8.2 years, and the mean hamstring graft diameter was 8.55 ± 0.52 mm. Semitendinosus tendon length demonstrated a statistically significant positive correlation with graft diameter ($r = 0.38$, 95% CI: 0.02–0.65; $p = 0.037$). Height ($r = 0.25$, $p = 0.17$), weight ($r = 0.18$, $p = 0.32$), BMI ($r = 0.05$, $p = 0.78$), and thigh circumference ($r = 0.12$, $p = 0.49$) showed weak, non-significant correlations with graft diameter.

Conclusions: Semitendinosus tendon length was significantly associated with hamstring graft diameter, whereas conventional anthropometric variables demonstrated limited predictive value. Tendon-specific assessment may improve preoperative estimation of graft size and assist surgical planning. Larger multicentre studies incorporating imaging-based tendon evaluation are warranted to validate these findings.

Keywords: Anterior cruciate ligament reconstruction; hamstring graft diameter; semitendinosus tendon; anthropometric predictors; tendon length.

INTRODUCTION

Anterior cruciate ligament (ACL) injury is one of the most common ligamentous injuries of the knee and frequently results from non-contact pivoting, sudden changes in direction, or landing during sports activities. Previous studies have described the biomechanical mechanisms of ACL injury and highlighted the importance of injury prevention strategies in reducing the incidence of these injuries. [3,4] Arthroscopic ACL reconstruction using autologous hamstring tendon grafts is widely accepted as the standard treatment for restoring knee stability and enabling return to functional activities.

Successful ACL reconstruction depends on several factors, among which hamstring graft diameter is a critical determinant of graft strength and long-term clinical outcomes. Hamstring grafts measuring less than 8 mm have been associated with an increased risk of graft failure and revision surgery, emphasizing the importance of accurate preoperative assessment of graft size. [1,2]

Several investigators have evaluated anthropometric parameters, including height, weight, body mass index (BMI), and thigh circumference, as potential predictors of hamstring graft diameter because these measurements are inexpensive, readily available and easy to obtain during routine clinical evaluation. However, the predictive value of these parameters has remained inconsistent across different populations and ethnic groups. [5-9]

More recent studies have suggested that tendon-specific and imaging-based parameters, particularly magnetic resonance imaging (MRI)-derived tendon

measurements, may provide more accurate estimation of hamstring graft diameter than anthropometric variables alone. [10-12,15]

However, evidence from South Asian populations remains limited, highlighting the need for population-specific studies evaluating predictors of hamstring graft diameter.

Therefore, the present study aimed to evaluate the relationship between anthropometric variables, semitendinosus tendon length, and hamstring graft diameter in patients undergoing primary arthroscopic ACL reconstruction using hamstring tendon autografts.

MATERIALS AND METHODS

Study Design and Setting

This prospective, single-centre, observational, non-randomized study was conducted in the Department of Orthopaedics, Sapthagiri Institute of Medical Sciences and Research Centre, Bengaluru, Karnataka, India, between May 2024 and October 2025, after obtaining approval from the Institutional Ethics Committee (Approval No. EC-06/PG-111/2023-24). Written informed consent was obtained from all participants before enrolment. Consecutive eligible patients undergoing primary arthroscopic anterior cruciate ligament (ACL) reconstruction were recruited during the study period to minimize selection bias. As this was an observational study, no random sequence generation or allocation concealment was performed.

Sample Size

The sample size was calculated using the standard formula for estimation of a single

mean ($n = Z^2\sigma^2/d^2$), where Z was 1.96 for a 95% confidence level, σ was the standard deviation obtained from a previous study, and d represented the allowable error. Based on these assumptions, the minimum required sample size was calculated to be 31 participants. Consecutive eligible patients were enrolled until the required sample size was achieved.

Patient Selection

Patients presenting with ACL injuries requiring primary arthroscopic ACL reconstruction using ipsilateral hamstring tendon autografts were screened for eligibility.

Inclusion Criteria

Patients were included if they were 20–50 years of age, had a clinically and/or radiologically confirmed anterior cruciate ligament (ACL) tear, were scheduled to undergo primary arthroscopic ACL reconstruction using hamstring tendon autograft, and provided written informed consent to participate in the study.

Exclusion Criteria

Patients were excluded if they had undergone previous ACL reconstruction or any other surgery on the affected knee, had inflammatory joint disorders, had associated medial collateral ligament injuries, had distal femoral or proximal tibial fractures, or declined to participate in the study.

Rationale for Eligibility Criteria

Patients undergoing primary ACL reconstruction were selected to obtain a homogeneous study population for evaluating anthropometric predictors of hamstring graft diameter. Patients with revision surgery, associated ligament injuries, inflammatory disorders, or fractures around the knee were excluded because these conditions could independently influence tendon morphology, graft characteristics, and surgical outcomes, thereby acting as potential confounding factors.

Data Collection

Baseline demographic data, including age and sex, were recorded. Anthropometric measurements, including height, weight, body mass index (BMI), and thigh circumference, were obtained preoperatively using standardized techniques. During surgery, the semitendinosus tendon length was measured after tendon harvest, and the prepared quadrupled hamstring graft diameter was measured using the same calibrated graft-sizing block with 0.5-mm increments. All intraoperative measurements were performed by the operating surgeon to minimize inter-observer variability. All measurements were prospectively documented in a standardized case record form.

Outcome Measure

The primary outcome measure was the intraoperative hamstring graft diameter. Secondary variables included height, weight, BMI, thigh circumference, and semitendinosus tendon length.

Statistical Analysis

Statistical analysis was performed using IBM SPSS Statistics version 22.0 (IBM Corp., Armonk, NY, USA). Continuous variables were expressed as mean $\pm$ standard deviation, while categorical variables were expressed as frequencies and percentages. The normality of continuous variables was assessed using the Shapiro–Wilk test. As the data were normally distributed, Pearson's correlation coefficient was used to evaluate the relationship between anthropometric variables and hamstring graft diameter. A two-tailed p -value of <0.05 was considered statistically significant.

RESULTS

Descriptive Statistics

The mean graft diameter was 8.55 ± 0.52 mm, with no patient having graft diameter <7 mm. Height showed a weak positive correlation with graft diameter ($r = 0.25$, $p = 0.17$). Weight also showed weak correlation ($r = 0.18$, $p = 0.32$). Semitendinosus tendon

length demonstrated a positive correlation with graft diameter ($r = 0.38$, $p = 0.037$).

Table 1. Baseline characteristics of study participants (n = 31)

Variable	Mean $\pm$ SD
Age (years)	32.9 $\pm$ 8.2
Height (cm)	168.7 $\pm$ 8.6
Weight (kg)	65.7 $\pm$ 6.8
Body mass index (kg/m ²)	23.16 $\pm$ 2.56
Thigh circumference (cm)	44.2 $\pm$ 5.0
Semitendinosus tendon length (cm)	28.16 $\pm$ 1.49
Graft diameter (mm)	8.55 $\pm$ 0.52

A total of 31 patients were included in the study. The mean age was 32.9 $\pm$ 8.2 years. The mean graft diameter was 8.55 $\pm$ 0.52

mm. Other demographic and anthropometric characteristics are summarized in Table 1.

Table 2. Correlation analysis of anthropometric and tendon variables

Variable	Correlation (r)	95% CI	p-value	Interpretation
Height	0.25	-0.11 to 0.54	0.17	Weak, not significant
Weight	0.18	-0.18 to 0.50	0.32	Weak, not significant
Body mass index	0.05	-0.30 to 0.39	0.78	Very weak, not significant
Thigh circumference	0.12	-0.24 to 0.44	0.49	Weak, not significant
Semitendinosus tendon length	0.38	0.02 to 0.65	0.037	Significant

Pearson correlation analysis demonstrated that semitendinosus tendon length showed a statistically significant positive correlation with hamstring graft diameter ($r = 0.38$, $p = 0.037$). Height ($r = 0.25$, $p = 0.17$), weight ($r = 0.18$, $p = 0.32$), body mass index ($r = 0.05$, $p = 0.78$), and thigh circumference ($r = 0.12$, $p = 0.49$) showed weak, non-significant correlations with graft diameter (Table 2).

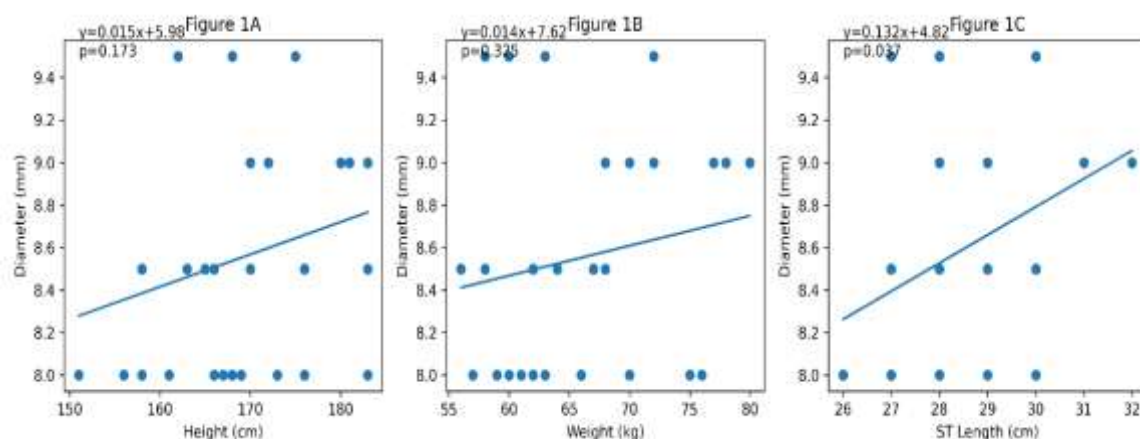
Table 3. Distribution of graft diameter categories

Category	Frequency (n)	Percentage (%)
<7mm	0	0.0%
7–8 mm	11	35.5%
>8 mm	20	64.5%

The majority of patients had a hamstring graft diameter between 8 and 9 mm. Only a small proportion had graft diameters below 8 mm, whereas grafts measuring ≥ 9 mm was observed less frequently.

Figure 1. Relationship between anthropometric and tendon parameters and graft diameter

- (A) Height vs graft diameter showing weak correlation
 (B) Weight vs graft diameter showing weak correlation
 (C) Semitendinosus tendon length vs graft diameter showing statistically significant correlation



DISCUSSION

The present prospective observational study evaluated the relationship between anthropometric variables, semitendinosus tendon length, and hamstring graft diameter in patients undergoing arthroscopic anterior cruciate ligament (ACL) reconstruction. The principal finding was that semitendinosus tendon length demonstrated a statistically significant positive correlation with graft diameter, whereas anthropometric variables such as height, weight, body mass index, and thigh circumference showed weak or inconsistent correlations. These findings suggest that tendon-specific measurements may provide a more reliable estimate of hamstring graft diameter than external anthropometric characteristics.

Adequate hamstring graft diameter is a critical determinant of successful ACL reconstruction. Previous studies have reported that smaller graft diameters are associated with an increased risk of graft failure and revision surgery. Magnussen et al. demonstrated that hamstring autografts with smaller diameters were associated with higher early revision rates following ACL reconstruction, highlighting the clinical importance of accurate preoperative prediction of graft size. [1] Similarly, Conte et al. emphasized that predicting graft diameter before surgery can facilitate appropriate surgical planning and reduce the likelihood of intraoperative graft inadequacy. [2]

Anthropometric measurements have traditionally been investigated as simple and inexpensive predictors of hamstring graft size. Tuman et al. observed that patient height correlated with graft dimensions, although the strength of this relationship varied among individuals. [5] Ho et al. also reported that height and body weight were associated with hamstring graft diameter; however, the predictive accuracy was only moderate. [7] In the present study, height and weight demonstrated weak positive correlations with graft diameter, while body mass index and thigh circumference showed minimal association. These findings are

consistent with those of Mardani-Kivi et al., who concluded that anthropometric measurements alone cannot reliably predict graft dimensions across different populations. [6] Similar observations were reported by Goyal et al., who found that anthropometric variables alone had limited predictive accuracy for estimating hamstring graft size. [9]

The most important observation in the present study was the statistically significant relationship between semitendinosus tendon length and graft diameter. Unlike external anthropometric measurements, tendon-specific parameters directly reflect the biological characteristics of the harvested graft and therefore provide a more accurate estimate of the final graft dimensions. Similar observations have been reported in recent studies evaluating tendon morphology and imaging-based assessment. Mayr et al. demonstrated that magnetic resonance imaging (MRI)-based measurements improved the prediction of hamstring graft diameter compared with anthropometric variables alone. [10] Likewise, Movahedinia et al. reported that preoperative tendon measurements showed superior predictive accuracy and may assist surgeons in identifying patients at risk of obtaining smaller grafts. [11] Bouras et al. further demonstrated that combining anthropometric and tendon-specific variables improved prediction models in patients undergoing ACL reconstruction. [12] Erquicia et al. also demonstrated that MRI and ultrasonographic assessment of hamstring tendons improved the prediction of graft dimensions and could facilitate individualized surgical planning. [15]

The findings of the present study support the growing concept that tendon-specific parameters should complement conventional anthropometric measurements during preoperative assessment. Accurate prediction of graft diameter enables the surgeon to anticipate the need for graft augmentation, alternative autografts, or allograft supplementation when inadequate hamstring graft size is expected. Such

preoperative planning may reduce operative uncertainty and improve surgical outcomes. Furthermore, studies by Mariscalco et al. and Ramkumar et al. have highlighted the clinical importance of graft diameter in influencing patient-reported outcomes and emphasizing the variability of hamstring graft size among individuals. [13,14]

The present study has certain limitations. It was conducted at a single tertiary care centre with a relatively small sample size, which may limit the generalizability of the findings. Although consecutive patient recruitment reduced selection bias, the modest sample size may have limited the statistical power to detect weaker associations between anthropometric variables and graft diameter. MRI-based tendon measurements were not evaluated and therefore could not be compared directly with anthropometric variables. In addition, postoperative functional outcomes, graft survival, and revision rates were not assessed because the study focused on intraoperative graft characteristics. These factors should be considered while interpreting the findings.

Future multicentre prospective studies involving larger and ethnically diverse patient populations are required to externally validate these findings. Integration of anthropometric variables with MRI-derived tendon measurements, ultrasonographic assessment, and advanced predictive models may improve the accuracy of preoperative graft size estimation and facilitate individualized surgical planning. [10-12,15]

Despite these limitations, the present study provides clinically relevant evidence that semitendinosus tendon length is a more reliable predictor of hamstring graft diameter than routine anthropometric measurements. Incorporating tendon-specific assessment into routine preoperative evaluation may improve graft selection, optimize surgical planning, and potentially reduce the risk of graft inadequacy and subsequent graft failure following ACL reconstruction.

CONCLUSION

Semitendinosus tendon length demonstrated a significant positive correlation with hamstring graft diameter, whereas conventional anthropometric variables showed weak or non-significant associations. These findings suggest that tendon-specific measurements may assist in preoperative estimation of hamstring graft size and improve surgical planning for patients undergoing arthroscopic ACL reconstruction. Larger multicentre studies incorporating imaging-based tendon assessment are required to validate these findings.

Declaration by Authors

Ethical Approval: The study was approved by the Institutional Ethics Committee (EC-06/PG-111/2023-24).

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Conflict of Interest: The authors declare no conflict of interest.

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