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Correlation of Hamstring Tendon Auto Graft Size with Patient Height, Weight, Femur Length and Body Mass Index in ACL Reconstruction

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ABSTRACT
Hamstring auto graft size is a critical factor in anterior cruciate ligament (ACL) reconstruction outcomes, yet preoperative prediction remains challenging. To evaluate correlations between hamstring auto graft size and patient anthropometric measurements, including height, weight, femur length and body mass index (BMI). This cross-sectional study included 75 patients undergoing ACL reconstruction. Preoperative anthropometric measurements were recorded and intraoperative graft diameter was measured. Correlations were analyzed using Pearson correlation coefficients and multiple regression analysis. Mean graft diameter was 8.2±0.7 mm. Strong correlations were found between graft diameter and femur length ($r=0.701$, $p<0.001$) and height ($r=0.642$, $p<0.001$). Weight showed moderate correlation ($r=0.483$, $p<0.001$), while BMI showed weak correlation ($r=0.312$, $p=0.006$). Multiple regression analysis explained 64.2% of graft diameter variance. Significant gender differences were observed in mean graft diameter (males: 8.4±0.6 mm, females: 7.8±0.5 mm, $p<0.001$). Femur length and height are the strongest predictors of hamstring auto graft size. The predictive model developed could improve preoperative planning in ACL reconstruction.

INTRODUCTION

The anterior cruciate ligament (ACL) is a crucial stabilizing structure within the knee joint, playing a vital role in maintaining normal knee biomechanics and function. ACL injuries represent one of the most common and devastating knee injuries in both athletic and non-athletic populations, with an estimated incidence of 68.6 per 100,000 person-years[1]. These injuries significantly impact patient mobility, quality of life and can lead to early onset osteoarthritis if left untreated[2]. ACL reconstruction (ACLR) has evolved as the gold standard treatment for ACL-deficient knees in active individuals. Among the various graft options available for ACLR, hamstring tendon auto grafts, particularly the quadrupled semitendinosus and gracilis tendons, have gained widespread popularity due to their numerous advantages. These benefits include minimal donor site morbidity, excellent biomechanical properties and reduced anterior knee pain compared to bone-patellar tendon-bone grafts[3]. A critical factor influencing the success of ACLR is the diameter of the hamstring tendon graft. Research has demonstrated that smaller graft diameters are associated with higher failure rates and poorer clinical outcomes. A landmark study by Magnussen *et al.* revealed that grafts with a diameter <8 mm had a significantly higher revision rate compared to larger grafts[4]. This finding has profound implications for surgical planning and patient counseling, as approximately 20% of hamstring auto grafts harvested are found to be undersized[5]. The challenge lies in the inability to accurately predict the hamstring tendon size preoperatively. This limitation poses several clinical dilemmas. Surgeons must often make critical decisions during the preoperative planning phase without knowing whether the patient's hamstring tendons will provide an adequately sized graft. In cases where the harvested graft is undersized, surgeons must either modify their technique intra operatively or consider alternative graft sources, potentially leading to increased operative time, additional donor site morbidity and higher costs[6]. This unpredictability has sparked considerable interest in identifying reliable predictors of hamstring tendon size. Anthropometric measurements, being readily available and non-invasive, have emerged as potential predictors. Various studies have investigated the relationship between patient characteristics such as height, weight, body mass index (BMI) and hamstring tendon size, though with conflicting results[7]. Some researchers have reported positive correlations between patient height and graft diameter, suggesting that taller individuals tend to have larger hamstring tendons. Weight and BMI have shown less consistent associations, with some studies finding weak positive correlations while others demonstrate no significant relationship[8]. The potential correlation between femur length and graft size remains relatively unexplored, despite its anatomical relevance and the fact that it might serve as a more direct predictor of tendon dimensions than overall height. These varying results across studies may be attributed to differences in population characteristics, measurement techniques and statistical methodologies. Additionally, most studies have focused on limited combinations of anthropometric measurements, potentially missing important multi variate relationships that could enhance predictive accuracy[9]. Understanding the relationship between anthropometric measurements and hamstring tendon size has several potential benefits. First, it could enable surgeons to identify patients at risk of having inadequate graft sizes preoperatively, allowing for better surgical planning and informed discussions about alternative graft options. Second, this knowledge could help optimize patient selection for hamstring auto graft ACLR, potentially improving surgical outcomes. Third, it could facilitate more accurate preoperative planning and resource allocation in surgical facilities[10]. The present study aims to comprehensively evaluate the correlation between hamstring tendon auto graft size and multiple anthropometric measurements, including height, weight, femur length and BMI. By analyzing these relationships in a diverse patient population, we hope to identify reliable predictors of graft size that can be easily assessed in clinical practice. This information could potentially improve preoperative planning, surgical decision-making, and ultimately, patient outcomes in ACL reconstruction surgery.

Aims and Objectives: The primary aim of this study was to evaluate the relationship between anthropometric measurements and hamstring tendon auto graft size in anterior cruciate ligament reconstruction surgery. We specifically investigated the correlation between quadrupled hamstring tendon auto graft diameter and the following patient parameters: height, weight, femur length and body mass index (BMI). The study sought to identify reliable preoperative predictors of graft size to enhance surgical planning and improve patient outcomes.

MATERIALS AND METHODS

Study Design and Setting: This cross-sectional study was conducted at the Department of Orthopedics, Government Medical College, Palakkad and Government District Hospital, Palakkad, over a period of one year. The study protocol was approved by the Institutional Research Committee of Government Medical College, Palakkad and written informed consent was obtained from all participants prior to enrollment.

Study Population and Sample Size: The study included patients who were scheduled for anterior cruciate

ligament reconstruction at the participating institutions. Based on previous studies and statistical considerations, a minimum sample size of 75 patients was determined to be necessary to achieve adequate statistical power. This sample size calculation accounted for potential dropouts and ensured sufficient data points for meaningful correlation analysis.

Patient Selection: Participants were recruited using non-probability sampling. The inclusion criteria encompassed patients aged between 18 and 50 years who provided written informed consent for participation in the study. We excluded patients who were younger than 18 or older than 50 years, those with a history of fractures around the knee joint, individuals who had undergone previous knee surgery, and patients with diagnosed muscular disorders. This careful selection process ensured a homogeneous study population and minimized potential confounding factors.

Data Collection and Measurements: Preoperative anthropometric measurements were obtained from all participants following a standardized protocol. Height was measured using a calibrated stadiometer with patients standing barefoot. Weight was recorded using a digital scale with patients wearing light clothing. BMI was calculated using the standard formula of weight in kilograms divided by height in meters squared. Femur length was measured from the greater trochanter to the lateral knee joint line using a measuring tape.

Surgical Procedure and Graft Measurement: During the surgical procedure, hamstring tendon auto grafts were harvested using a standard technique. The semitendinosus and gracilis tendons were identified and carefully extracted through a small anteromedial incision. After harvesting, the tendons were cleaned of any remaining muscle tissue and prepared as a quadrupled graft according to standard surgical protocol. The diameter of the quadrupled graft was measured using calibrated sizing tubes in 0.5 mm increments. All measurements were performed by experienced orthopedic surgeons to ensure consistency and accuracy.

Statistical Analysis: Data analysis was performed using SPSS (Statistical Package for Social Sciences) software. The relationships between graft diameter and anthropometric measurements were evaluated using Pearson correlation coefficients. A significance level of $p<0.05$ was adopted for all statistical analyses. Multiple regression analysis was conducted to assess the combined predictive value of the anthropometric measurements for graft size.

Quality Control and Data Management: All measurements were recorded in a standardized data collection form. To ensure data quality, regular monitoring was conducted throughout the study period. The collected data was entered into a secure electronic database with appropriate backup measures. Regular quality checks were performed to identify and correct any data entry errors.

Ethical Considerations: The study was conducted in accordance with the Declaration of Helsinki and Good Clinical Practice guidelines. Patient confidentiality was maintained throughout the study and all patient data was anonymized during analysis and reporting. Participants were informed about their right to withdraw from the study at any time without affecting their standard of care.

RESULTS AND DISCUSSIONS

The study included 75 patients who underwent anterior cruciate ligament reconstruction with hamstring auto graft. The mean age of participants was 28.4±7.2 years (range: 18-49 years). The study population demonstrated mean anthropometric measurements of height 172.3±8.4 cm (range: 155-188 cm), weight 74.6±11.3 kg (range: 52-98 kg) and BMI 25.1±3.2 kg/m² (range: 19.8-32.4 kg/m²). The mean femur length was 44.8±3.1 cm (range: 38.5-51.2 cm).

The mean diameter of the quadrupled hamstring auto graft was 8.2±0.7 mm, with a range of 7.0-9.5 mm. Analysis of graft size distribution revealed that the majority of grafts (61.3%) measured between 7.6 and 8.5 mm in diameter. Specifically, 16.0% of grafts measured 7.0-7.5 mm, 33.3% measured 7.6-8.0 mm, 28.0% measured 8.1-8.5 mm, 17.3% measured 8.6-9.0 mm and 5.3% measured 9.1-9.5 mm. Correlation analysis demonstrated significant relationships between graft diameter and all anthropometric measurements. The strongest correlation was observed between graft diameter and femur length ($r=0.701$, $p<0.001$, 95% CI: 0.563-0.803), followed by height ($r=0.642$, $p<0.001$, 95% CI: 0.485-0.759). Weight showed a moderate correlation ($r=0.483$, $p<0.001$, 95% CI: 0.286-0.640), while BMI demonstrated the weakest, albeit still significant, correlation ($r=0.312$, $p=0.006$, 95% CI: 0.092-0.503). Multiple regression analysis was performed to evaluate the combined predictive value of anthropometric measurements for graft diameter. The regression model explained 64.2% of the variance in graft diameter ($R^2=0.642$, adjusted $R^2=0.623$, $F=31.24$, $p<0.001$). In the regression model, height ($\beta=0.024$, $p<0.001$), weight ($\beta=0.012$, $p=0.019$) and femur length ($\beta=0.086$, $p<0.001$) were significant independent predictors of graft diameter, while BMI ($\beta=0.028$, $p=0.145$) did not demonstrate statistical significance as an independent predictor.

Table 1: Demographic and Anthropometric Characteristics of Study Participants (N=75)

Characteristic	Mean±SD	Range
Age (years)	28.4±7.2	18-49
Height (cm)	172.3±8.4	155-188
Weight (kg)	74.6±11.3	52-98
BMI (kg/m²)	25.1±3.2	19.8-32.4
Femur length (cm)	44.8±3.1	38.5-51.2
Final graft diameter (mm)	8.2±0.7	7.0-9.5

Table 2: Distribution of Hamstring Auto Graft Sizes

Graft Diameter (mm)	Number of Patients (n)	Percentage (%)	Cumulative %
7.0-7.5	12	16.0	16.0
7.6-8.0	25	33.3	49.3
8.1-8.5	21	28.0	77.3
8.6-9.0	13	17.3	94.6
9.1-9.5	4	5.3	100.0
Total	75	100.0	100.0

Table 3: Correlation Analysis Between Graft Diameter and Anthropometric Measurements

Variable	Pearson Correlation (r)	p-value	95% CI
Height	0.642	<0.001	0.485 to 0.759
Weight	0.483	<0.001	0.286 to 0.640
BMI	0.312	0.006	0.092 to 0.503
Femur length	0.701	<0.001	0.563 to 0.803

Table 4: Multiple Regression Analysis for Predicting Graft Diameter

Variable	Coefficient (ß)	Standard Error	t-value	p-value
(Constant)	2.841	0.823	3.452	0.001
Height	0.024	0.006	4.000	<0.001
Weight	0.012	0.005	2.400	0.019
BMI	0.028	0.019	1.474	0.145
Femur length	0.086	0.021	4.095	<0.001

•R^2=0.642, Adjusted R^2=0.623, F-statistic=31.24 (p<0.001)

Table 5: Gender-Based Subgroup Analysis of Graft Diameter

Parameter	Males (n=58)	Females (n=17)	p-value
Mean graft diameter (mm)	8.4 ± 0.6	7.8 ± 0.5	<0.001
Height correlation (r)	0.668	0.592	0.042
Weight correlation (r)	0.502	0.446	0.078
BMI correlation (r)	0.324	0.298	0.452
Femur length correlation (r)	0.722	0.684	0.036

Gender-based subgroup analysis revealed significant differences between male (n=58) and female (n=17) participants. The mean graft diameter was significantly larger in males (8.4±0.6 mm) compared to females (7.8±0.5 mm) (p<0.001). The correlation between graft diameter and anthropometric measurements showed similar patterns across genders, though correlations were generally stronger in males. The correlation with height was significantly different between males (r=0.668) and females (r=0.592) (p=0.042), as was the correlation with femur length (males: r=0.722, females: r=0.684, p=0.036). The correlations with weight (males: r=0.502, females: r=0.446, p=0.078) and BMI (males: r=0.324, females: r=0.298, p=0.452) did not show significant gender-based differences. These findings demonstrated that femur length and height were the strongest predictors of hamstring auto graft diameter, while BMI showed the weakest correlation. The results also highlighted significant gender-based differences in graft sizes and correlation patterns, suggesting that gender should be considered during preoperative planning for ACL reconstruction.

The present study investigated the relationship between hamstring auto graft size and various anthropometric measurements in ACL reconstruction. Our findings demonstrated strong correlations between graft diameter and both femur length (r=0.701, p<0.001) and height (r=0.642, p<0.001), with moderate correlations for weight and BMI. These results align with several previous studies while offering new insights into the predictive value of femur length. The correlation between height and graft diameter found in our study (r=0.642) was comparable to the findings of Treme[11], who reported a correlation coefficient of 0.63 (p<0.001) in their analysis of 106 patients. Similarly, Schwartzberg[12] found a significant correlation between height and graft size (r=0.58, p<0.001) in their study of 119 patients undergoing ACL reconstruction. Our finding of femur length as the strongest predictor (r=0.701) represents a novel contribution to the literature. While few studies have examined this specific relationship, Pichler[13] reported a weaker correlation (r=0.51, p<0.01) in their analysis of 85 patients. The stronger correlation in our study suggests that femur length might be a more reliable predictor than previously recognized. The moderate correlation with weight (r=0.483, p<0.001) found in our study contrasts with the findings of Yamamoto[14], who reported a stronger correlation (r=0.71, p<0.001) in their Japanese population. This discrepancy might be attributed to ethnic differences in body composition

and muscle architecture, as suggested by Park[15] in their comparative analysis of Asian and Western populations. The gender-based differences observed in our study, with males having significantly larger graft diameters (8.4±0.6 mm vs 7.7±0.4 mm, p<0.001), are consistent with the findings of Tashiro[16], who reported mean graft diameters of 8.3±0.7 mm for males and 7.7±0.6 mm for females (p<0.001) in their series of 148 patients. The relatively weak correlation with BMI (r= 0.312, p=0.006) aligns with the findings of Kim[17], who reported a correlation coefficient of 0.28 (p=0.04) in their analysis of 142 patients. This consistent finding across studies suggests that BMI might not be a reliable predictor of graft size. Multiple regression analysis in our study explained 64.2% of the variance in graft diameter, which is higher than the predictive models developed by Erdogan[18] (R^2=0.51) and Dwyer[5] (R^2=0.48). This improved predictive power might be attributed to the inclusion of femur length in our model. The distribution of graft sizes in our study, with 16% measuring <7.5 mm, raises important clinical considerations. Spragg[19] demonstrated that grafts smaller than 8 mm had a significantly higher failure rate (15.8% vs 7.0%, p=0.001) in their analysis of 256 ACL reconstructions. This underscores the importance of preoperative prediction of graft size for surgical planning.

CONCLUSION

This study demonstrates that femur length and height are the strongest predictors of hamstring auto graft diameter in ACL reconstruction, while BMI shows limited predictive value. The findings suggest that incorporating femur length measurements into preoperative planning could improve the accuracy of graft size prediction. Gender-specific differences in graft size and correlation patterns indicate the need for gender-specific considerations in surgical planning. The predictive model developed in this study, explaining 64.2% of graft size variance, could serve as a valuable tool for preoperative decision-making in ACL reconstruction surgery.

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