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Prediction of Hamstring Graft Diameter Based on Anthropometric Variables in Anterior Cruciate Ligament Reconstruction

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Abstract

Background: The diameter of the graft is an important determinant of successful anterior cruciate ligament (ACL) reconstruction. If the diameter of the hamstring graft can be predicted accurately, we can determine whether this graft is suitable or if we need to harvest a different one.

Methods: A cross-sectional study was conducted among 74 patients undergoing ACL reconstruction using hamstring autografts. Anthropometric variables recorded were age, gender, BMI, height, weight, and thigh length. Grafts were prepared as quadrupled or pentupled constructs and their diameters measured. The minimum acceptable graft size was 8 mm × 90 mm. Pearson correlation and bivariate analysis were used to assess associations between anthropometric variables and graft diameter.

Results: Graft diameter showed a positive correlation with patient height and significant associations with gender, BMI, height, weight, and thigh length.

Conclusion: Height was the strongest predictor of hamstring graft diameter. Patients taller than 160 cm, weighing >65 kg, with BMI >25 kg/m² and thigh length >37 cm were more likely to have graft diameters ≥8 mm. Graft diameter decreased with age, particularly after 40 years. A predictive equation based on height was developed.

Keywords: Anterior cruciate ligament, Anthropometric, Graft diameter

Introduction

Anterior cruciate ligament (ACL) reconstruction is a commonly performed orthopaedic surgery. The hamstring graft offers multiple fixation methods, is easy to harvest, and allows the same incision to be used for placing the tibial tunnel.[1,2] However, it is difficult to pre-determine the diameter of the graft.[3] Many studies have shown a higher revision rate and greater laxity with graft diameter <8mm.[4-8]

Several studies describe using MRI, CT, and anthropometric measurements to estimate graft

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diameter.[9-12] If we can predict the size of the hamstring graft pre-operatively, we can choose to harvest the graft only if a sufficient diameter ≥8mm is expected, thereby preventing morbidity from harvesting a smaller-diameter graft.[10,13]
The objective of this study was to assess the ability to predict the hamstring graft diameter based on anthropometric variables such as age, gender, height, weight, BMI, and thigh length, and formulate an equation.

Methods

An analytical cross-sectional study was conducted among seventy-four patients (Figure 1) from January 2021 to December 2022 who underwent ACL reconstruction using a hamstring autograft in the Department of Orthopaedics of a tertiary-level hospital in Nepal. Ethical approval was taken from the Institutional Review Committee (IRC Ref No. 077/78-007).

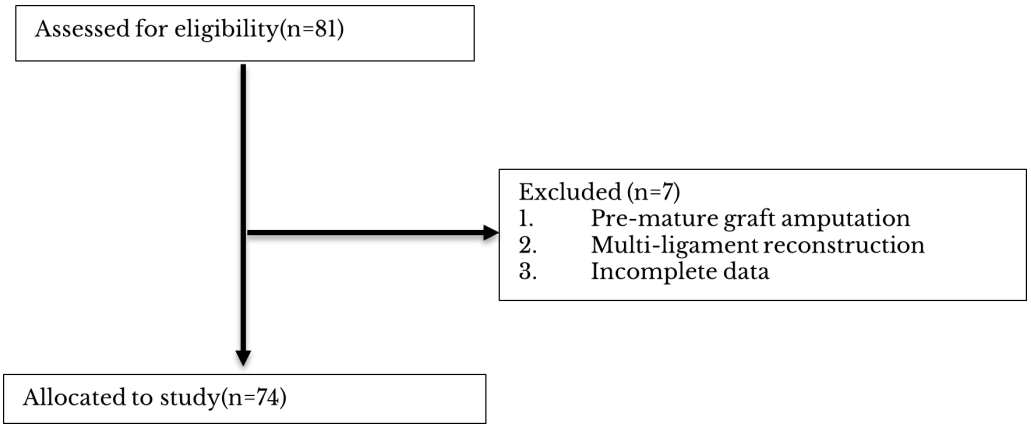

Figure 1 Patient Selection

All cases of ACL reconstruction with hamstring autograft during the period of 2 years at the Department of Orthopaedics were included in the study. Patients with pre-mature amputation of graft, multi-ligament reconstruction in which the hamstring graft was not detached from tibial attachment, and revision ACL reconstruction with peroneus longus were excluded from the study.

Anthropometric data were collected from the patients using a self-structured proforma. Each patient's age, gender, BMI, height, weight, and thigh length were recorded just before surgery. The height of the patient was self-reported. The thigh length was measured from the greater trochanter to the lateral joint line.
An anterolateral portal was made, and diagnostic arthroscopy was done. After confirming an ACL tear, an oblique incision, approximately 3 cm, was placed two finger widths below the medial joint line and one finger width medial to the tibial tuberosity. The semitendinosus and gracilis (ST-G) grafts were harvested. Muscles attached to the grafts were stripped off. A graft was triplicated only when it measured 27 cm or greater in length after preparation. It was doubled if it was shorter. The ends of the graft were whipstitched with no 4 non-absorbable sutures. The prepared graft was either quadrupled or pentupled and then passed through a cylindrical sizer to determine its diameter. The calibration of the sizer was 1 mm. The cylinder, which allowed the smooth passage with minimal resistance, was considered the diameter of the graft. The minimum dimension of the graft accepted, after preparation, was 8×90mm. If the diameter of the quadrupled or pentupled graft, thus obtained, was less than 8mm, it was either discarded and replaced or supplemented with another graft (peroneus longus or quadriceps). Then, ACL reconstruction was performed following the standard procedure.

The patients' data were collected, and their accuracy and completeness were verified. Collected data was entered into MS Excel and then imported into SPSS for subsequent analysis. Data was analysed using descriptive and inferential statistical tools. In the descriptive statistics, categorical variables like age and BMI were presented as frequency and percentage. For continuous variables, the mean and standard deviation were calculated. In inferential statistics, to find the association between categorical variables like diameter and other anthropometric information, the chi-square test was used. To find the correlation between diameter and continuous variables, the Pearson correlation was used. Regression analysis was employed to determine the strength of the relationship among continuous variables. The higher the correlation coefficient, the stronger the relationship between the variable and graft diameter. A p-value less than 0.05 was considered statistically significant.

Results

Out of 74 patients, 19 (25.67%) were females, and 55 (74.33%) were males. The mean age was 29.78 ±9.52 years, the mean BMI was 25.87 ± 4.26 kg/m², the mean height was 163.31 ± 8.07 cm, the mean thigh length was 39.13 ± 3.11 cm and the mean diameter of the graft was 8.02 ± 0.88 mm. 73% of the patients had a graft diameter greater than 8 mm (Table 1).

Table 1. Sociodemographic information of patients (n=74)

Variables	Frequency	Percentage
Age (years)		
<20	9	12.16%
20-40	55	74.32%
≥40	10	13.52%
Mean age	29.78 ± 9.52	
Sex		
Female	19	25.67%
Male	55	74.33%
BMI (kg/m²)	74	
<18.5	1	1.35%
18.5-24.99	33	44.59%
≥25	40	54.06%
Mean BMI	25.87 ± 4.26	
Height (cm)		
<160	32	43.24%
≥160	42	56.76%
Mean height	163.31 ± 8.07	
Weight (kg)		
<65	36	48.65%
≥65	38	51.35%
Mean weight	68.68 ± 10.93	
Thigh length (cm)		
<37	22	29.72%
≥37	52	70.28%
Mean thigh length	39.13 ± 3.11	
Diameter (mm)		
<8	20	27.03%
≥8	54	72.97%
Mean diameter	8.02 ± 0.88	

Pearson correlation between each predictor variable and the outcome variable was calculated (Table 2). There was a positive correlation (r=0.28, p=0.016) between the height of the patient and graft diameter. Out of all the variables, height had the strongest correlation with graft size. So, the most significant predictor of graft diameter was the height of an individual.

Table 2. Correlation between graft diameter and selected variables (Age, thigh length, height, weight, and BMI) (n=74)

Variables	Graft Diameter	
	Pearson Correlation(r)	P-value
Age	-0.179	0.131
Thigh length	0.135	0.256
Height	0.281	0.016
Weight	0.092	0.443
BMI	-0.086	0.479

Regression analysis of diameter with other variables was done (Table 3). The regression coefficients for each variable were estimated using the least squares method. This involves finding the values of the coefficients that minimize the sum of the squared differences between the predicted and actual values of the dependent variable. Then, the t-test was used to determine whether the regression coefficients are statistically significant. The regression equation of diameter and height was found to be statistically significant ($p < 0.05$). This equation suggested that the diameter of the hamstring graft will be 0.03 mm larger for every 1 cm increment in height of the individual.

Table 3. Regression equation of diameter with age, height, weight, BMI, and thigh length (n=74)

Regression equation	P-value
Diameter=8.51 -0.0167 (Age)	0.127
Diameter=3.081 +0.0302 (Height)	0.015
Diameter=7.52 -0.0073 (Weight)	0.42
Diameter=8.40 -0.014 (BMI)	0.40
Diameter=6.54 +0.037 (Thigh length)	0.25

The bivariate analysis between diameter and selected variables showed that there was a statistically

significant association of graft diameter with gender, BMI, height, weight, and thigh length ($p < 0.05$) (Table 4).

Table 4. Association of graft diameter with selected anthropometric variables (n=74)

Variables	Diameter (mm)		Chi-square	P-value
	<8	≥8		
	Frequency (%)			
Age (years)				
<20	1 (11.11)	8 (88.89)	1.87	0.401
20-40	17 (30.90)	38 (69.10)		
≥40	2 (20)	8 (80)		
Gender				
Female	10 (52.63)	9 (47.37)	8.49	0.004
Male	10 (18.18)	45 (81.82)		
BMI (kg/m²)				
<18.5	0 (0)	1 (100)	5.45	0.048
18.5-24.99	11 (33.33)	22 (66.67)		
≥25	9 (22.50)	31 (77.50)		
Height(cm)				
<160	14 (43.75)	18 (56.25)	7.99	0.005
≥160	6 (14.28)	36 (85.72)		
Weight(kg)				
<65	13 (36.11)	23 (63.89)	3.93	0.047
≥65	7 (18.42)	31 (81.58)		
Thigh length(cm)				
<37	9 (40.9)	13 (59.10)	4.05	0.037
≥37	11 (21.15)	41 (78.85)		

Graft diameter was most strongly correlated with the height of individuals. The patients taller than 160 cm (5 feet 4 inches) were likely to have graft diameters of 8mm or more, which was statistically significant ($p<0.05$). The patients younger than 20 years had larger grafts (≥8mm), which was not statistically significant ($p > 0.05$), while those older than 40 years had graft diameters smaller than 8mm ($p > 0.05$).
Male patients had a graft diameter of 8mm or more while females were more likely to have a diameter of less than 8 mm ($p < 0.05$). BMI and weight also showed a predictive value for graft diameter. Obese patients (BMI>25 kg/m²) had larger grafts (≥8 mm) ($p < 0.05$). Patients who weighed more than 65 kg (143.3 pounds) had larger diameter grafts (≥8mm) ($p < 0.05$). Furthermore, those with a thigh length of more than 37 cm had larger diameter grafts ($p < 0.05$).
The taller, heavier, and younger male patients with longer thighs were more likely to have bigger hamstring grafts. Out of these variables, height was the most important statistically significant predictor of hamstring graft diameter. The relationship of graft diameter with height was such that it was 0.03 mm larger for every 1 cm increment in height of the individual.

Discussion

The anterior cruciate ligament (ACL) reconstruction is one of the most commonly performed orthopaedic surgeries. There are several graft options for ACL reconstruction: quadriceps tendon, hamstring tendon, peroneus longus, and bone-patellar tendon-bone graft. We can predict the diameter of the quadriceps tendon and bone-patellar tendon-bone graft, but it is difficult to predict the length of the hamstring graft pre-operatively.
The hamstring graft offers multiple fixation methods: suspensory and interference.[1,2] It is also easier to harvest, and the same incision can be used for placing the tibial tunnel. Since the mean width of native ACL is 10 mm, it's justifiable to harvest a thicker graft to mimic an anatomical ACL reconstruction.[5] In a retrospective study of 310 patients, Park et al. in 2013 found a higher revision rate in graft diameter <8mm (5.2%) as compared to that in graft diameter >8mm (0%).[4] Magnussen et al. retrospectively analysed 256 patients and concluded a high revision rate with graft diameter (ST-G) of ≤8mm.[6] A study by Pagnani et al. has found that grafts for ACL reconstruction with smaller cross-sectional areas are weaker.[7] In females with ACL reconstruction using smaller-size hamstring grafts, greater laxity has been found.[8]
One of the morbidities is a decrease in hamstring muscle strength for up to nine months after surgery.[10,13] If we could predict the size of a hamstring graft, we would only choose it if we expected a sufficient graft diameter, thereby preventing the morbidity of harvesting a graft with an otherwise smaller diameter. The most important finding of this study was that anthropometric variables like height, weight, age, BMI, and thigh length can be used to predict the diameter of the hamstring graft used for ACL reconstructions. The correlation coefficients of the prediction variables with the outcome variable were variable. Regarding gender, male patients had larger grafts. The result of this study supported the research hypothesis.

In a study by Treme et al., 50 patients who underwent an ACL reconstruction were studied.[14] They demonstrated that grafts were of smaller diameter in short women with lower weight. In contrast to their findings, which revealed that height had a lower magnitude relationship with graft diameter, this study found that height had the strongest relationship to predict graft diameter.[14]

Similar to this study, another study by Tuman et al., similar anthropometric variables were correlated with graft diameter in 106 consecutive patients who had a primary or revision ACL reconstruction using a hamstring autograft.[10] Their study concluded that hamstring graft diameter was moderately correlated with height and was the most significant predictor of graft diameter.[10] They suggested that a patient <147 cm tall is likely to have a graft diameter <7 mm.[10] This study demonstrated that patients <160 cm tall were likely to have smaller diameter grafts.

Treme et al. concluded that weight and BMI were the best predictors of graft diameter.[14] Tuman et al. did not observe any relation between BMI and diameter, while we observed a moderate relationship between weight and BMI with graft diameter.[10] Regarding gender, Tuman et al. and Treme et al. found that females had smaller graft diameters, which were similar to our finding.[10,14]

Similar to this study, Gupta et al. observed that the patient's height and weight were significantly positively correlated with hamstring graft diameter.[15]

In contrast to this study, Singhal et al. found no significant association of age with graft dimension.[16] They also concluded that those patients shorter than 164 cm and who weighed less than 66 kg were at risk for having a graft diameter ≤8 mm.[16] This study suggested that the patients with height and weight less than 160 cm and 65 kg, respectively, were more likely to have a graft diameter ≤8 mm.

In another study by Goyal et al., it was demonstrated that patients with less than 147 cm height were at risk of graft diameter <7 mm.[17]

Schwartzberg et al. studied 119 consecutive patients undergoing ACL reconstruction and evaluated the correlation between anthropometric measurements and graft diameter.[18] In contrast to this study, they found a moderate correlation (r=0.51) to weight and weak correlations (r=0.42) to age and height.

In a study of forty-one patients for anterior cruciate ligament tear using hamstring autograft, Challa et al., found that only the height of patients can be considered as a reliable predictor of hamstring graft diameter in the Indian population, while other factors like weight and gender cannot be used as definitive predictors.[19] Their finding is different from the finding of this study.

The findings of our results are consistent with those of Benjamin et al., who concluded that tall males had larger grafts.[20] They studied 536 patients and found that males had larger graft diameters (8.1±0.8 mm) than females (7.5±0.6 mm).

This study's findings are partly consistent with Pereira et al.'s evaluation. They evaluated 64 patients who underwent anterior cruciate ligament reconstruction using quadrupled hamstring grafts and concluded that there was a positive correlation between height and diameter of the graft.[21] However, they found that age and weight showed no correlation, which is different from the current study's finding.

This study has a few limitations. The graft sizer we used had an increment of 1 mm only. If the increment of 0.5 mm were available, the measurement would be more precise. The sample size was small, and a separate analysis for males and females was not done. The result has been assumed to apply to both male and female populations.

Conclusion

This study found that the best predictor of hamstring graft diameter for ACL reconstruction was the patient's height. Graft diameter was greater than 8mm for individuals who were taller than 160 cm (5 feet 8 inches). Patients who were obese or over 65 kg were more likely to have grafts that were 8 mm or larger. These variables would apply to both male and female populations. Compared to female patients, male patients were more likely to have grafts larger than or equivalent to 8 mm. This information enables us to predict the hamstring graft diameter. Using the existing data, if the anticipated graft diameter is less than 8 mm, a surgeon can counsel the patient and make plans for alternate graft options.

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