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Prediction of the quadruple hamstring autograft thickness in ACL reconstruction using anthropometric measures

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Objective: The aim of this study was to determine whether simple anthropometric measurements, such as height, weight, body mass index (BMI), age, and thigh circumference can be used to accurately predict the diameter of hamstring tendons for anterior cruciate ligament (ACL) reconstruction surgery.

Methods: One hundred sixty-four consecutive male patients who underwent ACL reconstruction using quadruple hamstring autograft between January 2010 and December 2011 were prospectively evaluated. Anthropometric measurements including height, weight, BMI, age and thigh circumference were recorded preoperatively. The thickness of the quadruple hamstring autograft was intraoperatively determined using sizing cylinders. Correlation coefficients (Pearson's r) and stepwise, multiple linear regression were used to determine the relationship between the outcome variable (hamstring graft diameter) and the predictor variables (age, height, weight, BMI, thigh circumference).

Results: Correlation analysis revealed a positive relation between the height, weight and graft thickness (p=0.000 and p=0.002, respectively). Taller and heavier patients tended to have thicker quadrupled hamstring graft. However, age, thigh circumference, and BMI did not correlate with the graft thickness (p=0.700, p=0.290 and p=0.727, respectively). Stepwise, multiple linear regression indicated that height was statistically important as a predictor for hamstring graft diameter (R^2=0.157, p=0.0001) and yielded the following regression equation for predicting quadrupled hamstring graft thickness: graft thickness = [(height in cm) × 0.052) - 1.07] mm.

Conclusion: Height can be used as a practical and accurate measurement to preoperatively predict quadruple hamstring graft diameter in male patients. Identification of possible hamstring tendon autograft insufficiency allows for preoperative determination of additional graft source possibilities, resulting in a more prompt surgical strategy.

Key words: Anterior cruciate ligament; anthropometric measures; graft thickness; hamstring; knee.

Various autografts, allografts and synthetic ligaments are available for the reconstruction of the anterior cruciate ligament (ACL). Autografts include bone-patellar tendon-bone, quadriceps tendon and hamstring tendon. Allograft options include the same type of tendons harvested from donors, in addition to the Achilles

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and anterior and posterior tibialis tendons, as well as the fascia lata.[1] All of these options have inherent advantages and disadvantages.

The bone-patellar tendon-bone autograft is the most widely used graft source with the largest number of reported outcomes in the literature. However, the use of the quadruple hamstring autograft is gaining popularity due to its excellent stiffness and tensile load properties, reduced donor site morbidity, improvements in fixation techniques and implants, less postoperative anterior knee pain, better cosmesis and excellent clinical outcomes.[2]

The average diameter of the normal ACL is 11 mm and a graft with a minimum thickness of 7 mm is recommended.[3,4] One of the disadvantages of using a quadruple hamstring autograft is the possibility of obtaining a graft of a smaller diameter than optimally required. The surgeon may need to continue with an alternative graft source and fixation technique when such a situation is encountered during surgery. Therefore, preoperative prediction of the sufficiency of the hamstring graft thickness for ACL reconstruction would be useful in order to arrange alternative fixation methods or graft choices ready to use at the operation theater.

A few studies have investigated several anthropometric and clinical characteristics of patients to predict the quadruple hamstring autograft thickness.[5-9] Currently there is no well-documented standard to accurately predict the diameter of quadruple hamstring autografts for ACL reconstruction and existing studies present controversial findings.

The aim of this study was to determine whether simple anthropometric measurements, such as height, weight, body mass index (BMI), age, thigh circumference and gender can be used to accurately predict the diameter of hamstring tendons for ACL reconstruction surgery.

Patients and methods

We prospectively collected anthropometric data of 172 consecutive patients (164 male, 8 female) with ACL deficiency treated with arthroscopic primary ACL reconstruction in our institution between January 2010 and December 2011. Female patients were excluded in order to obtain a uniform study population and analysis was performed on the data obtained from the remaining 164 male (mean age: 29.23±7.98) patients. The research was carried out according to the Declaration of Helsinki principles and local ethics committee approval was granted. Anthropometric measurements including height, weight, BMI, age, gender and thigh circumference were taken preoperatively. Thigh circumference was measured at the mid-point between the trochanteric tip and lateral knee joint level.

All operations were performed by the same surgeon. All patients had semitendinosus and gracilis tendon autografts harvested in a similar manner. An oblique incision was made in the skin along the distal insertions of the semitendinosus and gracilis tendons on the proximal tibia. Tendons were removed using a hamstring graft harvester and prepared using a single-bundle, 4-strand technique with each end of the tendon grafts whipstitched with a no. 2 nonabsorbable polyester suture. The graft was passed through sizing cylinders to determine the diameter of the quadruple graft.

Correlation coefficients (Pearson's r) and stepwise, multiple linear regression were used to determine the relationship between the outcome variable, quadruple hamstring graft thickness and the predictor variables (age, gender, height, length, thigh circumference, BMI). A p value of less than 0.05 was considered statistically significant.

Results

Average measurements included height (179.17±5.23 cm), weight (82.50±8.85 kg) and BMI (25.66±2.32). Average value for thigh circumference was 51.04±4.73 cm. None of the patients had a quadrupled hamstring graft of less than 7 mm diameter intraoperatively. The average quadrupled hamstring graft diameter was 8.17±0.68 mm. Summary of all data is presented in Table 1.

Table 1. Summary of all data.

Variables	Results
Number of patients	164; all male
Age (years±SD) (range)	29.23±7.98 (15-51 years)
Height (cm±SD) (range)	179.17±5.23 (161-198 cm)
Weight (kg±SD) (range)	82.50±8.85 (52-110 kg)
Thigh circumference (cm±SD) (range)	51.04±4.73 (38-60 cm)
Body mass index [weight(kg)/length^2(m)]±SD (range)	25.66±2.32 (17.9-34.7)
Quadruple hamstring graft thickness (mm±SD) (range)	8.17±0.68 (7-10 mm)

Table 2. Correlation coefficients for relationships between quadruple hamstring graft thickness and clinical data.

Quadruple hamstring graft thickness	Age	Height	Weight	Thigh circumference	Body mass index
Pearson's correlation (rho value)	-0.030	0.397	0.245	0.083	0.028
Significance (p value)	0.700	**0.000***	**0.002***	0.290	0.727

*p<0.05

There was a positive relation between height, weight and graft thickness (p<0.001 and p=0.002, respectively). Taller and heavier patients tended to have thicker quadrupled hamstring grafts. However, age, thigh circumference and BMI did not correlate with graft thickness (p=0.700, p=0.290 and p=0.727, respectively). Correlation coefficients are presented in Table 2.

Height was statistically important as a predictor for hamstring graft diameter (R^2=0.157, p<0.001) and yielded the following regression equation for predicting quadrupled hamstring graft thickness: graft thickness = [(height in cm) × 0.052) - 1.07] mm. We calculated the predicted graft thickness using this equation. The mean difference between the predicted graft thickness and real graft thickness (Δ graft thickness) was 0.5±0.3 (range: -0.05 to 1.07) mm with a 95% confidence interval.

Discussion

Quadruple hamstring tendon graft thickness has been shown to be directly correlated with graft stiffness, stability, ability to withstand against tensile loads, graft failure and risk of re-rupture.[10,11] Preoperative prediction of the thickness of the tendon graft could allow for the arrangement of alternative graft options and patient notification of other graft options in patients with a potential graft size insufficiency.

In this study, we investigated the predictive value of various anthropometric measures, including height, weight, BMI, thigh circumference and age on quadruple hamstring tendon graft thickness. Our results show that age, BMI and thigh circumference did not correlate with graft thickness while weight and height did have a positive correlation. Further analysis with a stepwise regression revealed that height was the only important clinical predictor for graft thickness. Predicted graft diameter measurements using regression equation were, on average, 0.5±0.3 mm different from actual graft diameter measurements. Graft thickness is 1 mm less than 0.05% of the patient's height.

Five studies in the literature have investigated preoperative anthropometric parameters for the estimation of quadruple hamstring tendon graft thickness (Table 3). Tuman et al.[5] reported that height is the best predictor for hamstring graft thickness in both genders among the

Table 3. Previously published studies that investigated preoperative anthropometric parameters for the estimation of quadruple hamstring tendon graft thickness.

	Study design	Number of patients	Anthropometric parameters evaluated	Predictive parameters found
Tuman et al.[5] (2007)	Retrospective	106 (51 male, 55 female)	Height, mass, gender, age, BMI	Only for men Height (weak), weight (weak), age (weak), BMI (weak)
Treme et al.[6] (2008)	Prospective	50 (29 male, 21 female)	Height, weight, BMI, age, gender, leg length, thigh length, shank length, thigh circumference, Tegner score	Only for men Weight (strong), thigh circumference (strong), BMI (strong), height (moderate), leg length (moderate)
Schwartzberg et al.[7] (2008)	Prospective	119 (65 male, 54 female)	Height, weight, age, leg length, thigh girth	Weight (moderate), leg length (moderate)
Ma et al.[8] (2010)	Retrospective	536 (302 female, 234 male)	Height, weight, age, gender, BMI	Height (most significant), gender
Pinheiro et al.[9] (2011)	Prospective	80 (65 male, 15 female)	Height, gender, weight, BMI, leg length, thigh length, thigh diameter age, gender, operated side, dominant side, sports activity	Height (most significant), gender, leg length, thigh length, thigh diameter
Current study	Prospective	164 (all male)	Height, weight, BMI, age, thigh circumference	Height (strong)

parameters they studied; height, weight, age, and gender. Based on their analysis, they concluded that a patient less than 147 cm tall is likely to have an insufficient graft thickness (less than 7 mm in diameter). Ma et al.[8] published a retrospective study on 536 patients, the largest series of patients in the current literature. Preoperative measures of height, weight, BMI, gender and age were investigated. The results of their study demonstrated that males had significantly larger grafts than females. Height was shown to be a specific predictor solely in men. However, none of the preoperative measures were predictive of graft diameters in female patients. Pinheiro et al. reported that height, gender, and lower limb length were the variables that most influenced graft diameter with height as the most important parameter.[9] All these previous studies shared the common message that short patients were at a high risk of having insufficient tendon graft. Similarly, findings in our study are consistent with these studies that the height of the patient is the single most important predictor for graft thickness estimation. In our study, no patients were less than 161 cm tall and 52 kg weight. This may be an explanation as to why no patients had graft thickness less than 7 mm, which is accepted as the safe limit.

In contrast to our findings, correlation with other anthropometric parameters has also been shown in the literature. Treme et al.[6] reported a good correlation between the patient's height, thigh circumference, BMI and hamstring graft sizes with valuable cutoff rates in a prospective study including 50 patients. They reported that patients weighing less than 50 kg, of less than 140 cm in height, with less than 37 cm thigh circumference and with a BMI less than 18 should be considered as high risk for having a quadrupled hamstring graft diameter of less than 7 mm. They emphasized caution in female patients with small stature and lower weight. Schwartzberg et al.[7] analyzed the predictive value of age, height, weight, bilateral leg length and bilateral thigh girth 5 and 10 cm proximal to the superior pole of the patella to estimate the length and diameter of the semitendinosus and gracilis grafts of 119 patients. They demonstrated that leg length can be used to predict hamstring length to within 20 mm and that weight can be used to predict graft diameter to within 1.2 mm using regression equations. Correlations to age, height, and thigh girth were weak. Ethnic differences may play a role in this disagreement with our study. Chiang et al. have shown that Caucasian and Chinese populations were different regarding hamstring graft length.[12]

Other studies in the literature have used radiological cross-sectional measurement techniques including three-dimensional computed tomography and magnetic resonance imaging in order to predict graft sizes preoperatively. However, conflicts between these studies exist. Although some authors have found good correlation between measured cross-sectional area and intraoperative tendon thickness, others could not show any correlation.[13-17]

Lack of standardization regarding level of measurements, lack of reliability and accuracy of measurements, necessity of a trained radiologist and a software program and radiation exposure could be listed as major limitations of radiological techniques.

There were some strengths and limitations with this study. As only male patients were included in our study, our results cannot be used for female patients. However, our study is the largest prospective study on this subject in the relevant literature. Additionally, that both the anthropometric and intraoperative graft thickness measurements were performed by the same surgeon increases the reliability of our data.

In conclusion, the prediction of quadruple hamstring graft diameter based on the patient height is a practical and accurate method for male patients. Preoperative identification of insufficiency in hamstring tendon autograft allows surgeons to contemplate a more prompt surgical strategy when other possible graft sources are available prior to surgery.

Conflicts of Interest: No conflicts declared.

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