

Prediction of quadruple hamstring graft diameter for anterior cruciate ligament reconstruction by anthropometric measurements

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ABSTRACT

Background: The literature is scanty regarding the anthropometric predictors on the diameter of quadruple hamstring graft obtained in anterior cruciate ligament (ACL) reconstruction in Indian population. Minimum diameter of the graft for ACL reconstruction should be >7 mm to preclude failure. The objective of this study was to assess the prediction of the hamstring graft diameter by several anthropometric parameters including age, thigh circumference, weight, height and body mass index (BMI).

Materials and Methods: 46 consecutive patients who had undergone ACL reconstruction by the same surgeon using quadruple hamstring grafts were evaluated. The age, thigh circumference of the normal side, height, weight and BMI were recorded preoperatively and Pearson correlation was done using these parameters with graft diameter measured intraoperatively. Regression analysis in a stepwise manner was undertaken to assess the influence of individual anthropometric parameters on the graft diameter.

Results: There were 44 males and 2 females. Mean age was 29.4 years, mean height was 172.6 cm, mean weight was 70.9 kg, mean BMI was 23.8 kg/m², mean thigh circumference was 47.1 cm and mean graft diameter was 7.9 mm. There was a positive correlation individually between the thigh circumference and graft diameter obtained ($r = 0.8, P < 0.01, n = 46$), and between the height and graft diameter ($r = 0.8, P < 0.01, n = 46$). On the regression analysis thigh circumference and height were found to be significant predictors of graft diameter giving the following equation: Graft diameter (mm) = 0.079 height (cm) + 0.068 thigh circumference (cm) - 9.031.

Conclusion: Preoperatively using the above equation if graft diameter came out to be <7 mm then alternate options of graft material must be kept in mind in order to prevent failure.

Key words: Anterior cruciate ligament, anthropometry, arthroscopy, hamstring graft, diameter

MeSH terms: Anterior cruciate ligament reconstruction, Anterior cruciate ligament, arthroscopic surgical procedure, arthroscopy

INTRODUCTION

Among ligament reconstruction, the anterior cruciate ligament (ACL) is the most commonly reconstructed ligament of the knee.¹ Many graft options are available for ACL reconstruction. Bone-

patellar tendon-bone autograft has a rigid fixation and has bone-to-bone healing, but it has donor site morbidity, among the complications, anterior knee pain is the most common.^{2,3}

The “quadrupled hamstring autograft” is obtained by harvesting the semitendinosus and the gracilis tendons at the pes anserinus and then folding them over twice to create 4 strands.²

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Failure, however, can be prevented using a graft that is significantly stronger than the native ACL and graft strength has been found to be directly proportional to the cross-sectional area of the graft.⁴

Scott and Insall concluded that the length of normal ACL is 38 mm (range 25–41 mm) and the width is 10 mm (range 7–12 mm), on average.⁵ In order to have an optimal 7 cm quadrupled graft construct length for ACL reconstruction (2 cm in the femoral tunnel, 3 cm intraarticular and 2 cm in the tibial tunnel), it is essential to obtain a minimum tendon length of 28 cm (ranged from 28 to 30 cm) and it should have a minimum thickness of 7 mm.⁶⁻⁸

Grafts used for ACL reconstructions, which have a smaller thickness have been shown to be weaker;⁹ graft length could also influence the thickness by multiple looping. Sometime harvesting an adequately sized hamstring graft may not be possible and in such cases the provision of using an alternate graft may be required. Very few studies have been conducted to find out the correlation between anthropometric variables and graft thickness in Asian populations. The objective of this study was to assess the prediction of hamstring graft diameter in Indian population by several anthropometric parameters: Age, thigh circumference, weight, height and body mass index (BMI). This would help in the preoperative planning of ACL reconstructions and opt for alternative graft options; if an adequate hamstring graft were unlikely to be obtained at the time of surgery. We hypothesized that anthropometric parameter do influence hamstring graft thickness in ACL reconstruction.

MATERIALS AND METHODS

46 consecutive patients (44 males and 2 females) who underwent primary ACL reconstruction in our institution using a 4 strand semitendinosus and gracilis autograft from May 2012 to October 2014 were reviewed. Patients who were treated using graft other than hamstring were not included in this study. Age, gender, height, weight, BMI and thigh circumference of the normal side at 15 cm above the upper pole of the patella of each patient were recorded preoperatively. Surgery was performed by the same surgeon in all cases and hamstring tendon autografts (semitendinosus and gracilis) were harvested by the same manner. The standard operating technique was followed in all cases with regional anesthesia (spinal anesthesia) and a high thigh tourniquet. A longitudinal incision was made on the skin over the pes anserinus attachment (inferomedial to the tibial tuberosity) area on the proximal tibia to retrieve semitendinosus and gracilis. Each tendon was looped so as to form a 4 strand graft. After both hamstring tendons harvest each one of them became double strand to create



Figure 1: Graft diameter measurement guides (Smith and Nephew), with increments of 0.5 mm

a 4 strand graft with both tendons.² The graft diameter was then measured using the ACL reconstruction graft diameter measurement guides (Smith and Nephew, Andover, USA), with increments of 0.5 mm [Figure 1]. The graft diameter was considered to be the dimension of the smallest calibration that the graft could pass through. The corresponding femoral and tibial tunnels were then drilled using arthroscopy. The graft was then passed through the tunnels in the tibia and then in the femur followed by fixation at the femoral end with EndoButton (Smith and Nephew, Andover, USA) and tibial side using interference screw (RCI, Smith and Nephew, Andover, USA) of appropriate size. Finally, arthroscopic anatomical single bundle ACL reconstruction was performed. The anthropometric variables were then individually correlated with the graft diameter obtained during surgery.

Statistical analysis

Mean age, weight, height, BMI, thigh circumference and a range of various variables were assessed in order to describe the demographic data of the population. The normal distribution of the data was performed utilizing a test for normality [Figure 2]. Pearson's correlation coefficient was used to measure the correlation between various variables and the diameter of the hamstring graft obtained [Figures 3-7]. Regression analysis was employed to assess the influence of various variables such as age, thigh circumference, height, weight and BMI on the thickness of the graft obtained.

RESULTS

Mean age was 29.4 (range 17-58 years), mean height was 172.6 (range 160-180 cm), mean weight was 70.9 (range 42-100 kg), mean BMI was 23.8 (range 15.4-32 kg/m²), mean thigh circumference was 47.1 (range 39-63 cm) and mean graft diameter was 7.9 (range 6.5-9.5 mm) [Table 1]. There was a positive correlation individually between the height and graft diameter obtained ($r = 0.8$, $P < 0.01$, $n = 46$) [Figure 5] and between the thigh circumference

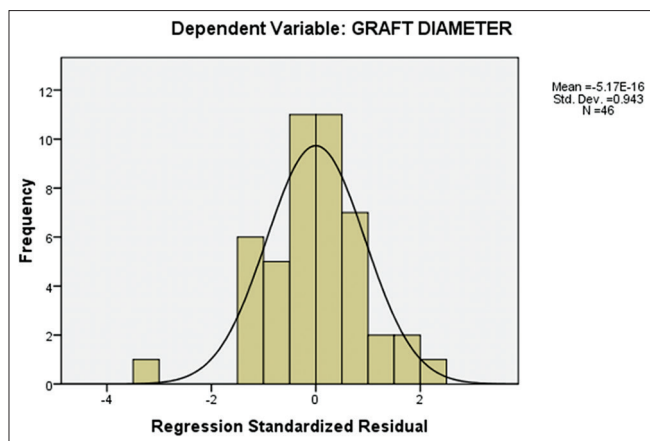


Figure 2: A histogram showing graft diameter having normal distribution curve

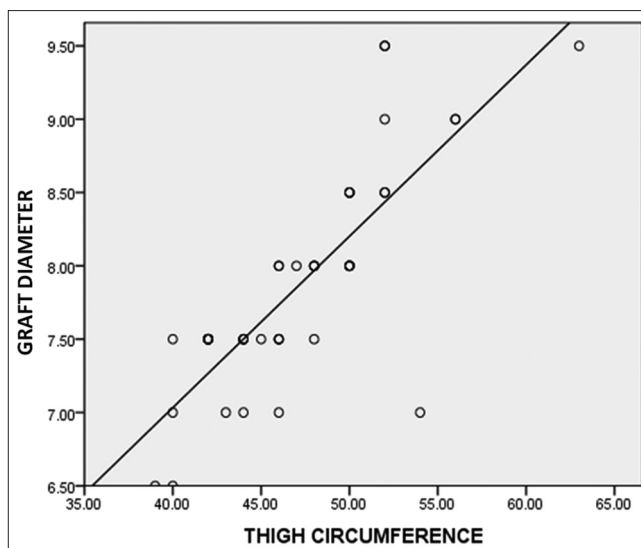


Figure 4: Scattered plot showing relationship between thigh circumference and graft diameter. This plot shows a significant correlation between these two variable ($r = 0.8$, $R^2 = 0.6$, $P < 0.01$)

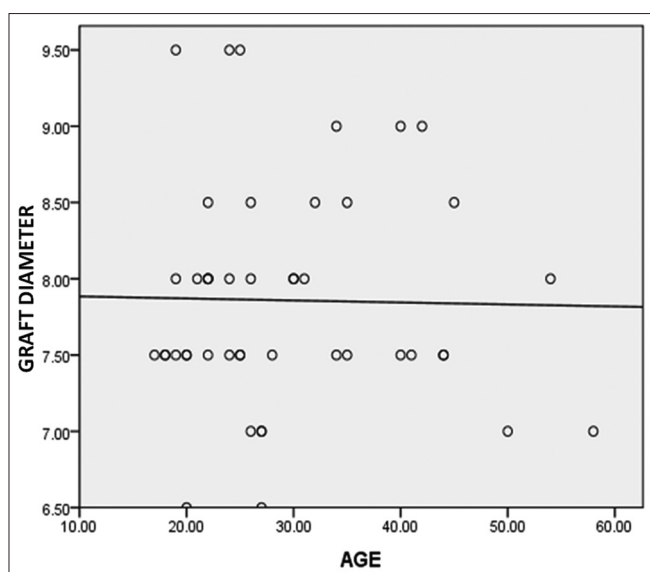


Figure 3: Scattered plot showing relationship between age and graft diameter. This shows no correlation between age and graft diameter ($r = -0.01$, $R^2 < 0.01$, $P > 0.05$)

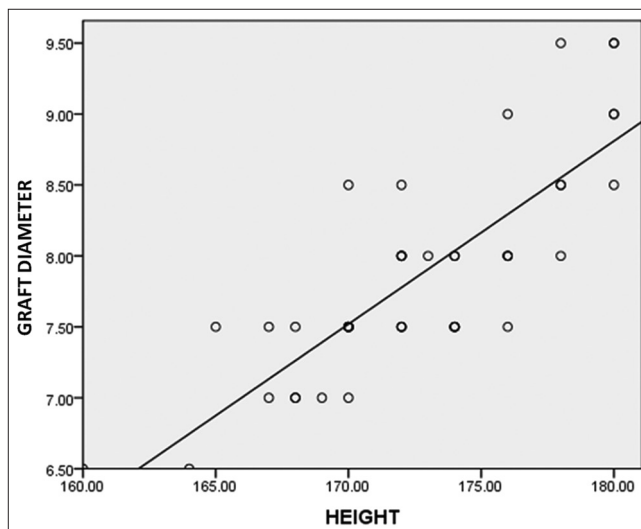


Figure 5: Scattered plot showing relationship between height and graft diameter. This shows strong correlation between height and graft diameter ($r = 0.8$, $R^2 = 0.7$, $P < 0.01$)

Table 1: Age and anthropometric details of patients

Variable	n	Range	Minimum	Maximum	Mean	SD
Age (years)	46	41	17	58	29.4	10.2
Thigh circumference (cm)	46	24	39	63	47.1	5
Height (cm)	46	20	160	180	172.6	4.6
Weight (kg)	46	58	42	100	70.9	11.5
BMI (kg/m ²)	46	16.6	15.4	32	23.8	3.7
Graft diameter (mm)	46	3	6.5	9.5	7.9	0.7

SD=Standard deviation, BMI=Body mass index

and graft diameter ($r = 0.8$, $P < 0.01$, $n = 46$) [Figure 4]. There was no correlation individually between age and graft diameter ($r = -0.01$, $P > 0.05$, $n = 46$) [Figure 3], weight and graft diameter ($r = 0.18$, $P > 0.05$, $n = 46$) [Figure 6] and BMI and graft diameter ($r = -0.11$, $P > 0.05$, $n = 46$) [Figure 7] [Table 2].

Regression analysis was done using a stepwise method. Graft diameter was the dependent variable and the independent variables were age, height, weight, BMI and thigh circumference. Only height and thigh circumference were found to be significant predictors of graft diameter giving the following equation: Graft diameter (mm) = 0.079 height (cm) + 0.068 thigh circumference (cm) - 9.031. Two regression models were obtained one with height ($R^2 = 0.8$) and with the height and thigh circumference ($R^2 = 0.9$). Detailed statistics and demographics of the patients are listed below in the tables and graphs.

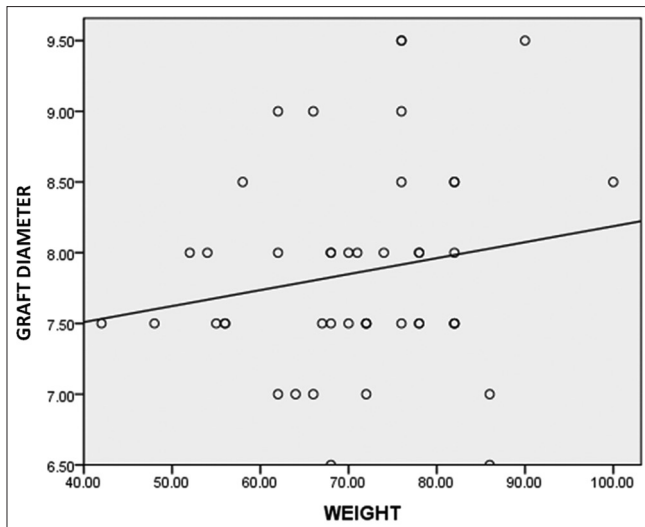


Figure 6: Scattered plot showing relationship between weight and graft diameter. This shows no correlation between these two variable ($r = 0.2$, $R^2 = 0.03$, $P > 0.05$)

Table 2: Pearson correlation between graft diameter and various anthropometric parameters

Anthropometric parameters	r	R^2	P
Graft diameter and age	-0.01	<0.001	0.9 (>0.05)
Graft diameter and thigh circumference	0.8	0.6	<0.01
Graft diameter and height	0.8	0.7	<0.01
Graft diameter and weight	0.18	0.03	0.23 (>0.05)
Graft diameter and BMI	-0.11	0.01	0.48 (>0.05)

BMI=Body mass index

DISCUSSION

In the beginning of our study, a hypothesis was made that anthropometric parameter do have influence over graft thickness in ACL reconstruction. The results of our study showed that the height and the thigh circumference have correlation with the graft diameter. Our results confirm the hypothesis anthropometric variables do have a predictive value on the thickness of the hamstring graft obtained during ACL reconstruction. We found that, the height and the thigh circumference were statistically significant predicting for graft diameter ($P < 0.01$) like in the study conducted by Treme *et al.*¹⁰ in 2008 that included 50 samples. He also reported a good correlation between the patient's BMI and hamstring graft sizes with valuable cutoff rates in a prospective study. They reported that patients weighing <50 kg, of <140 cm in height, with <37 cm thigh circumference and with a BMI <18 should be considered as high risk for having a quadrupled hamstring graft diameter of <7 mm.

As in our study, height had been demonstrated as the strongest predictor of graft diameter by the study done by Ma *et al.*,⁴ in 2010 and Pinheiro *et al.*¹¹ in 2011. Ma *et al.*,

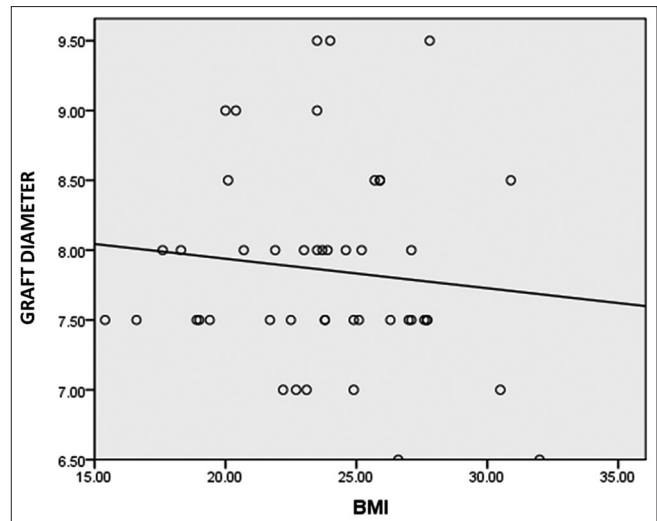


Figure 7: Scattered plot showing relationship between body mass index and graft diameter. This shows no correlation between BMI and graft diameter ($r = -0.1$, $R^2 = 0.01$, $P > 0.05$)

did a retrospective study on 536 patients, one of the largest series of patients in the current literature. Preoperative measurement of height, weight, BMI, gender and age were investigated. The results of their study demonstrated that the height was a specific predictor especially in men. In the prospective study of Pinheiro *et al.*, in 2011 on 80 subjects reported that among height, gender and lower limb length, the variables that most influenced graft diameter was the height.

Similar to the retrospective study of Ma *et al.*,⁴ in 2010, prospective study of Pinheiro *et al.*¹¹ in 2011 and Çeliktas *et al.*,¹² in 2013 we have found no predictive influence of BMI on graft diameter. In contrast, the study of Treme *et al.*,¹⁰ we have found no correlation between BMI and graft diameter. This difference in the result may be due to different geographical variation.

In our study, we have found no correlation between weight and graft diameter. This was against the results obtained in the prospective study of Treme *et al.*,¹⁰ in 2008 and Schwartzberg *et al.*,¹³ in 2008. In his prospective study, Schwartzberg *et al.*,¹³ 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 predict the length and diameter of the semitendinosus and gracilis grafts of 119 patients (65 males and 54 females). 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. They found weak correlations with age, height and thigh girth. This dispute in the result is probably due to the extreme difference in the level

of activities (indirect determinant of weight) and racial difference in India and Western World.

There are studies in the literature that suggest the use of radiological cross sectional measurement techniques including three-dimensional computed tomography and magnetic resonance imaging in order to predict graft sizes preoperatively. However, some authors have found good correlation between measured cross-sectional area and intraoperative tendon thickness, others could not show any correlation.^{8,14}

The limitations of our study include less number of samples and the retrospective nature of the study. A prospective study required to assess the validity of this study.

The radiological measurements are lack of reliability and accuracy of measurements, lack of standardization regarding level of measurements, the necessity of a trained radiologist and a software program as well as radiation exposure.

In our cohort of patients, the mean hamstring graft diameter in this study was on the lower side the range reported from Western counterparts. In the Western literature, the mean graft sizes for 4 strand hamstring grafts range from 7.9 to 8.6 mm for males,^{9,15} and our results showed that the mean hamstring graft diameter was 7.9 mm. This may be due to the height and the thigh circumference in our population is less than the Western population. In our study, we had two patients with graft diameter 6.5 mm [Table 3]. In those cases, augmentation of the graft was done in order to enhance the graft diameter. We could not estimate the predictive influence of gender on graft diameter because we had only 2 female in our study sample. However, in the retrospective study conducted by Tuman *et al.*⁹ in 2007 on 106 (51 males and 55 females) subjects had found no correlation of gender with graft diameter.

CONCLUSION

In this retrospective study of 46 patients, correlation between the height and the graft diameter and between the thigh circumference and graft diameter were very strong.

Table 3: Frequency distribution of hamstring graft diameter

Graft diameter (mm)	Frequency	Percentage
6.5	2	4.3
7	5	10.9
7.5	17	37.0
8	11	23.9
8.5	5	10.9
9	3	6.5
0.5	3	6.5
Total	46	100.0

In our study out of many variable, after regression analysis using stepwise manner, only height and thigh circumference were found to be significant predictors of graft diameter giving the following equation: Graft diameter (mm) = 0.079 height (cm) + 0.068 thigh circumference (cm) - 9.031. Preoperatively using this equation if graft diameter came out to be <7 mm then alternate options of graft material must be kept in mind.

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Nil.

Conflicts of interest

There are no conflicts of interest.

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