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Original Article

Prediction of peroneus longus graft diameter for anterior cruciate ligament reconstruction by inframalleolar harvest and from anthropometric data

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Abstract: Background: The literature is gradually drifting towards a graft of larger diameter for successful ACL reconstruction. There is no published literature regarding the anthropometric predictors for the diameter of the peroneus longus tendon (PLT) graft obtained in ACL reconstruction through the inframalleolar approach. Methods: Fifty-two patients were finally evaluated for anthropometric parameters to predict quadrupled PLT graft diameter in ACL reconstruction using the inframalleolar technique. Intraoperative quadrupled PLT graft diameter was correlated to the patient's anthropometric data such as age, height, weight, duration of injury, and BMI. We used regression analysis in a stepwise manner to ascertain anthropometric indices associated with the graft diameter. Results: This study included 46 males and six females. Mean age was 28.2 ± 7.4 years, mean height was 172.7 ± 2.8 cm, mean weight was 75.6 ± 3.4 kg, mean BMI was 25.3 ± 0.9 kg/m^2, mean duration of injury was 9.2 ± 3.9 months, and mean graft diameter was 9.3 ± 0.4 mm. Positive correlation with graft diameter was found only with height ($r = 0.6$, $P < 0.01$) and weight ($r = 0.4$, $P < 0.01$). On analysing through linear regression, height and weight had significant association with graft diameter, and we formulated the following prediction equation: PLT graft diameter (mm) = 0.083 × height (cm) + 0.011 × weight (kg) -5.854. Conclusion: Patients' characteristics, including height and weight, have a significant correlation with quadrupled PLT graft diameter and the average diameter of graft is > 9 mm through this approach.

Keywords: Anterior cruciate ligament, anthropometry, peroneus longus graft diameter, inframalleolar approach

Introduction

The anterior cruciate ligament (ACL) is an essential structure that maintains the knee joint's integrity and stability [1]. The Anterior cruciate ligament reconstruction (ACLR) is the most commonly done procedure worldwide among all torn ligaments of the knee [2]. ACL reconstruction is now considered the gold standard method for a complete ACL tear [3, 4]. Several factors like age, sports activities, graft types, the tension of the graft, graft diameter, and anatomical placement are mentioned in the literature that could affect ACL reconstruction outcome [5, 6]. Out of these factors, the graft's diameter is one of the most critical parameters for a successful outcome [7]. Earlier, a graft diameter of 7 mm was considered the minimum size to avoid failure [2, 7]. However, a graft diameter of 8 mm or more has become the accepted norm now, and it has been proven that with an increase in graft thickness, the chances of revision surgeries also decrease [8, 10]. Therefore, prediction of the graft diameter in ACL reconstruction is exceptionally vital as it helps surgeons prepare preoperatively with other graft options.

Various imaging techniques like MRI, CT scan, ultrasonography of knee, and anthropometric parameters predict hamstring graft diameter [2, 11-16]. MRI of the knee and anthropometric parameters are being used most commonly. MRI findings show marked similarity in sensitivity and accuracy as compared to anthropometric parameters. However, its high cost restricts

Figure 1. It Shows an incision of 2 cm proximal to the posterior border of lateral malleolus (A), exposing PLT (peroneus longus tendon) proximally and showing distal incision over the base of 5th metatarsal (B), pulling out of distal end of PLT through the proximal incision (C).

its frequent use [14]. The anthropometric measurements are easier to perform with minimal expertise and no additional charge.

The height, weight, and body mass index (BMI) of patients are some of the few anthropometric indices associated with hamstring graft diameter [2, 17]. The hamstring graft is commonly used for ACL reconstruction. However, many complications like decreased internal rotation strength, sensory loss (inner side of the lower leg), insufficient diameter, and a short graft length are associated [7, 15, 18]. Moreover, hamstring tendon grafts usually have a smaller diameter with an average of < 8 mm [2, 10]. Hence, alternative grafts are required to curb the shortcomings related to hamstring graft [19, 20]. The peroneus longus tendon (PLT) seems to fill the necessary criterion with encouraging results [21]. Almost all the authors barring a few, have harvested grafts from the supramalleolar region [15, 16, 22]. However, none have tried to establish the relationship between the graft diameter gathered through the inframalleolar approach and anthropometric indices. Hence, this study evaluated the association between various anthropometric parameters and the PLT graft diameter harvested out through this specific approach. We hypothesized that anthropometric data would be valuable in predicting the PLT graft diameter, and this method would yield a thicker graft.

Methods

Study design

This research was a retrospective cohort study of patients requiring ACL reconstruction using a four-stranded peroneus longus autograft at our center from May 2015 to August 2018. This study got approval from the institutional ethical committee (D. No. 242/FM/IEC).

Inclusion and exclusion criteria

The inclusion criteria were patients between 20-50 years of age, patients with an ACL tear alone, multi-ligament knee injury and a complete follow up of 2 years following ACLR. Exclusion criteria were stiff ankle and fracture around the ankle and the foot.

Position and preparation

A senior surgeon did all cases of ACL reconstruction. Patients were given spinal anaesthesia and were placed in a supine position on the OT table. Tourniquet was used in all cases. Standard anterolateral and anteromedial arthroscopy portals were formed. ACL rupture was confirmed through clinical examination and diagnostic arthroscopy. Peroneus longus autograft was taken out from the ipsilateral leg for ACL reconstruction.

Graft harvesting technique: The first incision of 2 cm was given around 2 cm proximal to the posterior border of the lateral malleolus just over the tendon of Peroneus longus (**Figure 1A**). The tendon of PL was identified (**Figure 1B**). A distal incision of 4 cm was given over the base of the 5th metatarsal (**Figure 1B**). Dissection was done till the paratenon level. Peroneal tendon sheath was excised, peroneus brevis tendon (PBT), and peroneus longus tendon were identified and separated. The Tendon of PL was stitched to the tendon of the perone-

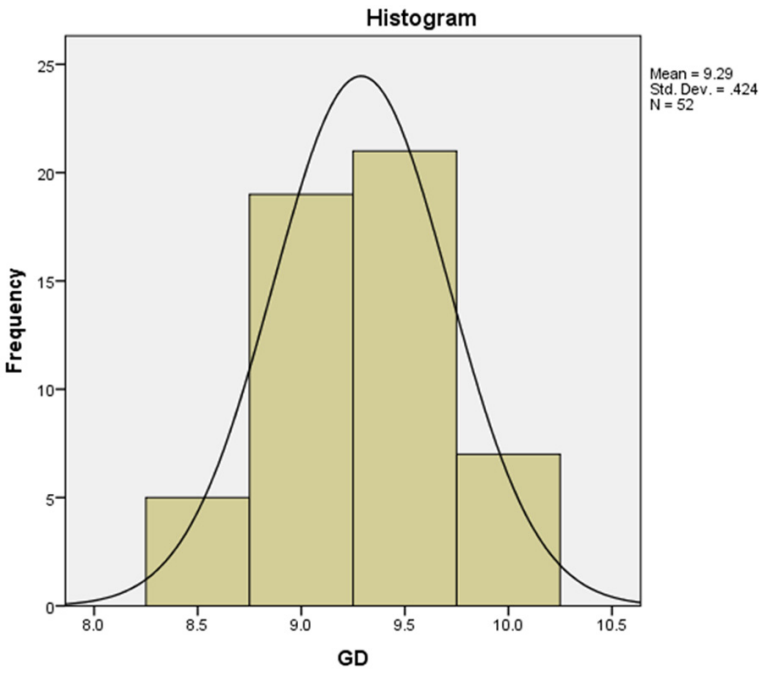

Figure 2. A histogram showing graft diameter with normal distribution curve.

us brevis near its insertion, and then the tendon of PL was cut entirely at a distance 2 cm proximal to the base of the fifth metatarsal just above the stitches. The immediately cut distal end of PLT was pulled out of the Proximal incision (**Figure 1C**). After that, a stripper was used to harvest the tendon of peroneus longus. Care was taken to keep stripper 4-5 cm distal to the fibular head to prevent common peroneal nerve injury [19]. A four-stranded graft was prepared by doubling it from the middle, and ends were stitched with a No. 2 polyester suture. Graft diameter measurement was done with the help of a measuring guide (Smith and Nephew measuring device with 0.5 mm increments) [15, 16, 22]. Graft diameter was taken as the smallest calibration which could pass through the guide. A femoral tunnel was made from the anteromedial portal. The PLT graft was fixed with a bioabsorbable interference screw in the tibial tunnel and a suspensory device in the femoral tunnel [2].

Measuring tools: All patients (n = 52) gave an informed consent form for inclusion in this study. Patient particulars like age, sex, weight, height, BMI, and injury duration were recorded preoperatively. The diameter of quadrupled peroneus longus tendon graft was measured intraoperatively. Our primary research indicator was to analyse the diameter of the peroneus longus tendon graft obtained through inframalleolar approach and its correlation with anthropometric parameters by formulating a predictive equation.

Statistical analysis

Data analysis was done through SPSS software, version 20.0 (IBM Corp., Chicago). The normality of data was ascertained through the test of normality (**Figure 2**). Pearson correlation coefficient was utilized for measurement of the correlation between anthropometric variables and PLT diameter. Regression analysis was done to make out the impact of variables like age, height, weight, BMI, and injury duration on graft diameter. Predictive values were reported by the correlation coefficient (R^2). A *p* value of less than 0.05 was considered statistically significant.

Results

Fifty-two patients were included in this study, with 46 males and six females. The mean age was 28.2 ± 7.4 years (20-45 years), the mean height was 172.7 ± 2.8 cm (167-179 cm), the mean weight was 75.6 ± 3.4 kg (70-85 kg), and the mean BMI was 25.3 ± 0.9 (23-29) (**Table 1**). The mean length of the peroneus longus tendon was 321.4 ± 26.7 mm (280-370). The mean graft diameter of the Peroneus longus tendon was 9.3 ± 0.4 mm (8.5-10 mm). Five patients (9.6%) had a graft diameter of 8.5 mm, 9 mm in 19 patients (36.5%), 9.5 mm in 21 patients (40.4%), and 10 mm in 7 patients (13.5%). The mean AOFAS score after 24 months of follow-up was 99.19. MRC grade of the foot after 24 months of follow-up was 5 in all the patients. PLT graft diameter distribution is outlined in **Table 2**.

Only height and weight were significantly associated with graft diameter out of various anthropometric indices (**Table 3**). Positive correlation was found between the height and graft diameter (r = 0.6, P < 0.01) [**Figure 3**] and between

Table 1. Patients' demographics

Variable	n	Mean	Minimum	Maximum	SD
Age (year)	52	28.2	20	45	7.4
Sex					
Male	46				
Female	6				
Mechanism of injury					
RTA	10				
Sports Injury	27				
Domestic fall	15				
Graft Diameter (mm)	52	9.3	8	10	0.4
Quadrupled graft length (mm)	52	81.4	70	90	6.8
Height (cm)	52	172.7	167	179	2.8
Weight (kg)	52	75.6	70	85	3.4
BMI	52	25.3	23	29	0.9
Duration of Injury (months)	52	9.2	3	18	3.9
Peroneus longus tendon length (mm)	52	321.4	280	370	26.7
AOFAS Score (24 month)	52	99.2	97	100	1.3
MRC GRADE (Power in ankle)	52				
Plantarflexion/Dorsiflexion		5	5	5	
Eversion/Inversion		5	5	5	

RTA = Road Traffic Accident, AOFAS = American Orthopaedic Foot and Ankle Society, MRC = Medical research council.

Table 2. PLT graft diameter description

Diameter (mm)	Frequency	Percentage
8.5	5	9.6
9	19	36.5
9.5	21	40.4
10	7	13.5

Table 3. Pearson correlation between peroneus longus tendon graft diameter and different anthropometric parameters

Anthropometric parameters	r	95% CI	P
Height	0.6	0.55 to 0.125	< 0.01
Weight	0.4	0.015 to 0.081	< 0.01
BMI	0.06	-0.149 to 0.097	> 0.05
Age	0.2	-0.006 to 0.026	> 0.05
Graft diameter and duration of injury	0.09	-0.040 to 0.021	> 0.05

r = Pearson's correlation coefficient, BMI = body mass index, CI = confidence interval.

the weight and graft diameter ($r = 0.4$, $P < 0.01$) [**Figure 4**]. No correlation was found between BMI and graft diameter ($r = 0.06$, $P > 0.05$), age and graft diameter ($r = 0.2$, $P > 0.05$) and duration of injury and graft diameter ($r = 0.09$, $P > 0.05$). In the linear regression analysis also, only height and weight were significantly related to the graft diameter. Depending upon these two predictors, the following regression formula was established [2, 15, 22]. Diameter of graft (mm) = 0.083 × height (cm) + 0.011 × weight (kg) -5.854 ($R^2 = 0.36$). This equation has a positive predictive value of 36%.

Discussion

This study found that anthropometric parameters, including height and weight, were correlated with the PLT graft diameter. The results also confirmed that anthropometric data have a predictive association with the thickness of the PLT graft obtained during ACL reconstruction. We observed that the height and the weight were statistically significant predictors for graft diameter.

Studies on the predictors of the peroneus longus graft thickness are only a few. To the best of our knowledge, only three studies have been reported in the literature [15, 16, 22]. Our study

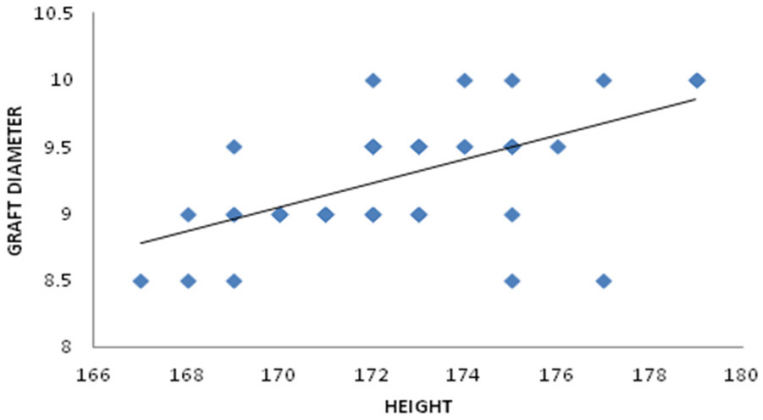

Figure 3. Scattered plot illustrating relationship between height and graft diameter. This shows a significant correlation between height and graft diameter ($r = 0.6$, $P < 0.01$).

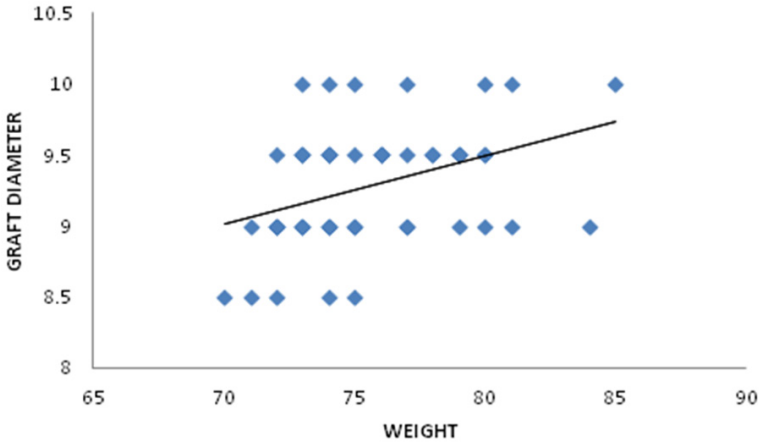

Figure 4. Scattered plot illustrating relationship between weight and graft diameter. This shows a significant correlation between weight and graft diameter (r = 0.4, P < 0.01).

is the first of its kind because all the authors, as mentioned earlier, have excised the peroneus longus tendon from the supramalleolar region. Height was strongly associated with the diameter of the peroneus longus in our study, as it had been seen in the case of the hamstring tendon graft. [23] Song et al. [15] in 2018 studied anthropometric data of 136 patients which is the largest series in the available literature. They found height as the strongest predictor of PLT diameter with a correlation coefficient = 0.62. Rhatomy et al. [16] 2019 studied 39 patients, and they also found height as the most vital determinant of graft thickness with a correlation coefficient = 0.41. Sakti et al. [22] included 20 patients and noticed a significant association between height and graft thickness. In our study, we also observed a similar pattern with height having a correlation coefficient of 0.6. Park et al. [10], Pereira et al. [24], Asif et al. [2], and Celiktas et al. [23] also found height as the strongest predictor of graft diameter in hamstring graft.

A similar pattern was noticed with weight as well [15, 16, 22]. Although Song et al. [15] and Rhatomy et al. [16] have graded weight as the second and BMI as the third in the strength of association with the graft diameter, we could not find a notable association between BMI and graft diameter. Our study has similar observations as of Celiktas et al. [23] and Sakti et al. [22], where hamstring graft thickness correlates only with height and weight. Pereira et al. [24] could not find any association between weight and height. However, Boisvert et al. [25] observed a significant relationship between hamstring graft diameter and BMI. We did not find any correlation regarding age and the graft diameter. This variation may be because of different racial and geographical conditions. In addition, we could not establish any relationship of graft diameter with the gender as we had only six females in our sample. However, Song et al. noticed a significant difference between male and female graft diameter of peroneus longus. Lastly, we did not find any correlation between duration of injury and graft diameter because most of our patients reported late to hospitals.

Moreover, chances of subjective variations in memory recall and frequency of error increase with the delay in reporting time of the patients. It probably did not allow us to record an accurate date of injury. In our study, the average reporting time was 9.2 months which is extremely high as compared to Song et al. [15].

Our study is different from all the previous studies. Kerimoglu et al. [26] removed only 10 cm long tendon by giving incisions above and below the lateral malleolus. Shi et al. [19] also harvested grafts from the inframalleolar region; however, they only did ACRL with two stranded grafts. The majority of other authors have harvested grafts from the supramalleolar region only. We incised graft from the foot, thinking that it would lead to a thicker diameter. Our hypothesis was true because if we remove graft from the supramalleolar area, it will involve more musculotendinous junction producing thin graft. We knocked out the tendon adjacent to the insertion of the peroneus brevis, which resulted in a thicker graft after making it four-stranded. Our second hypothesis also came true as the average graft diameter in our study was 9.3 ± 0.4 mm, with none of the grafts less than 8.5 mm. The average diameter of the graft was 8.3 in Song et al. [15], with 21 percent patients less than 8 mm and 51 percent patients had a diameter of 8 mm. Rhatomy et al. [16] reported an average diameter of PLT as 8.5 mm. In another study by Rhatomy et al. [27], the average diameter of PLT was 8.38 mm. A similar study done by Khajotia et al. [28] observed an average diameter of 8.24 mm.

Contrary to them, in our study, the average diameter was 9.3 ± 0.4 mm, with 90 percent of patients having graft diameter more than 8.5 mm. The average tendon length in our study is 321.4 ± 26.7 mm, which is comparable to the length reported by Shi et al. [19], where the average tendon length was 300 mm. This difference in length of the graft may be because of the ethnic features of the population. As the concept is slowly drifting towards the diameter of 8 mm, being the minimum figure, which is still not completely established [29], it will be prudent to consider PLT graft as the preferred choice.

We did not find any weakness in the eversion and plantarflexion of the foot (MRC grading-5). Furthermore, the AOFAS score (99.19) was comparable to normal foot in all patients at the follow-up of two years. Perhaps stitching the remaining portion of PLT with PBT preserved the foot's eversion and plantar flexion action. Shi et al. [19] also could not find any impairment in functions of the foot.

We formulated an equation to predict the graft diameter: PLT Diameter = 0.083 × height (cm) +0.011 × weight (kg) -5.854. The value of R^2 (correlation coefficient) is 36%, which is comparable to Song et al. [15] and Gupta et al. [14].

Radiological measurement is another mode through which graft sizes can be predicted preoperatively. However, no such studies have been done so far in the literature that could predict peroneus longus preoperatively. Moreover, the non-standardization of measurement protocol and expensive soft wares are critical limiting factors behind the infamous use of radiological techniques [23]. Furthermore, anthropometric parameters are easy to perform, and they do not require any expertise.

The major strength of this study is that it is the first study to establish a relationship between the anthropometric parameters and PLT graft diameter harvested through a different surgical approach compared to previous studies [15, 22, 27]. We found that two predictors were associated with PLT diameter. Moreover, it has more strength than the Hamstring autograft and native ACL [30]. Furthermore, as it lies superficially in the distal leg and foot, it can be conveniently harvested, which is another advantage. In addition, we constructed a predictive equation, which can be used to effectively plan arthroscopic ACL reconstruction by predicting the diameter of PLT.

Our study's limitations include a small sample size, fewer female patients, and the study's retrospective nature. Multicentre studies with a large sample size, a large number of females, and long follow up are warranted to corroborate our findings.

Conclusion

Anthropometric measurements do correlate with peroneus longus graft diameter. Among all the parameters, height has the strongest association. Anthropometric parameters can help surgeons to identify high risk patients who may not have adequate graft size for ACL reconstruction. This information can be used to guide surgeons about the possibility of alternative graft options. Also, average diameter of the peroneus longus graft tendon is more than nine millimetres through inframalleolar approach.

Disclosure of conflict of interest

None.

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