

Predicting the graft diameter of the peroneus longus tendon for anterior cruciate ligament reconstruction

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Abstract

The aim of this study was to evaluate the correlation between various anthropometric parameters and the graft diameter of the peroneus longus tendon (PLT).

We retrospectively analyzed the data of 156 patients who underwent anterior cruciate ligament reconstruction (ACLR) with the PLT graft at our institution. Anthropometric parameters, including height, weight, gender, age, duration of injury, and preinjury activity levels, were recorded. *t* tests, correlation coefficients (Pearson *r*), and a multiple linear regression analysis were used to evaluate the influence of these anthropometric variables on the diameter of the graft obtained.

The mean PLT graft diameter was 8.3 mm, and 21 patients (13.5%) had a diameter less than 8 mm; 85 patients (54.5%) had a diameter between 8 and 9 mm, and 50 patients (32.0%) had a diameter greater than or equal to 9 mm. The correlation analysis showed that height ($P < .001$), weight ($P < .001$), and duration of injury ($P = .012$) were significantly related to graft diameter. On the basis of these 3 predictors, the following regression equation was obtained: Diameter = $2.28 + 0.028 * \text{height (cm)} + 0.013 * \text{weight (kg)} + 0.289 * \text{duration of injury (0 or 1)}$. Patients who were short and thin were more likely to own smaller graft diameters (<8 mm), especially the one ruptured his or her anterior cruciate ligament (ACL) over 3 months.

Height, weight, and duration of injury were associated with the diameter of PLT. They are important preoperative information for surgeon about the size of PLT and can be used for alternative graft source planning and patient counseling.

Level of evidence: IV

Abbreviations: ACLR = anterior cruciate ligament reconstruction, BMI = body mass index, PLT = peroneus longus tendon.

Keywords: anterior cruciate ligament reconstruction, diameter, duration of injury, height, peroneus longus tendon, predict

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1. Introduction

The anterior cruciate ligament (ACL) is one of the most important structures maintaining the knee joints stability.^[1] With the increasing popularity of contact sports, the incidence of ACL injuries is raising now.^[2]

To restore the knee stability, ACL reconstruction (ACLR) has been recognized as the most common procedure.^[3] However, up to 4.0% to 15.3% of the operations are failed.^[2] According to literatures, a series of factors could influence the outcomes of ACLR surgery, including age, sport activities, graft type, initial graft tension, graft diameter, and anatomic reconstruction.^[4–6] Of those factors, the diameter of the graft play an important role.^[7] Magnussen et al^[8] considered 7 mm as the minimum graft size to avoid the revision surgery. Recently, researchers argued that a graft diameter of no less than 8 mm is the acceptable range.^[2,9,10] A cohort study of 2240 patients performed by Snaebjornsson et al.^[11] showed that, when graft diameter located at 7.0 to 10.0 mm, per 0.5 mm increase resulted in a 0.86 times lower likelihood of revision surgery. In addition, some studies have suggested that graft diameter is associated with postoperative complications such as knee joint instability.^[12,13] Hence, predicting the graft diameter in ACLR is of vital clinical importance by helping surgeons make comprehensive preoperative plans and opt for alternative graft choices.

Some recent researches have been performed to explore ideal methods to predict the graft diameter, including magnetic

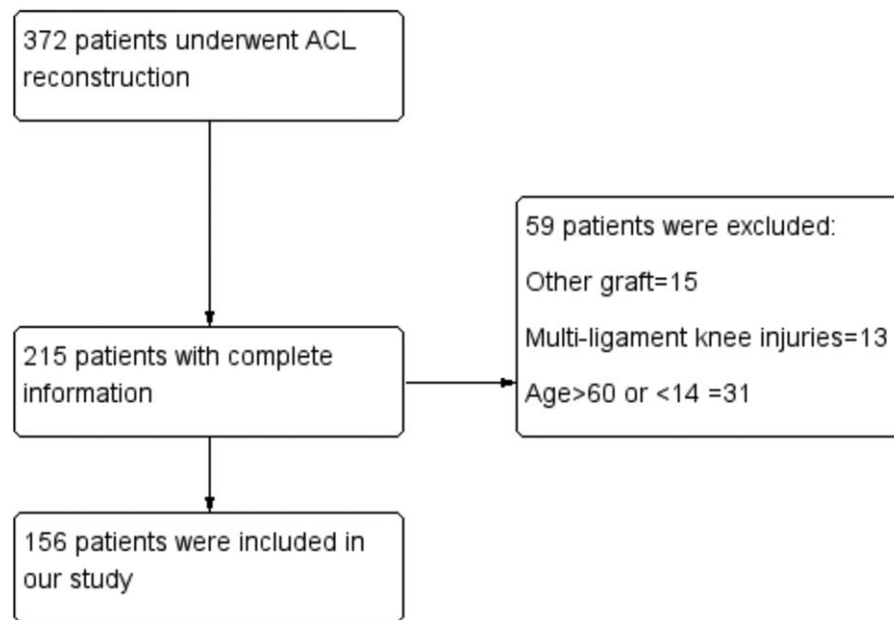


Figure 1. Flow diagram for inclusion of patients.

resonance imaging (MRI),^[14,15] computed tomography,^[16] ultrasound,^[17] and anthropometric parameters.^[18–21] Preoperative MRI and anthropometric parameters are the most widely used methods. Although MRI examinations show a similar sensitivity and accuracy compared with anthropometric parameters, its high costs limit its generalization.^[2,19] Conversely, anthropometric parameters are easy to obtain and free of charge.

Some anthropometric parameters have been identified to be related to hamstring tendon diameter such as the height, weight, and body mass index (BMI) of patients.^[18,20] Although the hamstring tendon is one of the most often used graft for ACLR, more and more complications were reported, including internal rotation strength deficit and sensory deficit.^[22,23] Accordingly, more ideal alternative grafts should be identified to fascinate ACLR.^[24–26] Among them, the peroneus longus tendon (PLT) has proven to be a promising graft and it has been reported to be safe and efficient.^[27–29] However, there are no studies investigating the importance of anthropometric parameters regarding the PLT diameter so far. Therefore, the purpose of this retrospective study was to evaluate whether those anthropometric parameters are also associated with the diameter of PLT graft. We hypothesized that those preoperative data could be used to predict the diameter of PLT graft before ACLR.

2. Materials and methods

2.1. Patients

This study was approved by the Drum Tower Hospital, School of Medicine, Nanjing University. Patients who underwent ACLR using the PLT between April 2015 and March 2017 for ACL injury were included in this study. The exclusion criteria were ACLR using other type graft such as hamstring tendon, multiligament knee injuries, age older than 60 years or younger than 14 years, and cases with incomplete information. Three authors independently collected anthropometric parameters, including height, weight, gender, age, duration of injury, and

preinjury activity levels via medical records. Finally, 156 consecutive patients were enrolled in this study (Fig. 1). Informed consent was obtained from all of those patients.

2.2. Operation procedures

All patients received single bundle reconstruction under general anesthesia. All PLT grafts were harvested in the same fashion with a 2-cm longitudinal skin incision at the posterolateral side of the fibula just over the peroneus tendon, 2 cm proximal to the posterior border of the lateral malleolus (Fig. 2A). After exposing the distal PLT, a stripper was used to harvest the tendon (Fig. 2B, C). The superficial fascia and fat of the PLT were removed, and the rough edge was trimmed carefully (Fig. 2D). Then, the PLT were doubled up at the middle to obtain a 4-strand graft and its ends were whip-stitched with a No. 2 polyester suture (Fig. 2E). The diameter of PLT graft was measured using the Smith and Nephew sizing cylinder in 0.5-mm increments (Fig. 2F). Finally, the prepared PLT was implanted and fixed using a bioabsorbable interference screw using an independent femoral approach as previously described.^[30]

2.3. Statistical analysis

All statistical analyses were performed using SPSS, version 23.0 (SPSS Inc., Chicago, IL). Independent-sample *t* tests were used to identify the relationships between the diameter of PLT graft and dichotomous variables (gender, duration of injury, level of activity). Correlation coefficients (Pearson *r*) were used to identify the relationships between the diameter of PLT graft and continuous variables (height, weight, age, and BMI). After the univariate analysis, a simple linear regression analysis was used to evaluate the influence of the anthropometric variables on the diameter of the graft obtained. In order to improve the matching degree of the regression equation and real parameters, we have taken log of those continuous variables. *P* values less than .05 were considered as significant.

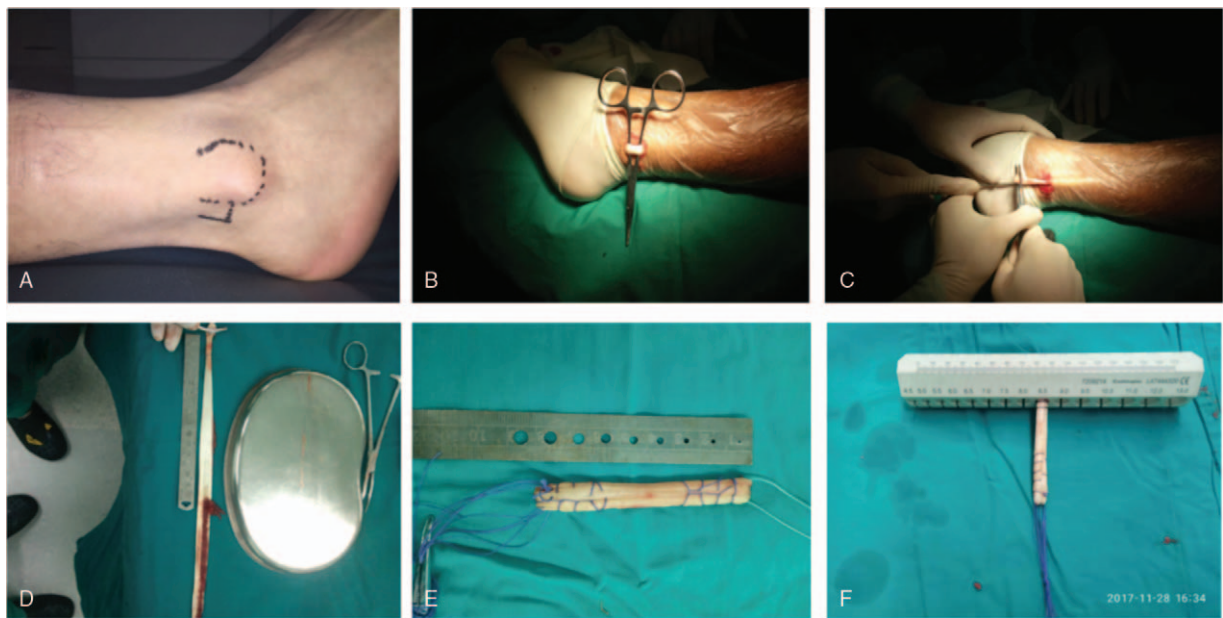


Figure 2. The procedure of the preparation of peroneus longus tendon (PLT). (A) A longitudinal skin incision (solid line) at the posterolateral side of the fibula, 2 cm proximal to the posterior border of the lateral malleolus (dotted line). (B) Exposing the distal end of the PLT with a mosquito hemostat. (C) Cutting off PLT at the distal end and putting the stripper toward the proximal end and then pulling out the tendon of peroneus longus. (D) Moving the superficial fascia and fat of the PLT and trimming the rough edge carefully. (E) Doubling up the PLT to obtain a 4-strand graft and suturing its ends in a whipstitch style with a No. 2 polyester suture. (F) Measuring the diameter of PLT graft using a cylinder in 0.5-mm increments. The final diameter is the smallest possible diameter that allowed smooth passage of the graft.

3. Results

3.1. Study population

A total of 156 patients were included in this study. There were 118 men and 38 women. The mean age was 29.5 years (14–51 years), the mean height was 174.1 cm (152.0–192.0 cm), the mean weight was 76 kg (54–110 kg), and the average BMI was 25.0 (16.7–34.6). When the samples were split by gender, the mean PLT graft diameters were 8.5 and 7.8 mm and the mean graft lengths were 8.6 and 8.2 cm for men and women, respectively (Table 1).

The mean PLT graft diameter was 8.3 mm in this study. A total of 21 patients (13.5%) had a graft diameter of less than 8 mm, 85 patients (54.5%) had a graft diameter between 8 and 9 mm, and 50 patients (32.0%) had a graft diameter greater than or equal to 9 mm. The distribution of PLT diameters is listed in Table 2.

3.2. Positive factors

The univariate analysis revealed that variables such as gender, preinjury activity levels, duration of injury, BMI, height, and

weight were all significantly related to graft diameter (Tables 3 and 4). However, in the final linear regression analysis, only height ($P < .001$), weight ($P < .001$), and duration of injury ($P = .012$) were significantly related to graft diameter (Fig. 3). On the basis of these 3 predictors, height, weight, and duration of injury, we obtained the following regression equation: Diameter = $2.28 + 0.028 * \text{height (cm)} + 0.013 * \text{weight (kg)} + 0.289 * \text{duration of injury (0 or 1)}$. For example, when one patient who is 175 cm, 70 kg, and undergo ACLR 5 months after injury, the theoretical diameter = $2.28 + 0.028 * 175 + 0.013 * 70 + 0.289 * 0 = 8.089$ cm. The R^2 value for the regression equation was 0.248, which means that 24.8% of the variance in PLT diameter can be explained by the predictors in this equation.

4. Discussion

In this study, we found that anthropometric parameters, including height, weight, and duration of injury, were associated with the PLT graft diameter and the results also confirmed that

Table 1
Demographic and anthropometric data in general and by gender.

Variables	Total	Women	Men	P
Diameter, mm	8.3 ± 0.8	7.75 ± 0.62	8.46 ± 0.76	<.001
Length, mm	8.5 ± 0.4	8.24 ± 0.39	8.54 ± 0.41	<.001
Age, y	29.5 ± 8.1	33 ± 10.4	28.3 ± 6.8	.01
Height, cm	174.1 ± 8.6	162.5 ± 4.2	177.8 ± 6.02	<.001
Weight, kg	76.2 ± 13.2	62.9 ± 9.3	80.5 ± 11.2	<.001
BMI	25.0 ± 3.4	28.4 ± 3.52	25.43 ± 3.22	.01

Values are represented in mean ± standard deviation; the P value refers to the t test for the differences between the means of the genders.

BMI = body mass index.

Table 2
PLT graft diameter distribution.

Diameter, mm	Total	Women	Men
7	19 (12.2)	13 (68.4)	6 (31.6)
7.5	2 (1.3)	1 (50)	1 (50)
8	81 (51.9)	19 (23.5)	62 (76.5)
8.5	4 (2.6)	2 (50)	2 (50)
9	37 (27.7)	3 (8.1)	34 (91.9)
10	13 (8.3)	0	13 (100)

Values are represented in number (%).

Table 3
Correlation between categorical variables and PLT graft diameter.

Variables	Number	P
Preinjury activity levels		.031
High	98	
Low	55	
Gender		<.001
Male	118	
Female	38	
Duration of injury		.012
No more than 3 mo	98	
More than 3 mo	49	
Operator		ns.
1	60	
2	56	
3	40	

PLT=peroneus longus tendon.

anthropometric data do have a predictive influence on the diameter of the PLT graft obtained.

Similar to those predictors of hamstring tendon diameter, height is the strongest predictor for PLT diameter ($P < .001$; $R^2 = 0.212$; explains 21.2% variance in diameter due to height).^[31] Weight is also associated with graft size ($P < .001$; $R^2 = 0.166$; explains 16.6% variance in diameter due to height). But, we did not find significant relationship between patients' BMI and PLT diameter. Strikingly, the duration of injury was associated with the graft diameter, which has never been reported before. Patients with a history of ACL rupture for more than 3 months were more likely to have a thinner PLT graft ($P = .012$). The explanation for this finding might be the disuse atrophy of skeletal muscle after ACL injury.^[32-34]

Finally, we constructed the following equation to predict the diameter based on 3 predictors: $PLT \text{ Diameter} = 2.28 + 0.028 * \text{height (cm)} + 0.013 * \text{weight (kg)} + 0.289 * \text{duration of injury (0 or 1)}$. The R^2 value for the regression equation was 0.225, which means that 22.5% of the variance in PLT diameter can be

Table 4
Correlation coefficients (Pearson) between continuous variables and PLT graft diameter.

Variables	r	P	95% CI	R ²
Height	0.627	<.001	0.059–1.019	0.212
Weight	0.450	<.001	0.014–0.030	0.166
Age	-0.112	ns.	-0.137 to 0.013	0.012
BMI	0.284	.014	0.012–0.093	0.039

BMI=body mass index, CI=confidence interval, PLT=peroneus longus tendon.

explained by the predictors in this equation. Those articles studying hamstring tendon size also obtained some regression equations based on their findings; however, the strength of correlation in those studies was all not strong ($R^2 < 20\%$).^[8,18]

Gender is a controversial factor. Some authors regarded female gender as a predicting factor of small graft size^[35]; however, others did not find significant difference between gender and graft diameter.^[21] In this study, we found that the PLT diameter among women was much smaller than that among men. However, other anthropometric data such as the age, height, BMI, and weight were all statistically different between the 2 groups. Hence, we could not identify that the different graft diameters between men and women are caused by gender or other anthropometric parameters. In the future, more studies with larger number of females should be undertaken to figure out if there is actually any effect of gender.

The present study recorded preinjury activity levels and divided them into 2 levels: high and low level. The results showed that the level of physical activity was not correlated with PLT diameter, which is similar to the findings of other articles.^[3,36] However, the patients' self-reported activity levels were not accurate and might not reflect true activity levels.

The major strength of this article is that it is the first study to determine the association between anthropometric parameters and PLT graft diameter. We found that 3 predictors were associated with PLT diameter. Of the 3 variables, duration of

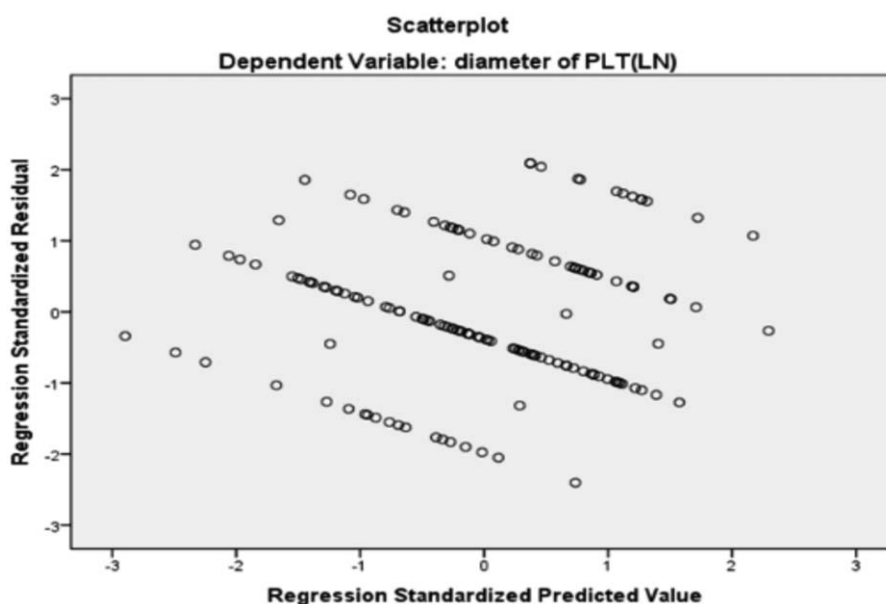


Figure 3. Scatter plots showing matching degree between height, weight, and duration of injury and peroneus longus tendon graft diameter ($R^2 = 0.248$).

injury is a new factor associated with PLT graft diameter. In addition, we constructed a predictive equation, and the strength of correlation was stronger than that of most other studies. This equation can be used to predict the diameter of PLT, to make preoperative plan, and to provide patient with counseling for graft selection.

However, the present study also has limitations. First, 3 surgeons performed the ACLRs, so some clinical bias may exist; however, they have similar clinical experiences and applied consistent tendon harvesting techniques. Second, preinjury activity level is self-reported, adding to the inaccuracy of this study. In the future, more objective and reasonable measuring methods for preinjury activity level should be explored. Third, the sample size of women is relatively small, which could lead to insufficient statistical power to detect small difference in clinical outcomes.

5. Conclusion

Height, weight, and duration of injury were found to be associated with the diameter of PLT graft. These 3 parameters can be used to identify those patients with a high risk of inadequate graft size and to provide important preoperative information for the surgeon.

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