




Relation of peroneus longus autograft dimensions with anthropometric parameters in anterior cruciate ligament reconstruction: Importance of the distal leg diameter

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The anterior cruciate ligament (ACL) is one of the most important ligaments which contribute to the stability of the knee joint. Currently, ACL injuries have become increasingly common due to the increasing interest in contact sports. Many patients with ACL rupture have to quit sports due to instability and undergo ACL reconstruction (ACLR), however; ideal conditions for healing are mostly non-existent.^[1]

Compliance with the basic principles of the surgical technique and an appropriate selection of the autograft to be used affect the results of ACLR. For successful results in ACLR, the ideal position of femoral and tibial graft fixation points is more critical than the other factors.^[2] Although there are publications reporting that the variability of the graft diameter to be used does not affect the results of ACLR,^[3] there are still some reports indicating that

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ABSTRACT

Objectives: This study aims to investigate the relationship between various anthropometric parameters and the diameter and length of the peroneus longus tendon (PLT) graft in the anterior cruciate ligament (ACL) reconstruction.

Patients and methods: A total of 52 patients (38 males, 14 females; mean age: 29.2±7.7 years; range, 17 to 51 years) who received PLT autograft for ACL reconstruction in our center between July 2018 and June 2020 were retrospectively analyzed. Demographic characteristics of the patients and leg length, and proximal and distal leg diameters were recorded before the operation. The PLT autograft diameter and length were measured during surgery.

Results: A statistically significant correlation was found between the graft diameter and length and weight, height, body mass index (BMI), leg length, and proximal and distal leg diameters ($p<0.01$). There was no statistically significant correlation between the graft diameter and length and age ($p>0.05$). Distal leg diameter had the highest correlation coefficient for the PLT autograft diameter ($r=0.956$), while the height had the highest correlation coefficient for the PLT autograft length ($r=0.982$).

Conclusion: Anthropometric parameters of height, weight, BMI, leg length, and proximal and distal leg diameters may be helpful for surgeons to predict the diameter and length of the PLT autograft before surgery. Distal leg diameter is a particularly important parameter in predicting PLT autograft diameter.

Keywords: Anterior cruciate ligament reconstruction, distal leg diameter, peroneus longus autograft, prediction.

the graft diameter affects the clinical results.^[4,5] Also, the easy removal of the graft, morbidity in the donor area, and the length and strength of the graft should be considered in the selection of the autograft to be used.^[6]

To date, the most commonly used autograft is the hamstring tendon (HT), followed by the patellar tendon (PT).^[7] The latter is less preferred than HT, due to both difficulty in the removal of the graft and the anterior knee pain after the operation.^[8] However, over

time, HT autografts have been found to have potential risks, such as insufficient diameter or length, lack of internal rotation strength, and sensory problems.^[9] As a result, surgeons have sought alternative autografts. The peroneus longus tendon (PLT) has been proposed as an alternative autograft which can be used in ACLR.^[10] It has been demonstrated that PLT has sufficient thickness and strength for use in ACLR.^[11] However, in the long-term follow-up of the donor ankle, deficiency in the first beam flexion and ankle instability can be seen.^[12]

In ACLR, predicting the autograft diameter and length before surgery is crucial, particularly in high-risk patients. Different methods such as magnetic resonance imaging, computed tomography, ultrasonography and anthropometric parameters have been used to preoperatively predict the graft diameter. However, anthropometric parameters are the most preferred, as they can yield similar results as other methods and are both cost-free and extremely easy to perform.^[13]

Since PLT has only gained popularity in recent years, very few studies exist in the literature on the use of anthropometric parameters to preoperatively predict the diameter and length of the PLT autograft.^[14-16] Most commonly, age, sex, height, weight, and body mass index (BMI) have been studied. To the best of our knowledge, there is no study investigating the use of the distal leg diameter parameter. In the present study, we, therefore, aimed to examine the relationship between various anthropometric parameters and the diameter and length of the PLT graft in the ACLR.

PATIENTS AND METHODS

This single-center, retrospective study was conducted at Orthopedics and Traumatology Department of Aydin State Hospital between July 2018 and June 2020. A total of 52 patients (38 males, 14 females; mean age: 29.2 ± 7.7 years; range, 17 to 51 years) who received PLT autograft for ACLR were included. Patients with additional injuries in the knee region or ankle and patients with missing information were excluded from the study. All operations were performed by a single surgeon using the same technique. All preoperative including height, weight, leg length, and distal/proximal leg diameter and intraoperative data including PLT lengths and diameters were obtained from the operating surgeon. A written informed consent was obtained from each patient. The study protocol was approved by the Adnan Menderes University Faculty of Medicine Ethics Committee (No. 2020/111). The study was

conducted in accordance with the principles of the Declaration of Helsinki.

Height and weight measurements of the patients were performed in the outpatient setting. The height was measured in cm, without shoes and while hands were perpendicular on the side. The weight was measured by a device in kg. The BMI was calculated using the formula kg/m^2 . To obtain the leg length, the distance from the medial knee joint line to the most distal end of the medial malleolus was measured in cm. The proximal leg diameter was measured at 10 cm distal of the knee joint line, while the distal leg diameter was measured at 10 cm proximal of the most distal end of the medial malleolus.

Surgical procedures

All patients were operated under spinal anesthesia. Tourniquet was applied to the thigh area. After sterilization with iodine solution, the knee was prepared with disposable covers. Standard anteromedial and anterolateral portals were opened,

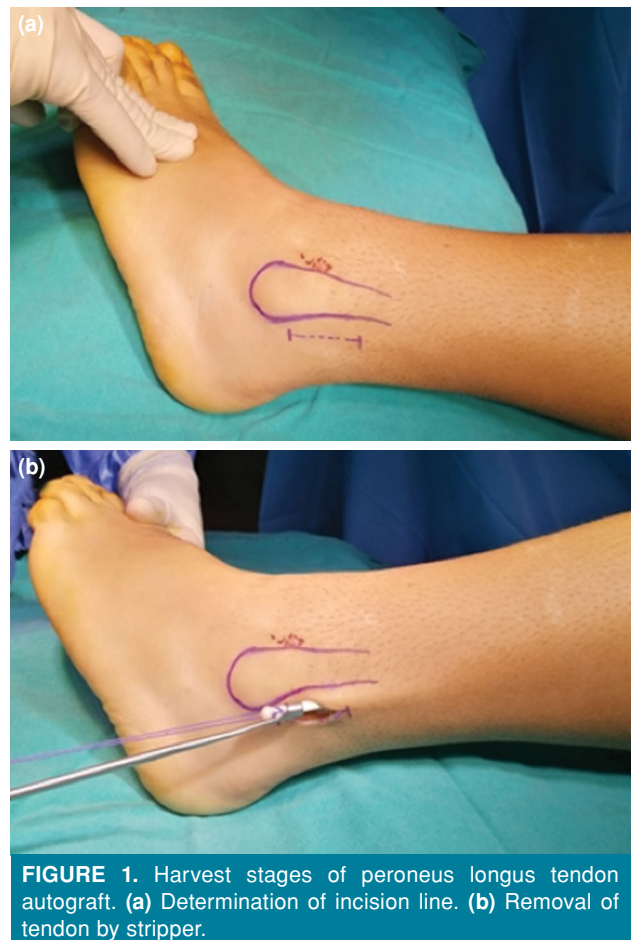


FIGURE 1. Harvest stages of peroneus longus tendon autograft. (a) Determination of incision line. (b) Removal of tendon by stripper.



FIGURE 2. Preparation stages of peroneus longus tendon autograft. (a) The first form of graft after harvesting. (b) Graft ready to be placed in femoral and tibial tunnel.

and the knee was arthroscopically entered. The diagnosis of an ACL rupture was, then, confirmed.

Approximately 2 to 2.5-cm incision was made from 1-cm posterior and 2-cm proximal to the posterior edge of the lateral malleolus. Cutaneous-subcutaneous tissue was penetrated and superficial fascia was opened. Peroneus brevis and peroneus longus were identified. The PLT was released by separating the distal end of the tendon with the help of a scalpel. Then, the graft was taken using the tendon stripper. The same technique was used for all patients (Figure 1). All fat and muscle tissues on the removed graft were cleaned. The tendon was folded in half from the middle. The tip of the graft was sewn in a whip style with suture. The prepared graft was, then, passed through a sizing cylinder to determine the smallest diameter allowing passage. The PLT length was measured in cm by a ruler (Figure 2). Finally, the prepared graft was inserted into the properly opened femoral and tibial tunnels and fixed.

Statistical analysis

Statistical analysis was performed using the IBM SPSS version 21.0 software (IBM Corp., Armonk, NY, USA). The suitability of continuous variables to normal distribution was investigated by visual (histogram and probability graphs) and analytical methods (Kolmogorov-Smirnov/Shapiro-Wilk tests). Descriptive data were expressed in mean \pm standard deviation (SD), median (min-max) or number and frequency, where applicable. The Student's t-test or one-way analysis of variance (ANOVA) was used for comparison of continuous variables in independent groups that met parametric requirements. The Mann-Whitney U test or Kruskal-Wallis variance analysis was used for comparison of continuous variables in independent groups that did not meet parametric requirements. For correlation analysis, Pearson test was conducted when parametric requirements were met; otherwise, the Spearman test was used. Linear regression analysis was used as a modelling method to predict the parameters representing the universe from the data in the sample. Before the linear regression analysis was used, the compatibility of the variables included in the analysis in the first stage was evaluated. In the second stage, correlation analysis was performed with normally-distributed variables. The variables with statistically significant correlations were included in the univariate linear regression analysis. A p value of <0.05 was considered statistically significant.

RESULTS

There was no significant difference in the age between the males and females; however, there was

TABLE I
Demographic and clinical characteristics of patients

	Sex			p
	Male (n=38)	Female (n=14)	Total (n=52)	
	Mean \pm SD	Mean \pm SD	Mean \pm SD	
Age (year)	29.6 \pm 7.6	28.1 \pm 8.1	29.2 \pm 7.7	0.534
Weight (kg)	81.8 \pm 8.9	60.5 \pm 6.5	76.0 \pm 12.6	<0.001
Height (m)	1.8 \pm 0.1	1.6 \pm 0.0	1.7 \pm 0.1	<0.001
Body mass index (kg/m ²)	26.6 \pm 2.3	23.9 \pm 2.2	25.9 \pm 2.6	<0.001
Leg length (cm)	35.0 \pm 1.2	30.8 \pm 0.7	33.8 \pm 2.2	<0.001
Proximal leg diameter (cm)	39.9 \pm 4.5	35.4 \pm 1.9	38.7 \pm 4.5	<0.001
Distal leg diameter (cm)	24.9 \pm 1.2	22.7 \pm 0.4	24.3 \pm 1.4	<0.001
Graft diameter (mm)	8.3 \pm 0.5	7.3 \pm 0.3	8.0 \pm 0.6	<0.001
Graft length (cm)	13.6 \pm 0.6	12.3 \pm 0.3	13.3 \pm 0.8	<0.001

SD: Standard deviation.

TABLE II Graft diameter according to sex						
	Sex				Total	
	Male		Female			
	n	%	n	%	n	%
Graft diameter (mm)						
7	0	0.0	6	42.9	6	11.5
7.5	7	18.4	8	57.1	15	28.8
8	12	31.6	0	0.0	12	23.1
8.5	12	31.6	0	0.0	12	23.1
9	7	18.4	0	0.0	7	13.5

TABLE III Correlation analysis results		
	Graft diameter (n=52)	Graft length (n=52)
Age	0.188	0.142
Weight	0.880**	0.781**
Height	0.916**	0.982**
Body mass index	0.540**	0.308*
Leg length	0.881**	0.953**
Proximal leg diameter	0.854**	0.690**
Distal leg diameter	0.956**	0.924**

* p<0.05; ** p<0.01.

a statistically significant difference in the weight, height, BMI, leg length, proximal leg diameter, distal leg diameter, graft diameter, and graft length. Baseline demographic and clinical characteristics of the patients are shown in Table I.

According to the graft diameter, the smallest graft diameter was 7 mm, and 75% of all participants had a graft diameter greater than 7 mm. According to the sex, the graft diameter was 7 mm in 42.9%

of women and 7.5 mm in 57.1%. Among males, the smallest graft diameter was 7.5 mm (18.4%) (Table II).

Correlation analysis of the graft diameter and graft length with age, weight, height, BMI, leg length, proximal leg diameter and distal leg diameter is shown in Table III. A statistically significant correlation was found between the graft diameter and graft length and weight, height, BMI, leg length, proximal leg diameter and distal leg

TABLE IV Evaluation of independent effects of demographic variables and clinical data on graft diameter by linear regression analysis					
	Constant	B	%95 CI	p	R ²
Age	7.546	0.015	-0.007-0.038	0.183	0.035
Weight	4.681	0.044	0.037-0.050	<0.001	0.775
Height	-2.866	0.063	0.055-0.071	<0.001	0.839
Body mass index	4.586	0.132	0.073-0.190	<0.001	0.291
Leg length	-0.534	0.252	0.214-0.290	<0.001	0.776
Proximal leg diameter	3.379	0.119	0.099-0.140	<0.001	0.730
Distal leg diameter	-2.329	0.424	0.387-0.461	<0.001	0.914

CI: Confidence interval.

TABLE V
Evaluation of independent effects of demographic variables and clinical data on graft length by linear regression analysis

	Constant	B	%95 CI	<i>p</i>	R ²
Age	12.824	0.015	-0.014-0.043	0.314	0.020
Weight	9.541	0.049	0.038-0.060	<0.001	0.611
Height	-1.434	8.589	8.114-9.064	<0.001	0.963
Body mass index	10.800	0.095	0.011-0.178	0.027	0.095
Leg length	1.610	0.344	0.313-0.375	<0.001	0.908
Proximal leg diameter	8.547	0.122	0.085-0.158	<0.001	0.476
Distal leg diameter	0.662	0.517	0.456-0.578	<0.001	0.854

CI: Confidence interval.

diameter ($p < 0.01$). However, there was no statistically significant correlation between the graft diameter and length and age ($p > 0.05$).

The univariate linear regression analysis was performed to evaluate independent factors of the graft diameter. Accordingly, a significant relationship was found between the weight, height, BMI, leg length, proximal leg diameter, distal leg diameter, and graft diameter.

The PLT autograft diameter and length prediction equations created by univariate linear regression analysis are shown in Table IV and Table V. According to these predicted equations, for the PLT autograft to be at least 8 mm, body weight should be 75.4 kg, height should be 172.4 cm, leg length should be 33.8 cm, proximal leg diameter should be 38.8 cm, and distal leg diameter should be 24.3 cm.

DISCUSSION

In the literature, there is a number of studies investigating the relation of anthropometric parameters with the dimensions of hamstring autografts.^[11,17-19] However, the number of studies regarding the relation of anthropometric parameters with PLT is still limited.^[14-16]

For the preoperative prediction of HT autograft measurements, different studies have obtained different results using different or the same parameters. One study reported that the height and true leg length were associated with hamstring autograft measurements,^[20] and subsequent studies showed that HT diameters significantly increased in males.^[19] Contrary to these studies, another study reported that the weight, age, and BMI had no effect on the HT diameter, while the height significantly affected the diameter and length of the HT autograft.^[21] Similarly, another study reported

that the thigh diameter and weight had no strong correlation with the diameter of the HT autograft, and only the height was statistically significant in estimating the HT diameter.^[22]

As the use of PLT autograft in ACLR has become popular in recent years, surgeons have attempted to preoperatively predict the diameter and length of the PLT autograft from anthropometric parameters. To date, only a few papers have been published on this subject. Song et al.^[14] conducted an anthropometric study by evaluating the height, weight, sex, duration of injury, and the level of activity before injury and found that only height, weight and duration of injury were significantly associated with the PLT autograft. However, the cases in that study were operated by three surgeons, which may raise a clinical suspicion. In the present study, all operations were performed by a single surgeon using the same implant and the same fixation technique. In addition, the height and weight were found to be associated with graft diameter in our study, while duration of injury was not used as a parameter. In a study by Rhatomy et al.,^[15] only five parameters (i.e., age, sex, height, weight, and BMI) were used, and all parameters except for age were found to be significantly correlated with intraoperative PLT measurements. In the present study, similar results were obtained. However, the sample size and number of parameters are larger in the present study. Sakti et al.^[16] also found that PLT autograft diameter could be predicted using the parameters of height, weight, true leg length and leg length, and they showed that the parameters of height, weight and true leg length were also associated with the length of the PLT autograft. However, their sample size was limited ($n=20$). In the present study, we found a statistically significant correlation between the PLT autograft

diameter and length and sex, weight, height, BMI, leg length, proximal leg diameter and distal leg diameter ($p < 0.01$). The parameter with the highest correlation coefficient for PLT autograft length was the height ($r = 0.982$). The parameter with the highest correlation coefficient for PLT autograft diameter was the distal leg diameter ($r = 0.956$). Among these parameters, the distal leg diameter was unable to be evaluated as a parameter in any study until the present study.^[23] This may be due to the fact that the vast majority of the non-muscular part of the PLT is located in the distal part of the leg.

There are many factors which affect the ACLR results, one of which is the diameter of the autograft used.^[5] A study showed that every 0.5-mm increase in the graft diameter reduces the need for revision by 0.82 times.^[24] In addition, the graft diameter should be at least 7 mm to reduce the risk of ACL re-rupture and minimize the need for revision.^[4] The smallest PLT autograft diameter in our study was 7 mm; all of these patients were females, accounting for only 11.5% of all patients.

The graft length is one of the most important components of ACLR. The insufficient graft length prevents strong fixation and increases the risk of revision.^[25] The length of the graft to be used must be at least 8 cm.^[26] Since the shortest PLT autograft length in the present study was 11.1 cm, no fixation problems were experienced. The PLT autograft provides a very long autograft and is, thus, advantageous compared to other autografts used in ACLR.

In our study, the PLT autograft diameter and length were found to be lower in women, compared to men. However, the effect of sex on graft measurements is still controversial.^[14] Pinherio et al.^[27] reported that female sex was associated with small graft dimensions. However, in another study, no significant relationship was found between sex and graft measurements.^[19] In the present study, the weight, height, BMI, leg length, and proximal and distal leg diameters differed between males and females. Since the number of women in our study was small (26.9%), we were unable to determine whether the smaller graft diameter in women was due to sex or another parameter.

One of the main limitations of the present study is its low number of female cases, which statistically limits the study. The second limitation is that duration of injury and activity levels of the patients were unable to be evaluated. During the time elapsed after injury, PLT may be atrophied and the patient's

activity level may also affect the PLT diameter and thickness. Nevertheless, this study can offer surgeons an alternative solution while making a preoperative autograft plan for ACLR and can be used to predict the dimensions of the PLT autograft to be selected.

In conclusion, anthropometric parameters of height, weight, BMI, leg length, and proximal and distal leg diameters may be helpful for surgeons to predict the diameter and length of the PLT autograft before surgery. Among these parameters, we believe that distal leg diameter is a particularly important parameter in estimating the autograft diameter. Although the results of this study are promising, further large-scale, long-term, prospective studies are needed to reach more accurate results.

Declaration of conflicting interests

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