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Original Article

Orthopaedics Section

Prediction of Semitendinosus Graft Length and Girth using Anthropometric Parameters: A Prospective Study in North Kerala Population

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ABSTRACT

Introduction: Semitendinosus, Gracilis and Bone-Patellar Tendon-Bone (BPTB) graft are the most popular grafts for Anterior Cruciate Ligament (ACL) reconstruction. Although bone-to-bone patellar tendon grafting improves knee stability and healing rates, there are drawbacks, including donor site morbidity, patellar tendinopathy, anterior knee pain, flexion contracture, and patellar fracture. The advantages of semitendinosus graft include preservation of bone stock, the ability to triple graft length when needed, and the ability to take Gracilis graft through the same incision, if graft diameter is too small.

Aim: To predict the semitendinosus graft length and diameter using anthropometric parameters (height, weight, Body Mass Index (BMI), waist circumference, thigh circumference and thigh length).

Materials and Methods: This prospective descriptive study was conducted in the Department of Orthopaedics, Malabar Medical College, Calicut, Kerala, India for a period of one year (from October 2021 to October 2022). A total of 50 patients in the age group 15-60 years with ACL insufficiency planned for hamstring autograft reconstruction were examined. A number of preoperative factors, including age, gender, height, weight, BMI, thigh length, thigh circumference and waist circumference were assessed. A 2-tailed test and Pearson's correlation was used to identify relationships between outcome variables (semitendinosus graft length and quadrupled tendon diameter) and predictor variables (age, gender, height, weight, BMI, thigh length, thigh circumference and waist circumference).

Results: A total of 32% of patients had a semitendinosus graft diameter ≥8 mm, while 68% were <8 mm. Compared to males, females had a lower body weight and height and their hamstring grafts were shorter with smaller diameter. Correlation analysis indicated that there was a significant positive relation between height and weight on graft length and diameter ($p<0.005$).

Conclusion: The study concluded that both hamstring diameter and length was related to height and weight of the person. Patients who were taller and heavier might be anticipated to have grafts with longer length and larger diameter. Also, thigh and waist parameters had no impact on hamstring tendon size.

Keywords: Anterior cruciate ligament, Bone-patellar tendon-bone graft, Hamstring graft

INTRODUCTION

For the reconstruction of the ACL, there are numerous graft choices available, including BPTB autograft, quadriceps tendon autograft, hamstring tendon autograft and various allograft sources. Prior to clinical use, it is important to weigh the pros and cons of each option. Hamstring graft usage has increased because of clinical studies showing comparable outcomes to BPTB reconstruction, less donor site morbidity, and better fixing techniques [1]. Other soft tissue reconstructions, that include extra-articular surgeries performed around the knee, elbow, and ankle, have shown to be effective when using hamstring tendon autograft [2,3]. The capacity to identify patients with hamstring tendons of inadequate length or diameter becomes essential as the usage of autograft hamstring tendons rises. To plan for alternate graft sources (such as patellar tendon autograft, quadriceps tendon, or other allograft sources) and to properly counsel patients on graft selection, it is necessary to identify these at-risk patients [4].

One of the excellent options for ACL reconstruction is semitendinosus graft. The muscle is named so, because its lower half is tendinous. The muscle takes origin from lower medial part of upper quadrilateral area of ischial tuberosity and is inserted into the upper part of medial surface of tibia. Supplied by tibial part of sciatic nerve it acts as a knee flexor and weak hip extensor along with other hamstring muscles [5]. Most used graft for ACL reconstruction is semitendinosus with or without gracilis and BPTB graft. Though, knee stability and healing rate is better with BPTB graft, it is associated with complication like donor site morbidity, knee extension stiffness, patellar tendinopathy, anterior knee pain, flexion contracture and patellar fracture. Semitendinosus graft have advantages like conservation of bone stock, when length of graft is insufficient with semitendinosus graft, it could be quadrupled or if diameter of graft is less, gracilis graft can also be taken through same incision [6]. Double bundle technique or quadrupled bundle technique may be applied using this tendon as a graft. Graft rupture and risk of failure is increased with the use of small diameter grafts [7]. The graft is harvested through a vertical para median incision at the level of tibial tubercle after exposing sartorial fascia through an 'L' shaped incision. Graft is harvested with the use of tendon stripper [8]. Gracilis tendons or doubled semitendinosus or even their combination has enough strength to replace the strength of an ACL. Collagen content is also more in hamstring tendons than in a BPTB graft. The quadruple hamstring tendon has a maximum strength of 1160 N, while the middle third of the 10 mm wide patellar ligament has a maximum strength of 1080 N. The triple hamstring tendon can be upto 250% stronger than a healthy ACL in laboratory settings [9].

In a study by Tuman JM et al., anthropometric information was used as a predictor of hamstring diameter and discovered that older, shorter, female patients were more likely to have a graft with an inadequate diameter. Following analysis of the data, the regression equation shown below was obtained from a moderate correlation between transplant diameter and patient height: Graft

diameter=2.4±0.03×height in cm [10]. Weight, BMI, self-reported height, and graft diameters were used in the study.

A study by Chiba D et al., hypothesised that further defining criteria predicting graft dimensions would need prospective study of these same values along with direct patient height measurement, the addition of thigh length and thigh circumference, and intraoperative assessment of hamstring lengths. They then used recent prospective data to verify the accuracy of the previously calculated regression equation in their latest literature [11]. Height, weight, BMI, waist circumference, thigh circumference and thigh length were used as anthropometric parameters for predicting graft size in the study. Not many studies have been conducted in Kerala, especially in North Malabar region regarding the same. Literature review suggests that graft smaller than 7 mm diameter have increased risk of failure [4]. It is essential to establish a minimum tendon length of 32 cm in order to ensure the ideal quadrupled hamstring graft length of 8 cm and 7 mm thickness (2 cm in the femoral tunnel, 4 cm intra-articular, and 2 cm in the tibial tunnel). The risk of obtaining a graft with a smaller diameter is one of the drawbacks of taking hamstring autograft. When such a situation arises during surgery, the surgeon might need to proceed with a different graft source and fixation method. Therefore, preoperative prediction of the thickness of the hamstring graft is crucial for the surgeon to arrange alternative fixation methods or graft choices [12]. Hence, it was decided to conduct a study for preoperative prediction of graft size so that operating surgeons will not face intraoperative difficulty because of smaller graft size.

The hypothesis was that the length and diameter of hamstring grafts and semitendinosus grafts used for ACL reconstruction can be predicted using clinically quantifiable anthropometric measurements.

MATERIALS AND METHODS

A prospective descriptive study was conducted in the Department of Orthopaedics, Malabar Medical College, Calicut, Kerala, India for a period of one year (from October 2021 to October 2022). A total of 50 consecutive patients with ACL insufficiency who underwent hamstring autograft reconstruction were examined. The study was approved from the Institution Ethical board with ethical clearance no: MMCH&RC/IEC/2021. Informed consent was obtained from all patients.

Inclusion criteria: All patients of the age group 15-60 years with clinico-radiologically confirmed ACL tear undergoing ACL reconstruction using semitendinosus graft were included in the study.

Exclusion criteria: Patients with preoperative hamstring weakness (neuromuscular disorders), acute tear (<4 weeks), multiligamentous knee injury, associated bony injury, prior ACL reconstruction of the same limb, septic arthritis were excluded from the study.

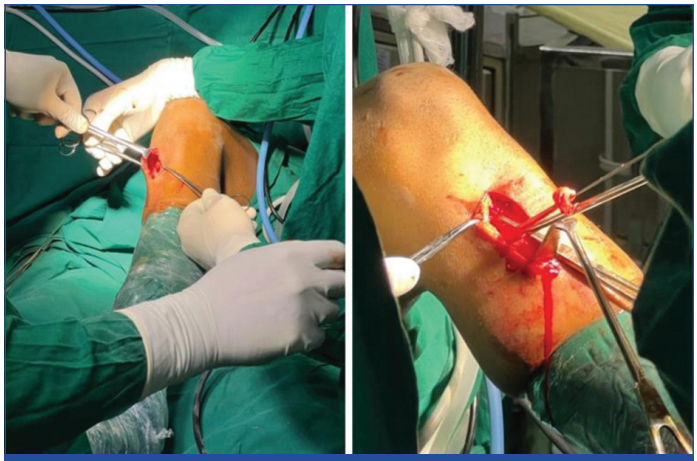
Sample size calculation: Sample size was calculated by hosmer and lameshow method [13].

$n=(z/\Delta)^2 \times p \times (1-p)$.

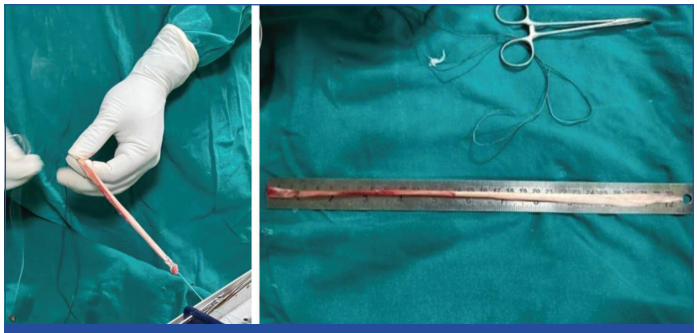
Using this test, sample size obtained was 50.

Study Procedure

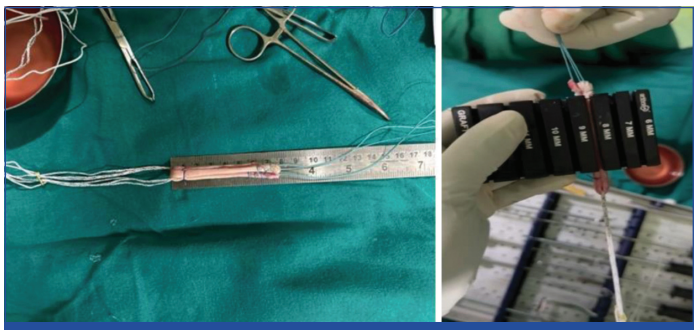
Several preoperative factors, namely age, gender, height, weight, BMI, thigh length, thigh circumference and waist circumference were included. The thigh length was measured from Anterior Superior Iliac Spine (ASIS) to the Medial Joint Line (MJL) and the thigh circumference from 15 cm above superior pole of patella. Surgical operation was performed by a single surgeon in all cases. All hamstring tendon autografts (semitendinosus) were extracted in the same way. An oblique incision was made on the skin over the pes-anserinus insertion site on proximal tibia and subcutaneous fat was incised [Table/Fig-1]. Incision of the sartorius fascia was made parallel to the direction of semitendinosus tendon. Semitendinosus tendon was dissected. Proximal attachment of the tendon was removed with a close tendon stripper [Table/Fig-2]. In order to preserve maximum length, the detachment of the tendon was done close to the bone on its tibial end. Graft preparation was done [Table/Fig-3]. Intraoperatively absolute length of semitendinosus graft and diameter of quadrupled tendon was measured using 1 mm calibrated scale [Table/Fig-4,5] and sizing cylinders with incremental size change of 0.5 mm [Table/Fig-6] [11].



[Table/Fig-1]: Oblique incision over the pes anserinus insertion site on proximal tibia.
[Table/Fig-2]: Extracting semitendinosus tendon. (Images from left to right)



[Table/Fig-3]: Semitendinosus graft preparation.
[Table/Fig-4]: Assessing semitendinosus tendon length. (Images from left to right)



[Table/Fig-5]: Quadrupled semitendinosus tendon length.
[Table/Fig-6]: Assessing semitendinosus tendon diameter. (Images from left to right)

STATISTICAL ANALYSIS

Single 2-tailed test and Pearson's correlation were used to identify relationships among anthropometric data and intraoperatively measured hamstring graft measurements using International Business Machines (IBM) Statistical Package for the Social Sciences (SPSS) version 25.0. Multiple linear regressions were used to calculate regression coefficients to determine variance explained between clinical predictor variables and outcome variables, that is, semitendinosus-graft length and diameter. Statistical results were considered significant at $p \leq 0.05$.

RESULTS

The demographic and predictor variables is shown in [Table/Fig-7]. Distribution of gender, side involvement and size of semitendinosus is shown in [Table/Fig-8]. A 2-tailed test and Pearson's coefficient correlation analysis indicated a significant positive relation between

Parameters	Mean±SD	Minimum	Maximum
Age (years)	26.88±8.13	16	57
Height (cm)	169.4±5.844	154	184
Weight (kg)	68.50±12.09	48	97
BMI (kg/m^2)	23.79±3.63	16.4	30.7
Waist circumference (cm)	79.28±12.85	60	104
Thigh circumference (cm)	45.97±7.75	31	69
Thigh length (cm)	54.76±3.84	47	67
Semitendinosus length (mm)	306.8±23.1	250	340
Semitendinosus diameter (mm)	8.03±0.71	6	9.5

[Table/Fig-7]: Distribution of predictor variables and outcome variables.

Parameters	n (%)
Gender	
Male	41 (82)
Female	9 (18)
Side	
Right	33 (66)
Left	17 (34)
Size	
>8 mm	16 (32)
<8 mm	34 (68)

[Table/Fig-8]: Showing distribution of gender, side involvement and size of Semitendinosus Graft (N=50).

height and weight on graft length and diameter (p<0.005) [Table/Fig-9]. Taller or heavier the patient, thicker was the tripled hamstring graft. However, gender, BMI, thigh length, thigh circumference and waist circumference did not correlate with graft length and thickness. Rule of thumb for interpreting size of a correlation coefficient has been provided in [Table/Fig-10]. Compared to males, females had a lower body weight and height and their hamstring grafts were shorter with smaller diameter.

DISCUSSION

The findings of the present study confirm the hypothesis that the length and diameter of semitendinosus grafts used for ACL reconstruction can be predicted using clinically quantifiable anthropometric parameters. It appears that height and weight are the best predictors for ST graft diameter. Even while hamstring grafts are still a common option for ACL restoration, the graft size requirements for a positive clinical outcome are still not well understood. In a biomechanical investigation, Hamner et al., showed that the number of tendon strands included in the graft increased the strength and stiffness of equally tensioned hamstring tendons [14]. These results show that the diameter of the graft influences the biomechanical characteristics of hamstring transplants [11]. Additionally, Grood et al., showed that anterior tibial translation had an inverse association with graft diameter in an animal model [15]. Clinical trials have not linked graft size to final knee stability, range of motion, or patient satisfaction, despite biomechanical data demonstrating that larger graft diameter leads in a stronger and stiffer construct.

Variables		Height (cm)	Weight (kg)	BMI (kg/m^2)	Waist circumference (cm)	Thigh circumference (cm)	ST length (mm)	ST diameter (mm)
Height	Pearson's correlation	1	0.449**	0.034	0.261	0.062	0.629**	0.312*
	Sig. (2-tailed)		0.001	0.813	0.068	0.668	<0.001	0.028
	N	50	50	50	50	50	50	50
Weight	Pearson's correlation	0.449**	1	0.906**	0.697**	0.608**	0.298*	0.298*
	Sig. (2-tailed)	0.001		<0.001	<0.001	<0.001	0.035	0.036
	N	50	50	50	50	50	50	50
BMI	Pearson's correlation	0.034	0.906**	1	0.652**	0.651**	0.041	0.165
	Sig. (2-tailed)	0.813	<0.001		<0.001	<0.001	0.777	0.252
	N	50	50	50	50	50	50	50
Waist circumference	Pearson's correlation	0.261	0.697**	0.652**	1	0.248	0.192	0.277
	Sig. (2-tailed)	0.068	<0.001	<0.001		0.083	0.183	0.051
	N	50	50	50	50	50	50	50
Thigh circumference	Pearson's correlation	0.062	0.608**	0.651**	0.248	1	0.145	0.140
	Sig. (2-tailed)	0.668	<0.001	<0.001	0.083		0.315	0.332
	N	50	50	50	50	50	50	50
ST length	Pearson's correlation	0.629**	0.298*	0.041	0.192	0.145	1	0.542**
	Sig. (2-tailed)	<0.001	0.035	0.777	0.183	0.315		<0.001
	N	50	50	50	50	50	50	50
ST diameter	Pearson's correlation	0.312*	0.298*	0.165	0.277	0.140	0.542**	1
	Sig. (2-tailed)	0.028	0.036	0.252	0.051	0.332	<0.001	
	N	50	50	50	50	50	50	50

[Table/Fig-9]: Correlation between anthropometric data and measured graft variables.
**Correlation is significant at the 0.01 level (2-tailed), *Correlation is significant at the 0.05 level (2-tailed). 2-Tailed test and Pearson's coefficient correlation test

Variables	ST length	ST diameter
Height (cm)	0.629**	0.312*
Weight (kg)	0.298*	0.298*
BMI (kg/m^2)	0.041	0.165
Waist circumference (cm)	0.192	0.277
Thigh circumference (cm)	0.145	0.140

[Table/Fig-10]: Rule of thumb for interpreting the size of correlation coefficients for relationships between intraoperative measurements and clinical data.
ST: Semitendinosus; BMI: Body mass index. *p<0.05, **p<0.01

The dimensions of the hamstring graft, which were measured and recorded at the time of the procedure, were compared to all anthropometric measurements that had been taken. These techniques enhanced the precision of hamstring size estimation and allowed for the study of numerous other characteristics. Both the diameter and length of the tendon could be measured. In the Western literature, the mean sizes of hamstring grafts range from 7.9 to 8.6 mm, and the results of this study showed the mean hamstring graft diameter as 8.03 mm. Most of the Western literature showed height as the best predictor among anthropometric data in hamstring graft size [4].

According to a study by Xie G et al., among Chinese Han population, a significant correlation was obtained between weight, height, and BMI of patients with the length and diameter of semitendinosus and gracilis grafts [16]. In contrast to the studies by Tuman JM et al., and Pinheiro LF et al., who established that BMI has no influence on graft diameter [10,17]. Treme G et al., in their study found a positive effect of BMI on graft diameter [11]. Pinheiro LF et al., in their study found that weight had less influence in graft diameter contrary to the study by Treme G et al. who observed the highest correlation with weight [11,17]. Finally in a study of 119 patients, Schwatzberg et al. observed moderate correlation between graft diameter and weight [18].

Pinheiro LF et al., in a study of 80 patients concluded that height is the most important variable that affects graft length the most [17]. Treme G et al., noted that hamstring tendon lengths had strong correlation with height and leg length [11]. In a study of 100 patients, Chiang ER et al., concluded that the patient's height is a predictor of both semitendinosus and Gracilis tendon lengths in Chinese population [19]. Height was found to be the most important variable, mainly in women according to the study by Tuman JM et al., [10]. Weak correlation to height was seen in the study done by Schwatzberg et al., [18].

Both hamstring diameter and length were found to be related to height and weight of the person. The results showed that patients who were taller and heavier, were anticipated to have grafts with longer length and larger diameter. It was interesting to note that neither waist circumference nor thigh length or circumference correlated to graft dimensions, indicating that thigh and waist parameters had no impact on hamstring tendon size. These results confirmed the study theory that hamstring measurements may be predicted using simple anthropometric measurements. The magnitude of the connections among the available data suggested that patient height followed by weight was the strongest predictor of graft diameter.

The need of predicting semitendinosus dimensions is highlighted by the usefulness of this tissue as a graft option. ACL reconstruction using quadrupled graft is its most popular application. In addition, some surgeons repair the ACL using a tripled semitendinosus graft. Both situations call for grafts that are the right length and diameter. Second, the significance of graft selection and size criteria have increased remarkably for preoperative planning because of increased research into double-bundle reconstruction and the development of new operating procedures. Finally, for additional periarticular reconstructive surgeries, hamstring tendons have proven to be a successful transplant option. Collateral ligament and posterolateral corner reconstruction in the knee have long utilised hamstring tendon grafts. Hamstring tendons are frequently used as grafts in reconstructive procedures for the elbow and ankle. The capacity of the surgeon to anticipate graft size and recognise patients who might have a tiny or insufficient graft will be more crucial as reconstructive procedures continue to advance [11].

The study had several merits. Firstly, the study was one of few that assessed the preoperative and intraoperative measurements in a practical environment. Secondly, since all surgeries were performed by a single surgeon at a single institute, there was the little chance for interobserver bias. It was noteworthy to mention that all the measurements were done in recommended standards and documentation was done with utmost care. This study strengthens the conclusions of earlier, nationally, and internationally published studies and describes the need of calculating hamstring graft size preoperatively.

Further research is needed to identify the physical characteristics of people with quadrupled hamstring graft diameters of <8 mm, in order to identify the clinical parameters that may be most predictive of this patient population. Identifying patients at a high-risk for having insufficient graft diameters by using a combination of anthropometric measurements and considering various relationships among clinical and operative data was taken into account. If the harvested hamstring graft is found to be insufficient for ACL reconstruction or other reconstructive procedures that use the patient's hamstring tendons as grafts, the surgeon can make plans for a second graft option, thanks to the current data.

Limitation(s)

If more patients were added, the anthropometric data may alter, and connections may not hold true at the extremes of the data continuum. For instance, the relationship between hamstring tendon diameter and weight in this study may not hold true if patients with extremely high weight were assessed. Other demerits included, small sample size, presence of confounders (like activity level, occupation, growth pattern, nutrition) etc., must have been considered when assessing the results. The ability to generalise the findings may be constrained because of small sample size who underwent surgery at a single facility, by a single surgeon.

CONCLUSION(S)

The findings of this study suggest that since shorter, lighter patients are more likely to yield a smaller graft, discussions about graft choice are crucial when considering ACL reconstruction in these patients. Height followed by weight of the patient has repeatedly shown to be of significance in predicting hamstring graft thickness. Patients at high-risk of having a quadrupled hamstring graft diameter <8 mm are those who weigh <62.5 kg and are shorter than 168.3 cm in height. It is not common for hamstring grafts to be <8 mm in diameter, and it is still challenging to identify these patients.

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