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# Factors predicting hamstring tendon autograft diameters and resulting failure rates after anterior cruciate ligament reconstruction

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**Abstract**
*Purpose* The purposes of this study are to confirm factors that affect the diameter of hamstring tendon autograft and to compare failure rates between the factors after anterior cruciate ligament (ACL) reconstruction.
*Methods* A total of 296 patients that underwent reconstruction using hamstring tendon autograft at our clinics for ACL injury between September 2005 and June 2008 were enrolled for this study. The diameters of gracilis and semitendinosus tendons (harvested from the affected knee) and four-strand graft tendon made by folding the gracilis and semitendinosus tendons in two layers were measured. Before operating, we recorded the age, height, weight, Body Mass Index (BMI), gender and athlete versus non-athlete identity of the subjects and checked their correlations with graft diameters. Patients that recorded a grade C or D on the International Knee Documentation Committee Knee Examination Form, as well as patients that underwent revision, were defined as failures and analysed by related factors.
*Results* The mean diameter was 1.5 mm ± 0.2 for gracilis tendon, 2.2 mm ± 0.3 for semitendinosus tendon and 7.2 mm ± 0.7 for graft tendon. Except for age, factors including height, weight, BMI, gender and athlete versus non-athlete identity were found to be significantly related to graft diameter. Correlation was strongest with height ($p < 0.001$). With respect to failure rates after ACL reconstruction, patients with a graft diameter of 8.0 mm or more demonstrated statistically better results than patients with a diameter of below 8.0 mm ($p = 0.043$). However, failure rates did not differ significantly with respect to other factors.
*Conclusions* The diameter of hamstring tendon autograft may be different depending on height, weight, BMI and gender of the patient, as well as whether or not the patient is an athlete. Although we did not find statistically significant differences in failure rates after ACL reconstruction, this study demonstrated relatively better results in patients with a graft diameter of 8.0 mm or more.
*Level of evidence* Case series, Level IV.

**Keywords** Diameter of hamstring tendon autograft · Related factors · ACL reconstruction · Failure rates

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## Introduction

There are multiple graft options for anterior cruciate ligament (ACL) reconstruction including bone-patellar tendon-bone (BPTB) autograft, quadriceps tendon autograft, hamstring tendon autograft and several allograft sources. Recently, the use of hamstring autograft has increased, due to similarly good results as another graft while also resulting in decreased donor site morbidity and improved fixation methods [10–12, 17]. However, the hamstring tendon does not always allow a graft with a wanted diameter, and sometimes, an excessively thin graft may be obtained [8]. As some fixation methods or devices can be used only when a graft tendon has a certain diameter or length and the strength of a graft tendon is related to its size [15], a graft tendon of inadequate diameter makes surgeons concerned over the strength and fixation method for the graft tendon during operation. Some studies have suggested a minimum graft tendon diameter of 7 mm to guarantee

good results in single-bundle reconstruction [15, 20]. Several authors have also performed studies to predict diameters of hamstring tendons before operating [5, 16, 34]. To our knowledge, however, there are no preoperative methods of accurately predicting hamstring tendon diameters. If such methods become available, the type or fixation method of a graft tendon can be changed when an inadequate diameter is predicted. In addition, donor site complications that result from excessive harvesting of hamstring tendons may be prevented. It is known that the muscle strength of hamstring tendons remains weakened until 9 months after an operation [35].

Some studies demonstrated that the strength of a graft tendon was related to size [15] and that the smaller the size of the tendon, the greater the likelihood of a weaker and more unstable graft tendon [21]. However, there is a lack of information as to whether a graft tendon of an inadequate diameter shows poorer clinical results after ACL reconstruction or increases the risk of retear. To date, no reports have shown any correlation between the diameter of hamstring tendon autograft in four strands and clinical results after ACL reconstruction.

This study has two purposes. First is to identify related factors by measuring the diameter of hamstring tendon autograft and relate it to the age, height, weight, Body Mass Index (BMI), gender and athlete versus non-athlete identity of the subjects. Second is to analyse clinical results of ACL reconstruction and compare failure rates based on the diameter of hamstring tendon autograft and related factors. In this regard, we hypothesized that the diameter of hamstring tendon autograft would be related to age, height, weight, BMI, gender and athlete versus non-athlete identity, but that this would not affect clinical results and failure rates.

## Materials and methods

Among 435 patients that underwent reconstructions using hamstring tendon autograft for ACL injury between September 2005 and June 2008 at our clinics, we excluded those with fractures, associated ligament injury, multiple ligament injury or meniscus transplantation in the affected side, as well as patients that underwent revision or those with associated injury in the unaffected knee. This left us with 310 patients available for the measurement of hamstring tendon diameters. To prevent any differences in results caused by the operative technique applied, we excluded 13 patients that underwent double-bundle reconstruction and one patient that used EndoButton CL® (Smith & Nephew, Andover, MA, USA) to fix the femoral region. As a result, the remaining 296 patients that underwent single-bundle reconstruction were enrolled for this study and were followed for a minimum of 2 years.

### Measurement of graft diameters

Both gracilis and semitendinosus tendons were harvested from all the knees by a single surgeon. From the harvested tendons, the muscle tissue and synovium were removed. Without any suture or alteration being applied, each tendon was then passed through a tube-shaped sizing device (Acufex, Smith & Nephew, Norwood, MA, USA) calibrated to 0.5 mm. The smallest diameter of the device through which a tendon passed was defined as the diameter of that tendon. As the measurement of the length of a tendon could have a large margin of error and could be affected by the harvesting technique used, we focused instead on the diameter of a graft tendon. Placing the gracilis tendon medially, gracilis and semitendinosus tendons, respectively, were folded to make four strands. In a similar manner, the diameter of a four-strand graft tendon was measured. The age, height, weight, BMI, gender and athlete versus non-athlete identity of the patients were recorded preoperatively, and their correlation with tendon diameters was analysed. Both professionals and elite amateurs were defined as athletes, while those who only exercised for leisure or as a hobby were not considered athletes. In each patient, we recorded meniscal tear and cartilage defects.

### Clinical assessment

At the last follow-up, each item on the International Knee Documentation Committee (IKDC) Knee Examination Form was measured to record a grade. The lowest recorded grade among them was defined as the final IKDC grade of the patient. Patients recording an IKDC grade C or D, or patients that underwent revision, were considered failures. Patients were classified by hamstring tendon autograft diameters and related factors to analyse respective failure rates.

### Operative technique

All operations were performed by the same surgeon. The harvested autogenous hamstring tendon was shaped like a tube using the baseball whip stitch method with No. 2 Ethibond sutures and then folded into two layers. The tibial tunnel was placed at the centre of the ACL footprint, and the femoral tunnel was located in the direction of half past 10 for the right knee (and in the direction of half past one for the left knee). For all operations, a transtibial technique was applied. Bioabsorbable cross pins (Rigid Fix® cross pin system, Mitek, Johnson & Johnson, USA) were used to fix the graft tendon to the femoral side. To fix the tendon to the tibial side, the knee was exercised 20–30 times from 0 to 100 degrees to provide sufficient preloading. Then, with the knee extended, impingement between the graft tendon and the intercondylar notch of the femur was checked.

Using cancellous screws and a spiked washer or a staple, the graft tendon was fixed with the knee flexed at an angle of 30 degrees and double fixed with a bioabsorbable interference screw suitable for the tunnel diameter.

### Statistical analysis

Statistical measurements were indicated in the mean ± SD. SPSS software (version 12.0, SPSS Inc, Chicago, IL, USA) was used. Correlations between hamstring tendon diameters and related factors were analysed with the bivariate correlation coefficient (Pearson $r$) and the independent samples $t$ test. The differences in failure rates of the patients, classified by diameters and related factors, were analysed with the Pearson's chi-square test. A value of $p < 0.05$ was considered statistically significant.

## Results

### Diameter of hamstring tendon autograft

The mean gracilis tendon diameter was 1.5 mm ± 0.2. The mean semitendinosus tendon diameter was 2.2 mm ± 0.3. The mean four-strand graft diameter was 7.2 mm ± 0.7. One patient had a diameter of 4.5 mm (0.3 %); four patients, 5.5 mm (1.3 %); 26 patients, 6.0 mm (8.4 %); 50 patients, 6.5 mm (16.1 %); 71 patients, 7.0 mm (22.9 %); 86 patients, 7.5 mm (27.7 %); 49 patients, 8.0 mm (15.8 %); 19 patients, 8.5 mm (6.1 %); three patients, 9.0 mm (0.9 %); and one patient, 10.0 mm (0.3 %). The most common diameter measurement, therefore, was 7.5 mm, followed by 7.0 mm (Table 1).

### Related factors

The mean values and range of related factors of the 310 cases are described in Table 1. And correlation between graft diameter and related factors is described in Table 2.

**Table 1** Graft diameter and related factors

| | Result |
|---|---|
| Gracilis diameter (mm) (range) | 1.5 ± 0.2 (1.0–2.5) |
| Semitendinosus diameter (mm) (range) | 2.2 ± 0.3 (1.5–3.0) |
| Four-strand graft diameter (mm) (range) | 7.2 ± 0.7 (4.5–10.0) |
| Age (year) (range) | 29.8 ± 10.7 (14–61) |
| Height (cm) (range) | 171.3 ± 7.6 (152–195) |
| Weight (Kg) (range) | 72.1 ± 12.2 (45–119) |
| BMI (range) | 24.5 ± 3.3 (15.0–36.3) |
| Gender (M:F) | 246:64 |
| Athlete or not (Athlete/non-athlete) | 33:277 |

**Table 2** Correlation coefficients for relationships between graft diameter and related factors

| | Gracilis diameter | Semitendinosus diameter | Four-strand graft diameter |
|---|---|---|---|
| Age | −0.001 | −0.161[a] | −0.107 |
| Height | 0.273[a] | 0.436[a] | 0.477[a] |
| Weight | 0.259[a] | 0.365[a] | 0.427[a] |
| BMI | 0.156[a] | 0.177[a] | 0.230[a] |
| Gender | −0.319[a] | −0.315[a] | −0.432[a] |
| Athlete or not | 0.165[a] | 0.153[a] | 0.217[a] |

[a] $p < 0.05$

**Table 3** IKDC grade and failure rates

| | A | B | C | D |
|---|---|---|---|---|
| IKDC grade (cases) (%) | 116 (39.2 %) | 169 (57.1 %) | 11 (3.7 %) | 0 (0.0 %) |
| Revision (cases) (%) | 1 (0.3 %) | | | |
| Total failure (cases) (%) | 12 (4.0 %) | | | |

Gracilis diameters demonstrated the strongest associations with gender ($r = -0.319$), while semitendinosus and four-strand graft diameters had the strongest associations with height ($r = 0.436$, $r = 0.477$, respectively) (Table 2).

### Clinical results

The mean follow-up period was 53.9 ± 8.8 months (ranging from 24.0 to 70.8 months). The IKDC grade at the last follow-up is described in Table 3. Revision was performed in one patient that had a retear caused by trauma. The characteristics of the patient are described in Table 4 (case 11). He suffered an injury at 2 years and 9 months while exercising and had to undergo revised ACL reconstruction for the retear. Final failure was observed in 12 patients (4.0 %): this included one patient (0.3 %) that underwent revision and 11 patients (3.7 %) that recorded an IKDC grade C (Table 3). Details of the 12 failed patients are described in Table 4.

### Related factors and failure rate

The relationships between related factors and failure rates are described in Table 5. We divided the patients into the groups by mean values of related factors. Especially in graft diameter, we analysed every 0.5-mm graft size from 5 mm to 9.5 mm. But, statistically significant differences were not observed except where patients were classified as below 8.0 mm and as 8.0 mm or over ($p = 0.043$)

**Table 4** Demographics of failure cases

| Cases | Age (yr) | Height (cm) | Weight (Kg) | BMI | Gender | Athlete or not | Gracilis diameter (mm) | SemiT diameter (mm) | Four-strand graft diameter (mm) |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 22 | 161.3 | 59.0 | 22.7 | F | No | 1.5 | 2.0 | 6.0 |
| 2 | 18 | 156.0 | 63.0 | 25.9 | F | Yes (Handball[a]) | 1.0 | 2.0 | 6.0 |
| 3 | 21 | 163.0 | 64.0 | 24.1 | F | Yes (Judo[a]) | 1.5 | 2.0 | 6.5 |
| 4 | 19 | 175.0 | 65.0 | 21.2 | M | No | 1.5 | 2.0 | 6.5 |
| 5 | 48 | 152.0 | 55.0 | 23.8 | F | No | 1.5 | 2.0 | 7.0 |
| 6 | 39 | 175.0 | 75.0 | 24.5 | M | No | 1.5 | 2.0 | 7.0 |
| 7 | 39 | 177.0 | 80.0 | 25.5 | M | No | 1.5 | 2.0 | 7.0 |
| 8 | 17 | 175.0 | 58.0 | 18.9 | M | No | 1.0 | 2.5 | 7.0 |
| 9 | 21 | 170.0 | 62.0 | 21.5 | M | No | 1.5 | 2.0 | 7.0 |
| 10 | 35 | 179.0 | 64.0 | 20.0 | M | No | 1.5 | 2.5 | 7.5 |
| 11[b] | 23 | 165.0 | 62.5 | 23.0 | M | Yes (Gymnastics[a]) | 1.5 | 2.0 | 7.5 |
| 12 | 21 | 185.0 | 80.0 | 23.4 | M | No | 1.5 | 2.5 | 7.5 |

*SemiT* semitendinosus, *BMI* body mass index

[a] Professional athlete

[b] Revision case due to retrauma

**Table 5** Related factors and failure rates

| | Failure (cases) (%) | *p* value |
|---|---|---|
| Age (<30:≥30) (year) | 8 (4.9 %):4 (3.0 %) | NS |
| Height (<171.5:≥171.5) (cm) | 6 (4.3 %):6 (3.8 %) | NS |
| Weight (<72:≥72) (Kg) | 9 (6.0 %):3 (2.1 %) | NS |
| BMI (<24.4:≥24.4) | 9 (5.6 %):3 (2.2 %) | NS |
| Gender (M:F) | 8 (3.4 %):4 (6.4 %) | NS |
| Athlete or not (Athlete/non-athlete) | 3 (10.7 %):9 (3.3 %) | NS |
| Graft diameter (<7.5:≥7.5) (mm) | 9 (6.0 %):3 (2.0 %) | NS |
| Graft diameter (<8.0:≥8.0) (mm) | 12 (5.2 %):0 (0.0 %) | $p < 0.05$ |

*NS* not significant

**Table 6** Combined injuries and treatments

| | Failure group (12 cases) | Non-failure group (284 cases) | *p* value |
|---|---|---|---|
| Medial meniscus | 7 (58.3 %) | 152 (53.5 %) | NS |
| Meniscectomy | 4 (33.3 %) | 82 (28.9 %) | NS |
| Repair | 3 (25.0 %) | 70 (24.6 %) | NS |
| Lateral meniscus | 5 (41.7 %) | 119 (41.9 %) | NS |
| Meniscectomy | 1 (8.3 %) | 32 (11.3 %) | NS |
| Repair | 4 (33.3 %) | 87 (30.6 %) | NS |
| Chondral defect | 3 (25.0 %) | 65 (22.9 %) | NS |
| Microfracture | 0 (0.0 %) | 4 (1.4 %) | NS |
| Observation | 3 (25.0 %) | 61 (21.5 %) | NS |

*NS* not significant

(Table 5). In another related factors, there were no statistically significant differences between the groups in failure rates (Table 5).

## Combined injuries

The combined injuries (meniscus tears and chondral defects) of all patients are described in Table 6. In patients of meniscal tear, a meniscectomy or meniscal repair was performed. Patients with a cartilage injury recording a magnitude Grade IV on the International Cartilage Repair Society (ICRS) scale, on an area greater than 1 $cm^2$ and surrounded by the normal cartilage, were treated by microfracture, and those with overall erosion of the cartilage were excluded. In the remaining patients, clinical courses were monitored. There was no difference between the groups (Table 6).

## Complication

Post-operative complications included severe swelling in one patient and limited range of motion in the joint in three patients. The single patient of severe oedema was successfully treated post-operatively at 6 weeks with arthroscopic irrigation. For the three patients with limited range of motion, arthroscopic adhesiolysis was performed on two patients and brisement on one patient, all post-operatively at 5 months. At the last follow-up, all the patients showed the normal range of motion.

## Discussion

The most important finding of the present study was that the four-strand graft diameter was related to height, weight, BMI, gender and athlete or not, but its associations with failure rates would not be statistically significant. The gracilis tendon diameters were related to factors such as height, weight, BMI, gender and athlete versus non-athlete identity, but not to age. Semitendinosus tendon diameters had correlations with all these factors, and four-strand graft diameters had correlations with everything but age. In addition, 12 patients were categorized as failures—11 of them recorded an IKDC grade C, and the other one underwent revision for retear of the graft tendon. When the patients were divided into two groups according to graft diameter, age, height, weight, BMI, gender and athlete versus non-athlete identity, no statistically significant differences were found to exist between the groups. However, patients with a graft tendon of 8.0 mm or over in diameter did not experience any failure. There were statistically significant differences between the groups whose graft tendons were less than 8.0 mm in diameter and other groups whose graft tendons measured 8.0 mm or more in diameter ($p = 0.043$). In this study, we hypothesized that the diameter of an autogenous hamstring tendon would be related to age, height, weight, BMI, gender and athlete versus non-athlete identity, but its associations with clinical results and incidence of retear would not be statistically significant. The results of this study supported part of our hypothesis.

Studies on autogenous hamstring tendon diameters and related factors are limited. Tuman et al. [33] investigated the diameter of quadrupled hamstring tendon autograft and related factors in 106 patients and found correlations with height, weight, age and gender but not with BMI. They reported that height had the strongest correlations with the diameter of hamstring tendon autograft. Treme et al. [32] studied 50 patients and described correlations with weight, BMI, thigh circumference, gender and height, finding the strongest correlations with weight and thigh circumference. In another study of 119 patients, Schwartzberg et al. [25] discovered that among gender, weight, height and length of leg, correlations existed most strongly with weight and length of leg. In our series, height, weight, BMI, gender and athlete versus non-athlete identity were all related, most strongly with height ($r = 0.477$), followed by gender ($r = -0.432$) and weight ($r = 0.427$). Results were similar to those of previous studies. Moreover, while previous studies analysed about 100 patients, our study targeted over 300 patients, and this increases the reliability of our results.

Studies that discuss the diameter of hamstring tendon autograft, its related factors and failure after ACL reconstruction are rare. Only a few studies reporting results relating to gender, age and athletic inclination can be found. Corry et al. [9] performed single-bundle ACL reconstruction and described a difference in laxity between male and female patients for the first time. They reported that female patients who underwent hamstring tendon autograft showed the greatest laxity. Since then, several authors have found worse results with female patients than with male patients [14, 19, 24]. Recently, however, Tohyama et al. [31] performed anatomic double-bundle ACL reconstruction using hamstring tendon autograft and noted that the diameter of hamstring tendon autograft was significantly smaller in female patients, but that clinical results and knee stability between male and female patients were not found to be different. They cited the importance of anatomic reconstruction for results that differed from those of previous studies, pointing out that because the difference in the diameter of hamstring tendon autograft between male and female patients reflected the size of the knee joint itself, small graft diameter should not be understood to be the reason for increased instability. This study also did not demonstrate statistically significant differences between male and female patients ($p > 0.05$). When patients were divided by the diameter of four-strand graft into those of below 7.5 mm (Group 1, 149 patients) and those of 7.5 mm or more (Group 2, 147 patients), no statistically significant differences were found to exist between the two groups ($p > 0.05$). In particular, there were no statistically significant differences between the group with a diameter of below 6.0 mm and another group with a diameter of 6.0 mm or more ($p > 0.05$). None of the four patients with diameters of 5.5 mm experienced failure. In the patient with the smallest diameter, of 4.5 mm, we fixed the femoral side with EndoButton CL® (Smith & Nephew, Andover, MA, USA) and excluded the patient from the analysis of clinical results to prevent any differences from arising based on surgical techniques. However, even this patient showed satisfactory results with IKDC grade B. Such results coincided with the results of Tohyama et al. [31] who insisted that a small graft diameter did not always increase instability and a risk of retear. Unlike them, we performed single-bundle ACL reconstruction, but at locations anatomically close to the original ACL. In addition, we did not observe any failure in patients with diameters of 8.0 mm or over, which was a statistically significant result ($p = 0.043$). Therefore, we concluded that small graft diameter did not necessarily increase instability and the risk of retear, but we did note that a diameter of 8.0 mm or more was expected to provide better results.

Several factors such as the type of graft, gender, age, activity level and initial injury mechanism are involved to produce successful results of ACL reconstruction [4, 18, 23, 24, 30]. Some studies have considered age and activity level as important factors affecting reconstruction results [4, 6, 18, 26].

In a study that compared results of ACL reconstruction by age, Brandsson et al. [7] reported no differences in recurrence of instability between patients older than 40 years of age and patients aged 20–24 years. Barber et al. [2] also compared patients under 40 years of age with those aged over 40 and observed no differences. In a review of related literature, Sloane et al. [28] could not find any differences in results by age. In contrast, Barrett et al. [3] reported a statistically higher failure rate in patients under 25 years of age (16.5 %) than in those older than 25 years of age (8.3 %). They attributed the result to the significantly high incidence of re-injury and Tegner activity scores among patients under 25 years of age. However, their study included bone-patellar tendon-bone autograft, hamstring tendon autograft and allograft (tibialis posterior tendon and patellar tendon), and failure rates varied according to the type of graft used. In our series, no statistically significant differences were found in terms of age ($p = 0.464$). The results coincided with the results of other studies. The reason our results were different from those of Barret et al. [3] was probably because we only used hamstring tendon autograft.

Activity level after ACL reconstruction plays an important role in the failure rate [22]. Theoretically, a higher level of activity may negatively affect reconstruction results. In a study analysing 21 failed patients after ACL reconstruction, Borchers et al. [6] observed a very high ratio of 5.53 in patients who maintained a high level of activity after their operation. As described earlier, Barret et al. [3] also confirmed significantly high Tegner activity scores in patients that showed high failure rates. To our knowledge, no reports have directly compared results of ACL reconstruction between athletes and non-athletes. In our series, failure was observed in three out of 28 athletes (10.7 %) and nine out of 268 non-athletes (3.4 %). The failure rate was higher in athletes, but the difference was not statistically significant ($p = 0.151$). George et al. [13] attributed failure after 1 year from ACL reconstruction mainly to trauma. We performed revision for a retear on one patient, a professional gymnast who suffered injury while exercising more than two years after their operation. Before the recurrence of an injury, the patient had recorded IKDC grade A, having returned to their professional gymnastics training. When compared with non-athletes, athletes are more exposed to the likelihood of repetitive chronic or severe trauma. This may explain why failure rates, although statistically insignificant, were higher among athletes. In our series, the number of athletes was relatively small compared to the number of non-athletes, and this may have resulted in a statistical error. For more accurate results, therefore, comparison and analysis of groups with larger sample sizes are considered necessary.

In this study, its associations between the related factors and the failure rates would not be statistically significant. This may be because clinical results of ACL reconstruction are determined not by one single factor but by the combination of several factors.

Our study has some limitations. First, the follow-up period was relatively short with a minimum of just 2 years. A long-term follow-up period is considered necessary. Second, hamstring tendon autograft diameters were measured in units of 0.5 mm, which may have caused errors in measurement. However, as the diameter of the tunnel during ACL reconstruction was also measured in units of 0.5 mm, its impact on clinical results was expected to be limited. In later studies, a more accurate measurement method will be required. Third, graft diameters may have been affected by the harvesting technique used. In this study, however, all graft tendons were harvested by a single skilful surgeon to minimize such errors. Fourth, patients with IKDC grade C or D, or those who required revision, were defined as failures in this study, but results may vary depending on how failure is defined. The failure rate based on our definition in this study was 4 %, similar to the rate reported by other authors [13, 29]. The definition of graft failure varies from author to author. Noojin et al. [19], for instance, defined failure as a 2+ Lachman result, a 1+ or greater pivot shift test result, or a greater than 5-mm side-to-side difference with KT-1000 knee ligament arthrometer testing. For Aglietti et al. [1], arthrometer differences of greater than 5 mm and a positive pivot shift test result were the criteria for determining failure. In addition, Sigel and Barber-Westin [27] considered KT-1000 knee ligament arthrometer differences of greater than 5.5 mm or a 2+ pivot shift result as proof of graft failure. The IKDC grade that we applied to this study was a stricter criterion as it evaluated not only instability but also effusion, joint range of motion, ligament stability and radiographic findings.

In spite of the above limitations, this study has several strong points. First, hamstring tendon autograft diameters were measured in a relatively large sample size and then analysed by age, height, weight, BMI, gender and athlete versus non-athlete identity to measure correlations. Second, harvesting of the hamstring tendon autograft and measurement of its diameter were done by a single experienced surgeon to minimize differences that might have resulted from the harvesting and measurement process. Moreover, ACL reconstruction was also performed by the same surgeon to prevent errors arising from different operative techniques. Third, to prevent any differences in results, we chose single-bundle reconstruction as an operative technique, hamstring tendon autograft as the type of graft and the same fixation method across the patients. Fourth, we did not simply confirm the factors affecting

graft diameters but went further by checking clinical results of ACL reconstruction and comparing failure rates for each related factor. To our knowledge, no reports have until now compared graft diameters with failure rates after ACL reconstruction.

Hamstring tendon autograft does not always allow a graft with a wanted diameter, and sometimes, an excessively thin graft may be obtained. Especially in Asian peoples, hamstring tendon diameter is smaller than western people. But we could not find statistically significant differences in failure rates after ACL reconstruction depending on the diameter of graft in this study. So we would not have to worry about it seems somewhat.

## Conclusions

Hamstring tendon autograft diameters may differ depending on the height, weight, BMI and gender of the patient, and on whether the patient is an athlete or not. Although we did not find statistically significant differences in failure rates after ACL reconstruction, our study demonstrated relatively better results in patients with a graft diameter of 8.0 mm or over.

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