

# Relationship Between Anthropometric Measurements and Hamstring Autograft Diameter in Anterior Cruciate Ligament Reconstruction

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## Abstract

The role of anthropometric measurements in the prediction of hamstring autograft size remains unclear. In this internal review board–approved study, we evaluated medical records for patients receiving anterior cruciate ligament (ACL) reconstruction with hamstring autograft at our institution between 2006 and 2008. One hundred and thirty-two patients received hamstring autografts. Correlation coefficients and step-wise multiple linear regression analysis were used to determine the relationships between sex, age, height, body mass index (BMI), and hamstring graft diameter. Women had significantly smaller grafts than men ( $P < .00001$ ). Twenty-four patients had grafts less than 7 mm in diameter and 18 of those patients were female. Age and BMI did not correlate with graft diameter in women. Height correlated to graft diameter in women ( $P = .002$ ,  $R^2 = 0.14$ ). Women shorter than 65 in had significantly smaller graft diameters (mean [SD], 6.94 [0.45] mm), than those women 65 in and taller (mean [SD], 7.20 [0.49] mm; ( $P = .03$ ). Age and height did not correlate with graft size in men. BMI greater than 25 kg/m<sup>2</sup> correlated with larger graft diameter, but BMI less than 18 kg/m<sup>2</sup> did not predict graft sizes less than 7 mm. Therefore, alternative graft options should be considered in women less than 65 in tall.

There are numerous graft options for reconstructing the anterior cruciate ligament (ACL). Although bone–patellar tendon–bone autograft has rigid fixation and provides bone-to-bone healing, it has the disadvantage of donor site morbidity, with anterior knee pain among the most common complications.<sup>1-4</sup> The “quadrupled hamstring autograft”

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is obtained by harvesting the semitendinosus and the gracilis tendons at the pes anserinus and then folding them over twice to create 4 strands.<sup>1,3,5</sup> Use of hamstring autograft for ACL repair has postoperative outcomes similar to those of patellar bone–tendon–bone repairs but without the associated donor site morbidity.<sup>1-6</sup> Prevention of rerupture, however, involves using a graft that is significantly stronger than the native ACL, and graft strength has been found to be directly related to the cross-sectional area of the graft.<sup>7,8</sup> Occasionally, harvested grafts are found to be of unacceptable size for use in reconstruction. Recent studies have attempted to identify anthropometric measurements that could be used before surgery to identify patients for whom graft size would be a problem, so that unnecessary harvest can be prevented and an alternative method of graft reconstruction planned.<sup>6,8-11</sup> Although results vary in this area, the one finding that has consistently correlated with graft diameter in all studies is measured height, though this too has varied.<sup>6,8,10,11</sup>

We conducted this retrospective study of 132 patients to test the validity of the findings of previous studies and to provide a definitive statement about which anthropometric measurements, if any, can predict hamstring autograft diameter in ACL reconstruction.

## METHODS

Institutional review board approval was obtained before this study was initiated. Using the billing code for ACL reconstruction, we identified 478 patients who had undergone this procedure between 2006 and 2008. Of those, 158 were scheduled to undergo quadrupled hamstring autograft reconstruction. Patients older than age 30 were excluded ( $n = 7$ ), leaving 151 patients for review. Of these 151 patients, 19 were converted to allograft during surgery and, therefore, eliminated from the study. The medical records of the remaining 132 patients were reviewed to identify patient sex, age, height, body mass index (BMI), and diameter of harvested autograft. All grafts were harvested by 1 of 3 sports medicine fellowship–trained orthopedic surgeons. During surgery, the diameter of the quadrupled hamstring graft was measured with a cylindrical sizing guide (Arthrex, Naples, Florida) calibrated to 0.5 mm. Correlation coefficients and stepwise multiple

**Table. Number and Percentage of Patients With Each Hamstring Graft Diameter**

Graft Diameter, mm	No. (%) of Patients
6	1 (0.76)
6.5	23 (17.42)
7	38 (28.79)
7.5	29 (21.97)
8	33 (25.00)
8.5	6 (4.55)
9	2 (1.52)

linear regression analysis were used to determine the relationships among sex, age, height, BMI, and hamstring graft diameter.

## RESULTS

This study evaluated 132 patients: 68 men (52%) and 64 women (48%). Mean age was 17.9 years. Mean height was 68 in (range, 60-71 in for women; range, 62-76 in for men). Mean BMI was 24.7 kg/m<sup>2</sup>. Regression analysis of the 132 patients who received quadrupled hamstring autografts showed that age was not related to graft diameter in the group as a whole ( $P = .46$ ), or on separate analysis based on sex. For men, mean (SD) graft diameter was 7.64 (0.62) mm (range, 6-9 mm); for women, the mean was 7.07 (0.49) mm (range, 6-8 mm) ( $P < .00001$ ) (Table). Twenty-eight percent of the female patients had graft diameters of less than 7 mm. There was a significant correlation of larger BMI with larger graft diameter ( $P < .0001$ ,  $R^2 = 0.12$ ), but analysis based on sex showed that this correlation was true only for men ( $P = .034$ ,  $R^2 = 0.067$ ). Patient height correlated with graft diameter ( $P < .0001$ ,  $R^2 = 0.17$ ) but, on sex-specific analysis, only in the female patients ( $P = .002$ ,  $R^2 = 0.14$ ). Female patients shorter than 65 in had significantly ( $P = .03$ ) smaller graft diameters (mean [SD], 6.94 [0.45] mm) than female patients 65 in or taller (mean [SD], 7.20 [0.49] mm). Of the 24 patients with graft diameters of less than 7 mm, 18 were female and 6 were male (Table). Twelve (average BMI 22.15 kg/m<sup>2</sup>) of these 18 women were shorter than 65 in, and 5 of the 6 men were 71 in or taller and had an average BMI of 25 kg/m<sup>2</sup>.

## DISCUSSION

This study provides an analysis of previous studies in this field and furthers the knowledge of predicting quadrupled hamstring graft diameter. The first area evaluated was correlation of patient age at time of surgery with graft diameter. All the patients evaluated in this study were aged 30 years or younger at the time of surgery. In this young cohort, age did not correlate with graft diameter. Pichler and colleagues<sup>6</sup> also found that age did not correlate with diameter, but the cohort in their study was older (mean age, 71.5 years). Despite that finding, other investigators, including Ma and colleagues,<sup>8</sup> Schwartzberg and colleagues,<sup>9</sup> and Treme and colleagues,<sup>10</sup> have consistently found that age is not related to graft size. Our results con-

firm their findings but, because of the young age of our study patients, it is difficult to fully assess the importance of age in this study.

Sex significantly correlated with graft diameter. Mean graft diameter was smaller for the women (7.07 mm) than for the men (7.64 mm) ( $P < .00001$ ). This has been found reliably in the studies conducted by Treme and colleagues<sup>10</sup> and Tuman and colleagues.<sup>11</sup> Ma and colleagues<sup>8</sup> found that 42% of their female patients had tunnel diameters of 7 mm or less. However, they used graft sizers in 1-mm increments to measure femoral tunnel diameters, whereas we measured quadrupled hamstring grafts sized to 0.5 mm.<sup>8</sup> Although the majority of our study patients (18/24, or 75%) with graft diameter of less than 7 mm were women, the overall percentage of women with graft diameter of less than 7 mm was 28%, significantly less than the percentage found by Ma and colleagues. Therefore, our results indicate that women are more likely than men to have smaller graft diameters. This information alone, however, is not sufficient for predicting graft diameter.

Mean BMI (23.25 kg/m<sup>2</sup>; range, 18.2-31.0 kg/m<sup>2</sup>) did not correlate with graft size in our female patients. In the male patients (mean BMI, 26.07 kg/m<sup>2</sup>; range, 17.2-34.0 kg/m<sup>2</sup>), however, those with BMI greater than 25 kg/m<sup>2</sup> had larger grafts ( $P < .0001$ ,  $R^2 = 0.12$ ). In their prospective study, Treme and colleagues<sup>10</sup> evaluated 50 patients and concluded that those with BMI less than 18 kg/m<sup>2</sup> were at risk for grafts less than 7 mm; however, BMI of less than 18 kg/m<sup>2</sup> did not predict the 24 patients who had graft diameters of less than 7 mm. We had 1 patient with BMI less than 18 kg/m<sup>2</sup>, but this patient did not have a graft diameter of less than 7 mm. Our findings suggest that low BMI may not predict a graft of insufficient size, but larger BMI may predict a larger graft in men. The conflicting results of BMI in predicting graft diameter may arise from the inability of BMI to distinguish between lean muscle and fat. Tuman and colleagues<sup>11</sup> showed that BMI should not be used as an indicator of graft diameter. Therefore, we suggest that BMI is of limited use in predicting graft diameter, as larger BMI may be used to predict larger graft sizes in men but is not predictive in women.

Finally, we found that height was significantly ( $P < .0001$ ) related to graft diameter. However, on sex-specific analysis, height correlated with graft diameter only in the female patients. Tuman and colleagues<sup>11</sup> also found that height was predictive and suggested a general rule that height less than 58 in was predictive of graft diameter less than 7 mm. The prospective follow-up study by Treme and colleagues<sup>10</sup> further narrowed those restrictions to a height less than 55 in. Our study also found that decreased height was associated with smaller graft diameters; however, none of our patients was shorter than 68 in, so we were unable to apply the findings of Treme and colleagues<sup>10</sup> or Tuman and colleagues<sup>11</sup> to our study. In our taller study population,

women shorter than 65 in were at highest risk for graft diameters less than 7 mm. Two thirds of the women (12/18) with graft diameters less than 7 mm were less than 65 in, excluding 1 female outlier who was 71 in. Ma and colleagues<sup>8</sup> also found that height was significant in determining graft diameter, except they found that height correlated with graft diameter only in men. In our study, height did not correlate with graft size in men ( $P = .81$ ), and 5 of the 6 men with grafts less than 7 mm were 71 in taller. Thus, although height remains the most significant measurement for the prediction of quadrupled hamstring diameter across all studies, this finding did not apply to the male population of this study.

The retrospective nature of this study does confer some limitations. Because all data were collected from medical records, we were unable to evaluate the role of thigh circumference in graft diameter. All the patients in this study were age 30 or younger, which limits the correlation of age with graft diameter. Also, this study is limited by the measurement increment that was used (0.5 mm). A graft with a diameter of 6.6 mm will not pass through a 6.5-mm sizer and thus will be considered a 7-mm graft. A more precise means of determining graft size is required for more accurate analysis of correlations and regression analysis.

As quadrupled hamstring autografts become more popular in ACL reconstruction, this area of research will continue to grow. Currently, the ability to clinically predict graft size is limited, and the findings of previous studies have varied significantly. Our study results demonstrate that one of the most significant factors in graft size may be patient sex. Women had overall smaller graft diameters, and there was a significant correlation between women shorter than 65 in and graft size less than 7 mm. This finding is important to consider, as most ACL tears occur in young women. Despite this finding, we must also conclude that clinical attributes are of limited value in predicting hamstring graft size. This study included several male athletes of significant height and overall size with graft diameters of 6.5 mm. In addition, 2 female patients who were significantly shorter than 65 in had graft diameters of 8 mm. Therefore, clinical attributes may raise a surgeon's concern about insufficient graft diameter, but they should not be used as the primary tool for prediction of graft size.

## CONCLUSION

This retrospective analysis of 132 patients represents an evaluation of anthropometric measurements in the prediction of quadrupled hamstring autograft diameter in ACL reconstruction. Our results suggest that age and height are not predictive of graft diameter less than 7 mm in men, but BMI of more than 25 kg/m<sup>2</sup> may predict larger graft diameter. However, height less than 65 in is a reliable, though not absolute, measurement predicting graft diameter less than 7 mm in women. Women who are younger than age 30 and shorter than 65 in may have a quadrupled hamstring autograft diameter less than 7 mm. Alternative graft options should be discussed with these patients before surgery.

## AUTHORS' DISCLOSURE STATEMENT

The authors report no actual or potential conflict of interest in relation to this article.

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