RESEARCH ARTICLE

Is There Any Correlation Between Patient Height and Patellar Tendon Length?

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Abstract

Background: A potential specific problem of patellar tendon graft in ACL reconstruction is the possibility of graft-tunnel mismatch which could be more problematic with anatomic ACL reconstruction where the femoral tunnel is placed low on the lateral wall of the lateral femoral condyle. The occasional occurrence of this mismatch raises the question that whether a correlation exists between patient height and patellar tendon length. The purpose of the present study was to measure patellar tendon length as an anthropometric finding and to evaluate whether a correlation exists between patient height and patellar tendon length.

Methods: Intra-operative measurement of patellar tendon length was carried out in 267 consecutive patients during bone-patellar tendon-bone (BTB) graft ACL reconstruction. Patient age, gender, height were recorded. The patellar tendon measurements were done independently by two surgeons and the possible inter-observer errors were checked. The data were analyzed using the Pearson correlation.

Results: The mean length of the patellar tendon was 46.4 ± 4.8 mm (Mean ± SD) with a range of 32–61 mm. The mean patient height was 177 ± 7 cm (Mean ± SD) with a range of 159–197 cm. A weak positive correlations were found between patient height and patellar tendon length (Pearson r = 0.24, $P< 0.001$). The linear regression equation for patellar tendon length (y, in millimeters) as a function of patient height (x, in centimeters) can be expressed as $y=16.54 + 0.17x$.

Conclusions: Our study showed a weak correlation between patellar tendon length and patient height. This finding is in contrast to the usual measurements in human anthropometry in which taller individuals have normally longer tendons and ligaments. The graft-tunnel mismatch may be the result of this variation.

Key words: ACL reconstruction, Graft-tunnel mismatch, Height, Patellar tendon length

Introduction

Bone-patellar tendon-bone (BTB or BPTB) graft is considered the "gold standard" for anterior cruciate ligament (ACL) reconstruction by many surgeons and has been used for years with a longstanding track record of good-to-excellent clinical outcomes (1). It allows for bone-to-bone healing within the tunnels and has favourable time-zero biomechanical strength.

One potential problem specific to patellar tendon grafts during ACL reconstructions is the possibility of graft-tunnel mismatch (2-6). Studies have shown the rate of graft tunnel mismatch to be between 10 and 26% (2, 7, 8). This occurs when the relative length of the bone-tendon-bone (BTB) construct exceeds the combined length of the intra-articular ACL distance and tibial tunnel length, resulting in extrusion of the tibial plug (9). Graft-tunnel mismatch may be more problematic with anatomic ACL reconstruction where the femoral tunnel is placed low on the lateral wall of the femoral notch, reducing the intra-articular graft length relative to non-anatomic vertical graft configurations. Intraoperative maneuvers to address the problem include recessing the

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Figure 1. Patellar tendon length measurement.

femoral bone plug, drilling a longer tibial tunnel, graft rotation, tibial tunnel bone grafting, and the modified harvesting and single bone plug techniques (6, 10-13).

The occasional occurrence of graft-tunnel mismatch raises the question of whether the length of the patellar tendon has a direct correlation with the patient's height. To our knowledge, there are only four previous studies that attempted to examine whether a correlation between patellar tendon length and height exists (4, 9, 14, 15). The results of these studies are controversial and only one of these studies has been conducted in a direct measurement setting (4).

The purpose of this study was to measure the length of the patellar tendon as an anthropometric finding and to evaluate whether a correlation exists between patient height and patellar tendon length.

Methods

During a 2-year period, 267 consecutive patients (246 males and 21 females) who underwent arthroscopic bone-tendon-bone graft ACL reconstruction were enrolled into our study. Patients with a history of knee surgery, patella bone/tendon and quadriceps tendon injury and developmental knee abnormalities such as patellar hypoplasia and Osgood-Schlatter disease were excluded. To harvest the full length of the patellar tendon, the whole width of the tendon was exposed and the central third with about 25 mm bone blocks over the patella and tibia was harvested. After removal of excess bone and graft preparation, the length of the tendinous part of the graft was measured using a ruler to the closest millimeter. The midpoint of the oblique end of the tendon was used as a measurement point [Figure 1]. The measurements were done independently by the chief surgeon and the senior resident and were recorded by the OR nurse. Patient age, sex, and height were also recorded. Statistical analysis was performed using SPSS software. Possible inter-observer errors were checked by the intraclass correlation coefficient. The data were analyzed using the Pearson correlation coefficient and statistical significance was defined as $P<0.05$.

Results

The average patient age was 28 years (range: 17-44 years) and 246 (92.1%) of them were male and 21 (7.9%) female. We performed two separate measurements for each tendon and the inter-observer agreement was evaluated and confirmed using the intraclass correlation coefficient (ICC=0.998, 95% CI: 0.997-0.999). The mean length of the patellar tendon graft was 46.4 ± 4.8 mm (mean ± SD) with a range of 32–61 mm. Distribution of the patellar tendon (PT) length is shown in Figure 2. Mean patient height was 177 ± 7 cm (mean ± SD) with a range of 159–197 cm. Figure 3 shows the scatter plot of the patellar tendon length versus patient height. Linear regression analysis defined a weak positive correlation between patient height and patellar tendon length (Pearson r = 0.24, $P<.001$). The linear regression equation for the patellar tendon length (y, in millimeters) as a function of patient height (x, in centimeters) can be expressed as $y= 0.168x +16.537$.

Weak positive correlation was found between height and patellar tendon length for men (Pearson r = 0.22, $P<0.001$), but no statistical correlation was shown for women (Pearson r = 0.09, $P=0.80$). The linear regression equation for male patellar tendon length as a function of patient height can be expressed as $y = 0.157x +18.634$. For women, the equation can be expressed as $y=0.025x + 37.827$.

Discussion

The results of our anthropometric measurements of the patellar tendon length were similar to that of previous studies. Table 1 shows the patellar tendon length studied

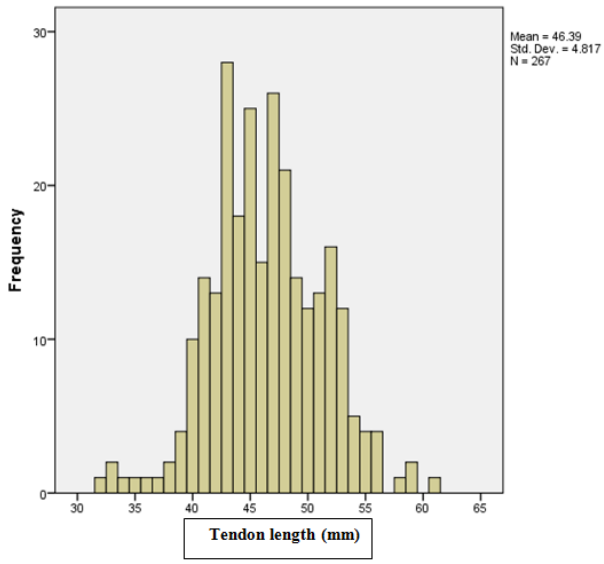

Figure 2. Distribution of patellar tendon (PT) lengths for all patients enrolled into the study. Mean tendon length was 46.39 ± 4.82 mm (range: 32 to 61 mm).

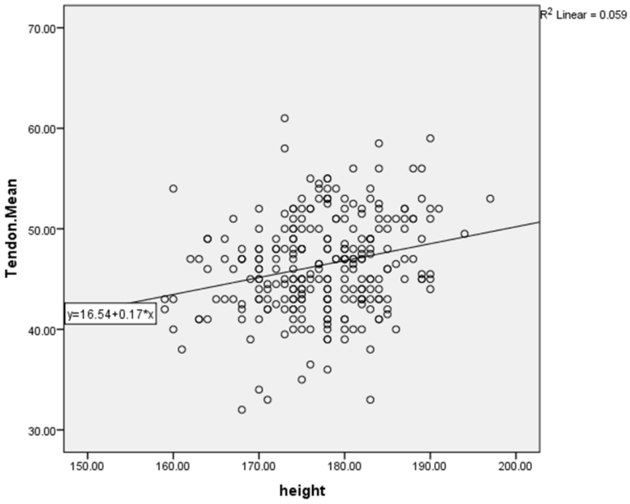

Figure 3. Scatter plot of patellar tendon length (mm) versus patient height (cm). (R2 Linear = 0.059).

in different races (2, 4, 16). These measurements show comparable findings with slight variations in different populations.

Graft-tunnel mismatch describes the variation between the length of the patellar tendon graft and the intra-articular distance between the ACL origin and insertion sites. This occurs when the relative length of the bone-tendon-bone (BTB) construct exceeds the combined length of the intra-articular ACL distance and tibial tunnel length, resulting in extrusion of the tibial plug (9). The rationale behind this mismatch is the occasional existence of long patellar tendons in relatively short individuals. This occurrence is in contrast to the usual findings in human anthropometry in which taller individuals have normally longer tendons and ligaments.

To our knowledge, there are only four previous studies that attempted to examine whether a correlation between patellar tendon length and height exists (4, 9, 14, 15). Brown et al. performed an MRI study looking at 414 knees and attempted to determine whether a correlation existed between patient height and either patellar tendon length or intra-articular ACL length (15). They noted a strong association between patient height and intra-articular ACL length; however, they reported a weak positive correlation between patient height and patellar tendon length. In a similar MRI study, Goldstein et al. reported moderate positive correlation between patient height and patellar tendon length, but concluded that variation occurs among patients of the same height and significant differences in mean patellar tendon lengths do exist between patients in different height subgroups (9). Wang et al. in their MRI study of 157 cases, were unable to show any correlation between patient height and patellar tendon length (14). Denti et al. studied patient height, patellar tendon length, and intra-articular ACL graft length in 50 arthroscopically reconstructed patients and nine cadaveric knees (4). They noted a weak correlation between patient height and patellar tendon length. Controversial findings from

Table 1. Comparison of mean patellar tendon length in different races

Author	No of Sample	race	PT tendon Length (Mean± SD)
Shaffer et al. (1993)	34	American	48.6 ±6.0
Denti et al. (1998)	50	Italian	45.5 ± 4.7
Luk et al. (2008)	120	Chinese	42.6 ± 4.6
Our study	267	Iranian	46.4 ± 4.8

no correlation to moderate correlation between patient height and patellar tendon length were found in these studies.

Because of these controversial results we studied this correlation by measuring the length of the patellar tendon in a relatively large number of cases with direct measurement during ACL reconstruction surgery. The accuracy of direct measurement of the patellar tendon length seems to be superior to indirect imaging techniques such as MRI. In a study conducted by Couppé et al., it has been shown that measuring the tendon cross sectional area on the grey-scale MRI images is associated with an underestimation, but by optimizing the measurement using a 3 tesla MRI and the appropriate color scale, this underestimation could be reduced (17). The inability to precisely define the proximal and distal tendon ends and the relative obliquity of MRI sagittal cuts may have a negative effect on accurate patellar tendon length measurements.

A weak positive correlation between patient height and patellar tendon length was found in our study. None of the previous studies showed a strong correlation between patient height and patellar tendon length. Similarly, we were unable to show any strong correlation. Brown et al. pointed out that in their study and one conducted by Denti et al. the measured patellar tendon lengths did show considerable variability (4, 15). Goldstein et al. also observed broad ranges of values within each height subgroup, but they believed that the confidence interval around the mean was fairly small for many of the groupings (9). In our study the range for patellar tendon length was between 32-61 mm, which also showed a wide range of sizes. The longest tendon in our study was twice as long as the shortest one and obviously, this ratio could not be found in the patients' height data. The tallest patient in this study was only 20% taller than the shortest one. According to our findings, it seems that patellar tendon length is an exception in human anthropometry and tall people may have short patellar tendons and vice versa.

Regarding this correlation in different sexes, weak positive correlation was found between height and patellar tendon length for men, but no statistical correlation was shown for women. Because of the low number of women in our study this difference should be considered as a questionable finding.

The low value of R2 in linear regression analysis showed that in only 6% of cases the tendon length could be predicted by the patient height. Accordingly, we do not agree with the recommendation of Goldstein et al. to use patient height and gender to predict the appropriate allograft length based on patellar tendon length (9). Because of the potential and unpredictable occurrence of the mismatch, it may be better to recommend measuring the patellar tendon length in a preoperative MRI. If a long tendon is encountered and a potential mismatch is anticipated, ordering a short allograft or using a modified harvesting or single bone plug technique can overcome this problem.

There are clearly some limitations to this study. The main limitation was the disproportionate percentage (92.1%) of men relative to women. It should be mentioned that in our region, women are less active in sport activities and consequently the number of their ligamentous injuries are relatively uncommon.

A second criticism may be that unlike previous MRI studies in which the measurements were carried out in patients undergoing knee MRI for a variety of pathologies, we studied only ACL-deficient cases. The presence of quadriceps atrophy and contractures around the knee in an ACL-deficient patient may have a temporary effect on actual patellar tendon length. These factors are not included in our study and future studies are needed to address their potential impact.

The third limitation of this study is related to its clinical implication. It may be assumed that knowing the relative lengthiness of the patellar tendon after harvesting has no utility in preventing graft-tunnel mismatch, but in this circumstance the surgeon can decide to recess the femoral bone plug or drill a longer tibial tunnel before using other possible options. Preoperative MRI measurement of patellar tendon length is another option to deal with this potential problem.

Our study showed that there is a weak correlation between patellar tendon length and patient height. This finding is in contrast to the usual measurements in human anthropometry in which taller individuals have normally longer tendons and ligaments. This point should be taken into account when using BTB allografts in ACL reconstruction and orthopedic surgeons should be prepared to face this relatively common situation.

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