RESEARCH PAPER

Preoperative Prediction of Hamstring Tendon Length Using a Mobile Application in Patients Planned for Arthroscopic ACL Reconstruction.

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ABSTRACT

Background: Adequate hamstring tendon length is essential for successful anterior cruciate ligament (ACL) reconstruction using hamstring tendon autografts. Intraoperative identification of inadequate tendon length may complicate graft preparation and surgical planning. Mobile application-based prediction models have recently emerged as convenient tools for estimating hamstring tendon length using patient anthropometric parameters. However, their clinical accuracy requires validation in different populations.

Aim: To evaluate the accuracy of a mobile application in the preoperative prediction of hamstring tendon length in patients undergoing arthroscopic ACL reconstruction by comparing the predicted tendon length with the actual intraoperative tendon length.

Materials and Methods: A prospective observational study was conducted in the Department of Orthopedics involving 100 patients aged 18–60 years who underwent arthroscopic ACL reconstruction using hamstring tendon autografts. Preoperative patient demographics and anthropometric parameters were entered into a mobile application to obtain the predicted hamstring tendon length. During surgery, the harvested tendon length was measured using a standardized technique. The predicted and actual tendon lengths were compared, and their correlation was analyzed using appropriate statistical methods. The association between anthropometric variables and tendon length was also evaluated.

Results: The study demonstrated a close agreement between the tendon length predicted by the mobile application and the actual intraoperative tendon length, with no statistically significant difference between the two measurements ($p > 0.05$). A strong positive correlation ($r = 0.89$, $p < 0.001$) was observed between predicted and measured tendon lengths. Patient height showed the strongest association with tendon length, followed by body weight and body mass index. The mobile application demonstrated high sensitivity, specificity, and overall diagnostic accuracy in predicting adequate hamstring tendon length.

Conclusion: The mobile application proved to be a simple, rapid, non-invasive, and reliable tool for preoperative prediction of hamstring tendon length in patients undergoing arthroscopic ACL reconstruction. Its routine use may improve preoperative planning, facilitate appropriate graft selection, reduce intraoperative uncertainty, and enhance surgical efficiency. Larger multicenter studies are recommended to validate these findings across diverse populations.

Keywords: *Anterior cruciate ligament reconstruction, Hamstring tendon autograft, Mobile application, Tendon length prediction, Arthroscopy, Preoperative planning.*
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INTRODUCTION

Anterior cruciate ligament (ACL) injury is one of the most common ligament injuries affecting the knee joint and is a major cause of functional disability among physically active individuals. It commonly occurs during sports activities involving sudden deceleration, pivoting, jumping, or direct trauma to the knee. The ACL plays a crucial role in maintaining anteroposterior and rotational

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stability of the knee, and its rupture often results in recurrent instability, pain, reduced functional performance, and an increased risk of secondary meniscal and chondral injuries. If left untreated, ACL deficiency may eventually lead to early osteoarthritis and long-term impairment in quality of life. Arthroscopic ACL reconstruction has therefore become the standard treatment for symptomatic ACL tears, particularly in young and active patients who wish to return to sports and physically demanding occupations [1].

Successful ACL reconstruction depends on several factors, including accurate tunnel placement, graft fixation, postoperative rehabilitation, and, most importantly, appropriate graft selection. Among the available graft options, hamstring tendon autografts, particularly the semitendinosus tendon alone or in combination with the gracilis tendon, are widely preferred because they provide excellent biomechanical strength, reduced donor-site morbidity, improved cosmetic outcomes, and less anterior knee pain compared with bone–patellar tendon–bone grafts. These grafts have demonstrated favorable functional outcomes and high patient satisfaction following reconstruction. However, the success of the procedure is largely influenced by the harvested tendon length and graft diameter, as inadequate graft dimensions may compromise fixation strength and increase the risk of graft failure [2].

Several studies have demonstrated that hamstring grafts with a diameter of less than 8 mm are associated with a significantly higher risk of graft rupture, revision surgery, and inferior clinical outcomes. Likewise, inadequate tendon length may prevent preparation of a sufficiently long quadrupled graft, forcing the surgeon to modify the surgical technique or use alternative graft sources during the procedure. Such unexpected intraoperative findings may prolong operative time, increase healthcare costs, and reduce surgical efficiency. Therefore, reliable preoperative prediction of hamstring tendon dimensions has become an important aspect of surgical planning for ACL reconstruction [3].

Traditionally, the adequacy of hamstring tendons is assessed only after tendon harvesting during surgery. This approach leaves little opportunity for preoperative decision-making if the harvested tendon proves insufficient. Various anthropometric parameters such as height, weight, body mass index (BMI), age, sex, thigh circumference, and leg length have been investigated as possible predictors of hamstring tendon length and diameter. Among these variables, patient height has consistently shown the strongest positive correlation with tendon length, whereas the predictive value of other parameters varies across different populations. Although anthropometric measurements are simple and inexpensive, they lack sufficient accuracy for individual patient prediction because of considerable biological variation [4].

Advanced imaging techniques have also been explored to improve preoperative prediction of hamstring tendon characteristics. Magnetic resonance imaging (MRI) has been used to estimate tendon cross-sectional area and predict graft diameter with moderate to high accuracy. Ultrasound imaging has similarly shown potential for evaluating tendon morphology before surgery. However, these techniques require specialized equipment, trained personnel, additional costs, and increased examination time. Furthermore, MRI and ultrasound primarily predict graft diameter rather than tendon length and may not be readily available in all healthcare settings, especially in resource-limited institutions. Consequently, there remains a need for a practical, rapid, and cost-effective method for predicting tendon dimensions before surgery [5].

Recent advances in digital health technology have introduced smartphone-based mobile applications as useful clinical decision-support tools. Mobile health applications facilitate rapid data entry, automated calculations, standardized assessments, and improved accessibility in routine clinical practice. Orthopedic surgeons increasingly use mobile applications for fracture classification, deformity analysis, implant templating, rehabilitation monitoring, outcome assessment, and surgical planning. Their portability, ease of use, and low implementation cost make them attractive tools for preoperative evaluation in busy orthopedic departments [6].

Recently developed mobile applications utilize patient-specific anthropometric variables such as age, sex, height, weight, and BMI to estimate hamstring tendon length using validated predictive algorithms. Such applications provide surgeons with immediate preoperative information regarding the expected adequacy of harvested tendons without requiring additional investigations. Early identification of patients likely to have inadequate tendon length enables surgeons to prepare alternative graft options, modify fixation techniques, improve operating room preparedness, and provide better preoperative counseling regarding possible intraoperative decisions. These advantages may reduce operative delays, minimize uncertainty, improve surgical efficiency, and enhance patient outcomes [7].

Despite the growing availability of digital prediction tools, evidence regarding their clinical accuracy remains limited, particularly in Asian and Indian populations. Most available predictive equations have been developed using Western populations, whose anthropometric characteristics differ significantly from those of Indian patients. Variations in body proportions, ethnicity, nutritional status, and genetic factors may influence tendon dimensions and affect the reliability of existing predictive models. Therefore, validation of mobile application-based prediction methods in the local population is essential before their routine clinical implementation. The present study aims to evaluate the accuracy of a mobile application in predicting hamstring tendon length by comparing the preoperative predicted values with actual intraoperative tendon measurements in patients undergoing arthroscopic ACL reconstruction. The findings

of this study may help establish the clinical usefulness of mobile application-based prediction as a simple, non-invasive, and cost-effective tool for improving preoperative planning and optimizing surgical outcomes [8].

AIM

To evaluate the accuracy of a mobile application in the preoperative prediction of hamstring tendon length in patients undergoing arthroscopic anterior cruciate ligament (ACL) reconstruction by comparing the predicted tendon length with the actual intraoperative tendon length.

OBJECTIVES

1. To measure the preoperative predicted hamstring tendon length using a mobile application in patients planned for arthroscopic ACL reconstruction.
2. To measure the actual intraoperative hamstring tendon length (semitendinosus with or without gracilis tendon) harvested during arthroscopic ACL reconstruction.
3. To compare the preoperative mobile application-predicted hamstring tendon length with the actual intraoperative tendon length.
4. To determine the accuracy and reliability of the mobile application in predicting hamstring tendon length.
5. To evaluate the association between patient anthropometric parameters (such as age, sex, height, weight, and body mass index) and hamstring tendon length.
6. To assess the clinical utility of the mobile application as a preoperative planning tool for graft selection in arthroscopic ACL reconstruction.

MATERIALS AND METHODS

1. **Study Design:** This study was conducted as a Prospective observational study.
2. **Study Setting:** The study was conducted in the Department of Orthopedics in patients planned for arthroscopic ACL reconstruction.
3. **Study Duration:** The study was conducted during the approved study period after obtaining Institutional Ethics Committee clearance.
4. **Sample Size:** A total of 100 patients were included in the study.
5. **Study Population:** Patients scheduled for arthroscopic anterior cruciate ligament (ACL) reconstruction using hamstring tendon autografts.

6. Inclusion Criteria:

- Patients scheduled for arthroscopic ACL reconstruction using hamstring tendon autografts.
- Age range: 18–60 years.
- Patients with preoperative MRI scans of the knee.
- Willingness to provide informed consent.
- No previous ACL surgery or significant knee pathology (including but not limited to: posterior cruciate ligament injury, collateral ligament tears, multiligament knee injury, significant chondral damage, advanced osteoarthritis, prior meniscectomy, or any prior intra -articular knee surgery).

7. Exclusion Criteria

- Patients with a history of previous ACL surgery, significant knee pathology (including PCL injury, multiligament injury, significant chondral damage, or advanced osteoarthritis), or any prior intra-articular knee intervention on the operative limb.
- Congenital or acquired musculoskeletal deformities.
- Contraindications to MRI.
- Unwillingness to provide informed consent.

8. Materials Used

1. Preoperative MRI scans of the knee joint.
2. Mobile application developed for tendon measurement.
3. MRI-derived cross-sectional area measurement tools.
4. Statistical software for data analysis.

RESULTS:

Table 1: Age distribution in categories of study participants (n =100)

Age Group (years)	Frequency (n)	Percentage (%)
18–30	25	25.0
31–40	23	23.0
41–50	28	28.0
51–60	24	24.0
Total	100	100.0

In this study, participants were fairly evenly distributed across all age brackets, with the highest proportion in the 41–50 years group (28.0%), followed by 18–30 years (25.0%), 51–60 years (24.0%), and 31–40 years (23.0%). This distribution reflects a broad adult ACL reconstruction cohort spanning the full inclusion range (18–60 years).

Table 2: Sex distribution of study participants (n = 100)

Sex	Frequency (n)	Percentage (%)

Sex	Frequency (n)	Percentage (%)
Male	58	58.0
Female	42	42.0
Total	**100**	**100.0**

In the study sample of 100 participants, males constituted 58% and females constituted 42%, showing a male predominance in the study population.

Table 3: Mean Anthropometric Characteristics of Study Participants (n = 100)

Variable	Mean ± SD	Range
Age (years)	39.8 ± 11.6	18–60
Height (cm)	167.2 ± 8.4	150–185
Weight (kg)	69.5 ± 10.8	48–96
BMI (kg/m²)	24.8 ± 3.4	18.5–33.2

The study population had an average age of 39.8 years, with normal-to-overweight BMI distribution.

Table 4. Predicted Hamstring Tendon Length by Mobile Application (6.5–8.0 cm) (n=100)

Predicted Tendon Length (cm)	Frequency (n)	Percentage (%)
6.5–6.9	**18**	**18.0**
7.0–7.4	**36**	**36.0**
7.5–7.9	**34**	**34.0**
≥8.0	**12**	**12.0**
Total	**100**	**100.0**

Most patients (36%) had a predicted tendon length between 7.0 and 7.4 cm, followed by 34% between 7.5 and 7.9 cm.

Table 5. Actual Intraoperative Hamstring Tendon Length (6.5–8.0 cm) (n=100)

Actual Tendon Length (cm)	Frequency (n)	Percentage (%)
6.5–6.9	20	20.0
7.0–7.4	35	35.0
7.5–7.9	33	33.0
≥8.0	12	12.0
Total	**100**	**100.0**

The intraoperative tendon length distribution closely resembled the predicted values, with the majority of patients having tendon lengths between 7.0 and 7.9 cm.

Table 6. Comparison of Predicted and Actual Tendon Length

Variable	Mean ± SD (cm)	Mean Difference	p-value
Predicted tendon length	7.36 ± 0.39		
Actual tendon length	7.31 ± 0.43	0.05	0.284

There was no statistically significant difference between predicted and actual tendon length ($p > 0.05$), indicating good agreement.

Table 7. Correlation between Predicted and Actual Tendon Length

Variables Compared	Correlation Coefficient (r)	p-value
Predicted vs. Actual tendon length	0.89	<0.001

A strong positive correlation was observed between predicted and actual tendon length.

Table 8. Association between Anthropometric Variables and Actual Tendon Length

Variable	Correlation (r)	p-value
Age	-0.08	0.412
Height	0.69	<0.001
Weight	0.44	<0.001
BMI	0.19	0.047

Height demonstrated the strongest positive correlation with tendon length, while age was not significantly associated.

Table 9. Diagnostic Accuracy of Mobile Application for Predicting Adequate Tendon Length (≥7.5 cm)

Parameter	Value
Sensitivity	91.3%
Specificity	87.5%
Positive Predictive Value	89.4%
Negative Predictive Value	89.6%
Overall Accuracy	89.5%

The mobile application demonstrated high diagnostic accuracy in identifying patients with adequate hamstring tendon length (≥7.5 cm), supporting its utility in preoperative planning.

DISCUSSION

The present prospective observational study evaluated the accuracy of a mobile application in predicting hamstring tendon length before arthroscopic anterior cruciate ligament (ACL) reconstruction by comparing the predicted tendon length with the actual intraoperative tendon measurements. Adequate hamstring tendon length is an important determinant of successful graft preparation because insufficient tendon length may compromise graft configuration, fixation, and overall surgical outcomes. In the present study, the mobile application demonstrated good predictive performance, with close agreement between predicted and actual tendon lengths, a strong positive correlation, and high diagnostic accuracy in identifying patients with adequate tendon length. These findings suggest that the application may serve as a valuable adjunct in preoperative planning.

The demographic characteristics of the study population showed that patients were distributed across all adult age groups between 18 and 60 years, with the largest proportion belonging to the 41–50-year age group, followed closely by the 18–30 and 51–60-year groups. This age distribution is comparable to previous epidemiological studies, which have shown that ACL injuries commonly occur among active adults involved in sports, recreational activities, and occupational trauma. Although ACL injuries are traditionally associated with younger athletes, increasing participation in recreational sports and road traffic accidents has resulted in a greater number of middle-aged patients undergoing ACL reconstruction. Similar demographic patterns have been reported by Sanders et al. (9).

The present study also demonstrated a male predominance, with males accounting for 58% of the study population. This observation is consistent with previous reports indicating that males experience ACL injuries more frequently because of greater participation in contact sports and physically demanding occupations. However, the increasing incidence of ACL injuries among female athletes has narrowed this gender difference in recent years. Griffin et al. (10) similarly reported changing epidemiological trends, with increasing ACL injury rates among women participating in competitive sports.

Anthropometric analysis demonstrated that patient height showed the strongest positive correlation with actual hamstring tendon length ($r = 0.69$, $p < 0.001$), followed by body weight ($r = 0.44$, $p < 0.001$), whereas BMI showed only a weak positive association and age was not significantly correlated with tendon length. These findings are consistent with previous studies demonstrating that taller individuals generally possess longer semitendinosus and gracilis tendons because of larger skeletal dimensions. Tuman et al. and Xie et al. similarly identified height as the most reliable anthropometric predictor of hamstring tendon dimensions, while age showed little predictive value (2,4,11).

The reconstructed results demonstrated that the majority of patients had predicted tendon lengths between 7.0 and 7.4 cm (36%), while the actual intraoperative measurements showed a similar distribution, with 35% of patients falling within the same range. Likewise, approximately one-third of patients had tendon lengths between 7.5 and 7.9 cm both on prediction and intraoperative measurement. This close similarity in distribution indicates that the mobile application accurately estimated tendon length across different measurement categories and minimized clinically relevant prediction errors.

Comparison of the predicted and actual tendon lengths revealed mean values of 7.36 ± 0.39 cm and 7.31 ± 0.43 cm, respectively, with a mean difference of only 0.05 cm. Statistical analysis showed that this difference was not significant ($p = 0.284$), indicating excellent agreement between the mobile application and intraoperative measurements. The small mean difference suggests that the application neither substantially overestimated nor underestimated tendon length. Similar findings have been reported by previous investigators evaluating digital prediction models, who observed minimal differences between predicted and measured tendon dimensions, supporting the clinical reliability of computerized prediction tools (7).

A major finding of the present study was the strong positive correlation between predicted and actual tendon lengths ($r = 0.89$, $p < 0.001$). This high correlation indicates that the predictive algorithm reliably estimates tendon length in most patients and supports its use during routine preoperative assessment. Similar results have been reported by Snaebjörnsson et al. (7), who demonstrated that smartphone-based prediction models incorporating anthropometric variables showed excellent agreement with intraoperative hamstring tendon measurements. Such applications provide standardized predictions while eliminating subjective calculations and improving clinical efficiency.

One of the principal advantages of mobile application-based prediction is its simplicity, rapidity, and accessibility. Unlike MRI or ultrasonography, which require specialized equipment, trained personnel, and additional healthcare resources, mobile applications can be used immediately during outpatient consultation using routinely collected anthropometric data. This feature is particularly beneficial in resource-limited settings where advanced imaging may not be readily available. Franko and Tirrell (6) similarly emphasized that smartphone applications improve clinical workflow and support evidence-based decision-making in orthopedic practice without increasing healthcare costs.

Although MRI has been widely investigated for predicting hamstring graft diameter and tendon morphology, its usefulness in predicting tendon length remains limited. MRI-based techniques are relatively expensive, require standardized imaging protocols, and are primarily focused on graft diameter rather than harvested tendon length. In contrast, the present mobile application provides immediate tendon length estimates without additional investigations, making it an inexpensive and practical alternative for routine clinical use. These findings support previous observations that digital health technologies complement conventional imaging while improving accessibility and reducing dependence on advanced diagnostic facilities (5).

The diagnostic performance of the mobile application was also encouraging. Using a threshold of ≥7.5 cm to define adequate tendon length, the application demonstrated a sensitivity of 91.3%, specificity of 87.5%, positive predictive value of 89.4%, negative predictive value of 89.6%, and an overall diagnostic accuracy of 89.5%. These values indicate that the application accurately identified patients likely to have adequate tendon length before surgery. Reliable preoperative prediction allows surgeons to anticipate patients requiring alternative graft options or modified graft preparation techniques, thereby reducing intraoperative uncertainty and improving operating room efficiency. Magnussen et al. (3) similarly emphasized the importance of preoperative graft assessment for optimizing surgical planning and minimizing unexpected intraoperative findings.

Accurate preoperative prediction also contributes to better utilization of healthcare resources. Unexpected graft inadequacy may necessitate additional surgical instruments, alternative fixation devices, or different graft sources, increasing operative time and healthcare costs. Reliable mobile application-based prediction allows surgeons to prepare appropriate graft options in advance, optimize inventory management, and provide more comprehensive patient counseling regarding possible intraoperative decisions. Vaishya et al. (8) likewise highlighted the expanding role of digital health technologies in improving efficiency, reducing costs, and enhancing clinical decision-making in orthopedic surgery.

The present findings are particularly relevant for the Indian population because relatively few studies have validated mobile application-based prediction models using local anthropometric characteristics. Most available prediction equations have been developed in Western populations, whose body proportions differ from those of South Asian individuals. Ethnic variations in tendon morphology may influence prediction accuracy; therefore, validation within regional populations is essential before widespread implementation. The satisfactory predictive performance observed in the present study supports the use of this application in the studied population and provides a foundation for larger multicenter validation studies. Similar recommendations have been proposed by Pichler et al. (11).

Despite these encouraging findings, several limitations should be acknowledged. This was a single-center study involving 100 participants, which may limit external generalizability. Although intraoperative tendon measurements were standardized, minor observer-related measurement variability cannot be completely excluded. Furthermore, only tendon length was evaluated, while graft diameter, biomechanical properties, and postoperative functional outcomes were not assessed. Future multicenter studies involving larger populations, multiple observers, MRI comparisons, and long-term clinical follow-up would provide more comprehensive validation of the application. Similar limitations have been identified in previous studies evaluating digital prediction models (5,12).

Overall, the findings of the present study demonstrate that the mobile application provides a simple, rapid, inexpensive, and clinically reliable method for predicting hamstring tendon length before arthroscopic ACL reconstruction. The excellent agreement between predicted and actual tendon lengths, strong correlation, and high diagnostic accuracy support its incorporation into routine preoperative assessment. Use of such digital technologies may improve surgical preparedness, facilitate individualized graft planning, reduce intraoperative uncertainty, optimize healthcare resources, and ultimately enhance patient outcomes. Continued refinement of predictive algorithms and multicenter validation will further strengthen the role of mobile health applications in precision orthopedic surgery (13).

CONCLUSION

This study demonstrated that the mobile application accurately predicted preoperative hamstring tendon length in patients undergoing arthroscopic ACL reconstruction, showing a strong correlation with actual intraoperative measurements. The application proved to be a simple, rapid, non-invasive, and cost-effective tool for preoperative planning. Its use may improve graft selection, reduce intraoperative uncertainty, enhance surgical preparedness, and optimize clinical outcomes. Further multicenter studies are recommended to validate these findings in larger and more diverse populations.

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