

Five-times sit-to-stand test following anterior cruciate ligament surgery: a cross-sectional reliability study

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Abstract

Aims

Patients who have had anterior cruciate ligament reconstruction (ACL-R) should periodically have their muscle strength assessed. The five-times sit-to-stand test (FTSST) can evaluate the muscle strength and balance of the lower extremities. This study's primary purpose was to assess the validity and reliability of the FTSST in patients who have undergone ACL-R.

Material and Methods

Forty-three people who had undergone ACL-R surgery were included in the study. The study's primary outcome measure, the FTSST, was assessed by two different investigators. Secondary outcome measures were body balance, quadriceps muscle strength, Tegner activity score (TAS), and Lysholm score.

Results

The FTSST's test-retest and inter-rater reliability were both high (ICC: 0.99). The FTSST also showed a strong statistically significant correlation with all secondary outcome measures, including balance, quadriceps muscle strength, TAS, and Lysholm score ($p < 0.05$).

Conclusions

According to the study results, the FTSST is a tool-free, simple method for assessing muscle strength and the body balance level, mobility level, and functional status of the knee in patients who have undergone ACL-R surgery.

Key words: Anterior cruciate ligament, Reconstruction, Five-times sit-to-stand test

Introduction

Anterior cruciate ligament (ACL) rupture is the most common knee injury and is seen primarily in adults aged 20–29. The ACL is often injured during sports activities that involve turning, jumping, and contact¹. ACL reconstruction (ACL-R) aims to restore knee stabilization, but deficiencies in knee extension strength, neuromuscular control, and proprioception persist for up to 2 years after reconstruction surgery². These deficiencies are also present in the contralateral uninjured knee³⁻⁵. Therefore, evaluation programs after ACL-R should include both knees.

Quadriceps muscle weakness and dysfunction are the most frequent symptoms in patients who have undergone ACL-R and may also occur in the years following reconstruction^{6,7}. Atherogenic muscle inhibition, which affects the periarticular musculature, is the underlying mechanism that results from damaged joint components. Theoretically, inaccurate sensory input from joint mechanoreceptors causes a reduction in efferent impulses to the quadriceps muscle in patients with knee joint injury. Consequently, a decreased number of motor units are triggered during contraction^{7,8}. Grindem et al. stated that quadriceps muscle weakness after ACL-R increases the risk of injury⁹. Therefore, continuous evaluation of quadriceps muscle strength is required after reconstruction.

Quadriceps muscle strength has traditionally been measured in clinical settings with isokinetic dynamometers or isometric dynamometers¹⁰. However, patients who require long-term follow-up, such as those who have undergone ACL-R, may find it difficult to come to clinical settings on a regular basis. Therefore, clinicians are trying to reach patients through telerehabilitation methods and frequently resort to easy, equipment-free methods.

The five-times sit-to-stand test (FTSST) is a simple, rapid, equipment-free method that evaluates balance and mobility, as well as lower extremity muscle strength^{11,12}. The FTSST's validity and reliability have been examined in different populations and diseases, with the conclusion that it is a valid and reliable method¹³⁻²⁰. After ACL-R, rapid and reliable tests such as FTSST that evaluate balance, mobility, and lower extremity muscle strength are very important in monitoring rehabilitation results. However, we could not find any study examining its validity and reliability in people with ACL-R. Thus, the aim of this study was to test the inter-rater and test-retest reliability of the FTSST in patients who had undergone ACL-R surgery. Additionally, it was to examine correlations between FTSST and other parameters.

Methods

Design

This cross-sectional study was approved by the Muş Alparslan

University Clinical Research Ethics Committee (Decision no: 1-2022/39). The Helsinki Declaration's guiding principles were followed during the study's execution. Written and verbal consent was obtained from the participants just before starting the study. Participants were randomly selected from those who had previously undergone ACL reconstruction surgery and presented applied to the Kırşehir Training and Research Hospital Orthopedics and Traumatology Clinic for a neuromuscular control exam. Then, two physiotherapists with four years of clinical expertise in ACL rehabilitation conducted each assessment one hour apart. Seven days later, the same physiotherapists conducted the evaluations once more.

Participants

Patients who underwent ACL-R surgery and were at least six months post-reconstruction and over the age of 18 were included in the study. Those who had a meniscus or posterior cruciate ligament injury accompanying an ACL injury and those who had undergone any surgery other than ACL surgery were excluded from the study. In addition, those with any orthopedic, vestibular disorders or neurological in addition to ACL-R, were excluded from the study. Current guidelines recommend the incorporation of 30 to 50 participants in reliability studies²¹. Considering the lack of precedent research concerning the validity and reliability of the FTSSST among individuals with ACL-R, we diligently followed this guideline and recruited a total of 46 patients with ACL-R for the present study.

Assessments

Patients' demographic and clinical characteristics (age, height, gender, weight, injured knee, and time elapsed after surgery) were recorded. Then, clinical evaluations were started.

FTSSST Test

For the FTSSST, the participants were asked to sit on a 42-45 cm chair with their hands crossed on their chest, and to sit and stand up from the chair five times with the start command, respectively. The test score was assessed with a stopwatch, and the time to complete the task was recorded in seconds²².

Balance

The Biodex Stability System (BSS) [(BSS) Biodex Inc., Shirley, New York] was used to measure body balance. The BSS consists of a transportable balance platform with a 20° tiltable surface connected to computer software that provides an objective assessment of balance. Each participant in the study received information about the tests and guidelines for compliance. In both static and dynamic balance measurements, we recorded three distinct postural sway amounts in centimeters, resulting in a total of six outcome measures: anterior-posterior (AP), medial-lateral (ML), and overall score (Overall score-OS). Each session of static and dynamic balance measurement, lasting 20 seconds each, was repeated three times with 10-second intervals of rest between measurements. The device automatically computed the averages for the static and dynamic balance parameters (AP, ML, and OS)²³.

Muscle Strength

Quadriceps muscle strength of the participants was evaluated with isometric dynamometer. While the participants were

seated on a flat surface and the knees and hips were 90° flexed, the dynamometer was placed above the malleolus and the participant was asked to push the dynamometer with maximum force. Three attempts were made and the highest score was recorded and recorded in kg²⁴.

Lysholm Score

The Lysholm score was developed in the 1980s as a patient-focused subjective assessment method to assess the functional status of patients with ACL injuries [23]. Çelik et al. developed a Turkish version of the Lysholm score and found it to be a valid and reliable method. The Lysholm score consists of eight questions, and the total score is in the range of 0–100. A high score indicates good knee functional status²⁵.

Tegner Activity Scale

The Tegner activity scale is a scoring system that measures activity levels in daily life and sports from 0 to 10. It has been found to have acceptable responsiveness for use in the early return to function following ACL treatment. Activity level is graded from 0 points for those who quit the activity due to injury or dysfunction to 10 points for those who play professional sports at the national team level^{26,27}.

Statistical Analysis

SPSS software (version 24) was used to conduct the statistical analysis. Using visual and analytical techniques, the variables' conformance to normal distribution was evaluated (Shapiro–Wilk tests). Since the data were normally distributed, descriptive statistics were given as the mean and standard deviation. Nominal variables were expressed as numbers and percentages. The inter-rater and test–retest reliability of the FTSSST were assessed using intraclass correlation coefficients (ICC). The ICC is rated as good (0.60–0.80) or excellent (0.80–1.0) 28. The FTSSST's concordance validity and relationship with other tests were assessed with the Pearson correlation test. The correlation coefficient was considered low between 0.05 and 0.4, moderate between 0.4 and 0.7, and high between 0.7 and 1.0 29. A statistically significant level was defined as a p-value of 0.05 or lower.

Results

The demographic and descriptive characteristics of the patients are given in Table 1.

The values of the FTSSST, balance, muscle strength, Lysholm, and Tegner activity scores of the ACL patients are given in Table 2.*

When the test–retest (ICC) and inter-rater (ICC) reliability of the FTSSST were examined, the first assessor's test–retest result, the ICC value, was found to be 0.997. Regarding consistency (inter-rater) between the first and second assessors, the ICC value was found to be 0.997. According to these results, the test–retest and the inter-rater agreement were interpreted as excellent (Table 3).

The correlation results of the Biodex Stability System, Tegner activity score, Lysholm score, and quadriceps muscle strength (injured and uninjured knees) are given in Table 4. There was a high positive correlation between FTSSST and static-dynamic parameters of the Biodex Stability System ($p < 0.05$).

Table 1. Demographic and clinical characteristics of ACL-R patients

| | | (n=46) | | | |
|----------------------------------|--------|----------|-------|------------|-------|
| | | Mean | SD | Min | Max |
| Age (years) | | 33.26 | 6.22 | 20 | 44 |
| Height (cm) | | 165.52 | 5.10 | 155 | 190 |
| Weight (kg) | | 76.35 | 10.86 | 58 | 96 |
| BMI (kg/m²) | | 27.39 | 6.61 | 20.9 | 34.52 |
| Post-surgery time (month) | | 8.70 | 1.96 | 6 | 12 |
| | | n | | (%) | |
| Gender | Male | 34 | | 73.9 | |
| | Female | 12 | | 26.1 | |
| Dominant side | Right | 12 | | 26.1 | |
| | Left | 34 | | 73.9 | |
| Injured Knee | Left | 14 | | 30.4 | |
| | Right | 32 | | 69.6 | |

N: Number, %: Percent, SD: Standard deviation, BMI: Body mass index

Table 2. Measurement values of the ACL-R patients

| | | (n=46) | | Min | Max |
|---------------------------------------|----------------------|--------|------|------|------|
| | | Mean | SD | | |
| Balance | Static AP (cm) | 1.9 | 1.2 | 0.2 | 4.1 |
| | Static ML (cm) | 1.3 | 0.9 | 0.4 | 3.8 |
| | Static-Overall (cm) | 2.8 | 1.8 | 0.7 | 6.7 |
| | Dynamic-AP (cm) | 2.6 | 1.5 | 0.4 | 6.1 |
| | Dynamic-ML (cm) | 1.7 | 0.8 | 0.2 | 3.9 |
| | Dynamic-Overall (cm) | 3.6 | 2.0 | 0.9 | 7.6 |
| Tegner activity score | | 2.5 | 1.7 | 0.0 | 5 |
| Lysholm score | | 51.1 | 21.3 | 15.0 | 85 |
| Quariceps muscle strength (kg) | Injured | 9 | 3.7 | 4.0 | 15 |
| | Uninjured | 10.4 | 4.1 | 4.0 | 17.5 |
| FTSST (1) (sec) | Test | 14.6 | 4.5 | 6.8 | 20.6 |
| | Retest | 14.8 | 4.7 | 6.1 | 20.7 |
| FTSST (2) (sec) | Test | 14.8 | 4.4 | 6.9 | 20.4 |
| | Retest | 14.9 | 4.7 | 6.4 | 21.2 |

cm: centimeter, n: Number, sec: second, 1: First assessor, 2: Second assessor, SD: Standard deviation, AP: Anterior-posterior, ML: Medial-lateral, FTSST: Five-times sit-to-stand test

Table 3. Inter-rater (ICC) and test–retest (ICC) reliability of the FTSST

| n=46 | Difference (Mean±SD) | Inter-rater (ICC _{1,2}) (95% CI) | Test-retest (ICC _{1,1}) (95% CI) | SEM | MDC ₉₅ |
|-------|----------------------|--|--|------|-------------------|
| FTSST | 0.20±0.48 | 0.997 (0.994-0.998) | 0.997 (0.995-0.998) | 0.02 | 0.05 |

n; Number, SD; Standard deviation, FTSST; Five-times sit-to-stand test, ICC; Intraclass correlation coefficient, CI; Confidence interval, SEM; Standard error of measurement; MDC₉₅; Minimum detectable change at the 95% confidence interval

Table 4. Correlation of the FTSSST with other tests

| | | | FTSSST |
|--|----------------------|---|---------------|
| Balance | Dynamic-AP (cm) | r | 0.873 |
| | | p | <0.001 |
| | Dynamic-ML (cm) | r | 0.843 |
| | | p | <0.001 |
| | Dynamic-Overall (cm) | r | 0.881 |
| | | p | <0.001 |
| | Static-AP (cm) | r | 0.877 |
| | | p | <0.001 |
| | Static-ML (cm) | r | <0.001 |
| | | p | <0.001 |
| | Static-Overall (cm) | r | 0.881 |
| | | p | <0.001 |
| Tegner activity score | | r | -0.912 |
| | | p | <0.001 |
| Lysholm score | | r | -0.793 |
| | | p | <0.001 |
| Quadriceps muscle strength (kg) | Injured Knee | r | -0.896 |
| | | p | <0.001 |
| | Uninjured Knee | r | -0.900 |
| | | p | <0.001 |

FTSSST: Five-times sit-to-stand test, AP: Anterior-posterior, ML: Medial-lateral, p<0.001

There was a statistically significant negative correlation between the FTSSST, Tegner activity score, Lysholm score, and quadriceps muscle strength (injured and uninjured knee) (p<0.05).

Discussion

The results of the current study demonstrate that the FTSSST has excellent test–retest and inter-rater reliability in patients who have undergone ACL-R. In addition, the FTSSST was found to be highly correlated with muscle strength, balance, activity level, and knee functionality in patients with ACL-R. These results support the validity of the FTSSST.

The validity and reliability of the FTSSST have previously been examined in intensive care patients¹³, patients with total hip arthroplasty¹⁶, patients with balance disorders¹⁴, older adults³⁰, chronic stroke patients³¹, and patients with pelvic girdle pain due to pregnancy³², and it has been concluded that the FTSSST is a valid and reliable method. In the present study, in parallel with the literature, we concluded that the FTSSST has excellent test–retest reliability in patients with ACL reconstruction. In light of these results, the FTSSST is a useful tool in patients with ACL-R.

The literature often refers to peripheral changes (morphological and cellular) in the quadriceps and weakness of the quadriceps following ACL-R³³⁻³⁵. This weakness and the resulting dysfunction have been shown to cause a decrease in knee-related quality of life, the development of

osteoarthritis, and decreased functionality^{6,36}. Noehren et al. stated that despite physical therapy after ACL-R, there was a loss of strength in the vastus lateralis muscle³⁵. In another study, Konisi et al. reported that dysfunction of the quadriceps muscles after reconstruction persisted for a long time in the uninjured knee³⁷.

In present study, a correlation was found between knee extension muscle strength and the FTSSST test. This may be because the quadriceps muscle is an antigravity muscle that plays an important role in both standing and sitting.

Proprioception is one of the most important sources of sensory information in maintaining body balance. After ACL reconstruction, proprioception decreases due to the removal of the Pacini and Ruffini bodies in the joint during surgery. Moussa et al. compared the postural stability of patients 2 years after ACL-R with that of healthy people and concluded that postural stability was worse in patients who had undergone ACL-R 38. Bonfirm et al. reported that ACL lesions have adverse effects on postural balance and proprioception³⁹. Similarly, in a study, Tookuni et al. stated that a unilateral knee ACL injury disrupts balance⁴⁰. The FTSSST assesses balance ability and muscle strength¹¹. Tiwari et al. stated that the strongest predictors of FTSSST performance in older adults were lower extremity muscle strength, and dynamic balance⁴¹. In another study, concluded that there is a strong correlation between the FTSSST and the Berg Balance Scale¹². In the present study, there was a strong

correlation between FTSSST and dynamic–static balance.

ACL injuries cause limitations in range of motion, loss of strength, muscle imbalance, atrophy, and functional instability of the knee. An attempt is made to regain stability and knee functionality through reconstruction surgery and an appropriate rehabilitation program. Patients are supposed to be followed for six months in rehabilitation clinics, but deficiencies in stabilization, mobility, and functionality can last for up to two years after surgery. Goldberg et al. stated that FTSSST is related to functional mobility in older adults⁴². Medina-Mirapeix et al. concluded that the FTSSST is related to functional mobility tests in patients with total knee arthroplasty⁴³. In the present study, a statistically significant relationship was found between the FTSSST and the Tegner activity score, which evaluates mobility, and the Lysholm score, which evaluates knee functionality. This result may be due to the fact that the sit-stand activity is also a mobility activity.

Study Limitation

The most important limitation of this study is that it was not conducted on professional athletes. Considering that ACL injury is common in professional athletes, it is recommended that future studies be conducted on different groups of athletes who have undergone ACL-R.

Conclusion

In conclusion, the FTSSST is a valid and reliable method for assessing muscle strength, balance, and mobility in patients who have undergone ACL-R. FTSSST may be preferred by clinicians and researchers working on ACL rehabilitation because it is simple, does not require equipment, and enables both face-to-face and remote evaluation.

Declarations

Conflict of interest

None

Funding

None

Authors' Contributions

HK: Conceptualization, Data curation, Formal Analysis, Methodology, Project administration Writing – review & editing. MY: Writing – original draft, Conceptualization, Formal Analysis. MC: Conceptualization, Writing – original draft. HA: Conceptualization, Writing – original draft. ŞK: Conceptualization, Formal Analysis. AÖ: Data curation, Writing – original draft.

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