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ΕΡΕΥΝΗΤΙΚΗ ΕΡΓΑΣΙΑ

Association between hop tests and self-reported knee function in patients after anterior cruciate ligament reconstruction

OBJECTIVE **To assess the asymmetries of the single, triple and crossover hop tests as predictors of function using International Knee Documentation Committee 2000 Subjective Knee Form (IKDC 2000) in anterior cruciate ligament (ACL) reconstructed patients 6–9 months after reconstruction.** METHOD **Twenty-four men (mean age 26.4±9.16 SD) at six to nine months (7.0±2.55 SD) after ACL reconstruction completed the single, triple and crossover hop tests and the IKDC 2000 form. Side-to-side asymmetries between the reconstructed and intact lower extremities were calculated for each test. After assessing for multicollinearity, a backwards multiple regression test was used with IKDC as the outcome variable and the side-to-side asymmetry of each hop test as predictors with cut-offs for entering the regression model at 0.05 and for removal at 0.15.** RESULTS **Multicollinearity did not pose a serious threat to the validity of the final model. All three hop tests were retained in the final model (adjusted R^2=0.33, p=0.012). Using a more conservative model, where variables were removed at the 0.10 level resulted in a model that included only the single leg hop test that was the most predictive of IKDC (adjusted R^2=0.25, p=0.008).** CONCLUSIONS **Asymmetries in the single, triple and crossover hop tests can predict knee function six-nine months after ACL reconstruction. Asymmetries in the single hop test are a strong predictor of self-reported knee function accounting for a quarter of the variance which increases to a third of the variance when all three hop tests are included.**

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ΑΡΧΕΙΑ ΕΛΛΗΝΙΚΗΣ ΙΑΤΡΙΚΗΣ 2025, 42(4):475–480

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Συσχέτιση μεταξύ αλτικών δοκιμασιών και της αυτοαναφερόμενης λειτουργικότητας του γόνατος σε ασθενείς μετά την ανακατασκευή του πρόσθιου χιαστού συνδέσμου

Περίληψη στο τέλος του άρθρου

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Treatment of anterior cruciate ligament (ACL) injury constitutes one of the most studied topics in orthopedic sports medicine.[1] Understanding and recognizing the risks for ACL injury is of crucial importance as approximately 200,000 ACL injuries occur annually in the United States[2,3] where incidence rates of ACL reconstruction increased the last decade.[4,5] ACL reconstruction is a high-volume procedure due to the cost of ACL reconstruction itself and the high incidence of post-traumatic osteoarthritis within ten years.[4,6–10]

In order for patients to safely return to sports, a plethora of rehabilitation protocols have been developed focusing on developing neuromuscular control, muscle strengthening and knee joint stability.[11–14] Despite the remarkably evolving scientific contribution to ACL rehabilitation, muscle strength, biomechanical and functional asymmetries persist for ACL reconstructed patients, more than two years after reconstruction.[15–20] The aforementioned asymmetries may predispose to increased risk of secondary injury.[2,21–24] Thus, it is of crucial importance for clinicians to have reliable and easy-to-use tools in order to evaluate functional asymmetries and identify athletes whose function after ACL reconstruction is still limited. Examples of such tools are the dynamic functional tests such as the hop tests

(single, triple, crossover hop tests). Hop tests have been widely used in order to assess knee functional side-to-side deference and dynamic knee stability, while reproducing sports specific functional maneuvers.[23,25–28] These tests have been shown to predict short-term dynamic stability in ACL deficient and reconstructed patients.[16,17,29]

To assess global knee function, the International Knee Documentation Committee 2000 (IKDC 2000) has been widely used with good reliability and validity.[30] The IKDC 2000 is a clinically relevant questionnaire which can additionally assess readiness of returning to sports after ACL reconstruction.[31,32] Thus, the purpose of the present study was to assess the association between functional asymmetries of three widely used hop tests (single, triple and crossover hop test) with functional outcomes of the IKDC 2000. We hypothesized that the hop tests were associated with functional outcomes in ACL reconstructed patients six-nine months after reconstruction.

MATERIAL AND METHOD

Participants

In order for the patients to be included in the study, strict selection criteria were used. All participants had completed an informed consent prior to data collection and the Institutional Review Board of the University approved the study protocol, following the Declaration of Helsinki (1975). All participants had to be diagnosed with a complete, unilateral, isolated ACL tear, with no previous injury to the lower limbs. Furthermore, all patients were male having undergone ACL reconstruction by the same surgeon (ADG) with a single bone-patellar tendon-bone (BPTB) autograft between six and nine months from injury. Participants should be able to jog brace free and with a minimum Tegner score of 4.0. Patients with musculoskeletal conditions affecting lower-limb kinematic, kinetic and functional ability, history of injury to the contralateral knee, meniscal damage more than 25%, collateral or posterior cruciate ligament damage at the time of surgery, serious coexistent chondral lesions (Outerbridge classification III or IV), complications after ACL surgery, persistent abnormal pain, swelling or laxity of the knee at the time of testing (anterior tibial translation exceeding 3 mm compared to the healthy knee, measured by a KT1000 arthrometer), patellofemoral joint irritability, cardiorespiratory ailments, or vestibular dysfunction.

Twenty-four (n=24) men (tab. 1) who were included in this study, according to the above criteria, completed a postoperative rehabilitation program in outpatient physical therapy departments. As mentioned in a previous study,[16,17] the rehabilitation program was not controlled, in an effort to increase the external validity. Nevertheless, although the compliance was not recorded, all physical therapists were provided with a rehabilitation protocol.[33]

Testing procedure

All testing was done by a single examiner at the same lab. Participants were using comfortable clothing and athletic footwear. Anthropometric data were collected for all participants and limb dominance was defined by the preferred limb to kick a ball as far as possible.[22] In terms of questionnaires, Tegner activity scale was used to identify the activity level and the subjective form of the IKDC 2000[34,35] was completed to assess the functional state of the involved knee. Even though these data were not used in the present study, patients also performed an isokinetic evaluation as part of a larger project and between the isokinetic and the functional hop testing, participants rested for five minutes, in order to avoid fatigue.[16,17] Hop testing included the single hop for distance, the triple hop for distance and the triple crossover hop for distance which are presented in the literature with an excellent test-retest

Table 1. Demographics of participants (n=24).

Mean age in years *(SD, range)*	26.43 (9.16, 17.39–48.39)
Mean height in meters *(SD, range)*	1.77 (0.08, 1.65–1.92)
Mean body mass in kg *(SD, range)*	75.83 (18.04, 55–108)
Injured side	12 left, 12 right
Partial meniscectomy	3/24
Time from surgery to evaluation in months *(SD, range)*	7.93 (2.55, 6.06–18.16)
Time from injury to surgery in months *(SD, range)*	5.89 (5.50, 0.23–20.4)
Main sport participated before injury *(N)*	Soccer (11), basketball (2), running (1), skiing (2), indoor soccer (8)
Median Tegner before injury *(range)*	7.5 (6–9)
Main sport participated at evaluation *(N)*	Running and swimming (15), running and cycling (2), soccer (5)
Median Tegner at tested time *(range)*	5.16 (4–7)
Mean IKDC *(SD, range)*	72.5 (8.8, 57.5–86.2)

ACLR: Anterior cruciate ligament reconstruction, IKDC: International Knee Documentation Committee, Subjective Knee Evaluation Form, SD: Standard deviation, N: Number

reliability.[28,36–38] All participants were given details regarding the execution of the hop tests and trial repetitions were allowed to ensure safe and efficient technique. A test was considered successful only if the participant landed on one foot and maintained his balance for at least two seconds.[37] In order to record three successful hops of the different single hop test for each lower limb, participants performed three practice trials and three test trials for each of the different hops. For all single, triple and crossover hops, testing began with the intact lower extremity, followed by the reconstructed, while the use of any brace was not allowed during the functional hop testing. The sequence of jumps was always from single hop to the triple hop and finally to the crossover hop. Sufficient rest was provided between hops whenever needed. Side-to-side asymmetries between the two lower extremities were calculated as per the following formula: distance when jumping on the reconstructed lower extremity/distance when jumping on the intact lower extremity ×100.

Statistical analysis

For the statistical analysis of the data, the Statistical Package for Social Sciences software, version 20.0 was used (IBM SPSS Statistics) and a backwards multiple regression test was performed with IKDC as the outcome variable and the asymmetry of each one of the three hop tests as the predictors. The cut-offs for entering the regression model was set at 0.05 and for removal at 0.15. Multicollinearity statistics were produced as the hop tests may be highly correlated to each other.

RESULTS

All three hop tests were retained in the final model (adjusted R^2=0.33, p=0.012) (tab. 2). The collinearity statistics found that the variance inflation factor was <2.5 for each hop test; thus it was determined that multicollinearity did not pose a serious threat to the validity of the final model. Using a more conservative model where variables were removed at the 0.10 level resulted in a model that included only the single leg hop test that was the most predictive of IKDC (adjusted R^2=0.25, p=0.008). However, as performing all three tests is relatively quick and simple, the authors believe that the additional explanation of the variance by the triple and crossover hop tests may be valuable.

Table 2. Regression models.

Models	R	R^2	Adjusted R^2	p values
Single hop	0.528	0.278	0.246	0.008*
Single, triple and crossover hop	0.646	0.417	0.329	0.012*

* Statistical significance p≤0.05

DISCUSSION

The purpose of the present study was to examine if asymmetry of three commonly used hop tests can predict self-reported knee function assessed with the IKDC 2000 in patients six-nine months after ACL reconstruction. This period is crucial, since it usually coincides with the return to sport after ACL reconstruction. Thus, functional assessment plays a key role for a safe return to sports, especially considering that the first year after surgery is the most dangerous for a re-injury. The findings demonstrate that a combination of the three hop tests explains one third of the variability in the IKDC while the single hop test alone explains a quarter of the variability. Although the single hop test is the strongest predictor of self-reported knee function, the combination of all three hop tests (single, triple and crossover hop tests) explains a higher percentage of the variability.

Considering the large number of ACL injuries and ACL reconstructions, physical therapists would benefit from easy and reliable evaluation tools to decrease the cost and enable safe assessment of patients' functional competency. Dynamic functional tests, such as the hop tests, have been widely used in recent years as they can easily assess function and performance of ACL reconstructed patients.[39] Furthermore, hop can be easily used on the field with no special equipment. Hop tests such as the single, triple, and crossover hop tests have been commonly used for the recognition of dynamic functional asymmetries. The findings of the present study showed that the single hop test can strongly predict self-reported knee function, in patients six-nine months after reconstruction, which is in line with the results of the findings of a previous study,[32] indicating that the single hop test conducted six months after reconstruction is a predictor of medium-term self-reported knee function one year after reconstruction. By recognizing easily and timely knee functional asymmetries, clinicians can reasonably intervene in order to restore knee function[17,32] and possibly reduce re-injury rates.

Furthermore, ACL reconstruction targets the restoration of knee stability and function which is a multifactorial process, as the biomechanics and the neuromuscular coordination of both the reconstructed and healthy lower limbs have to be restored for a safe return to sports.[13,16,18] Although, muscle strength as well as biomechanical and neuromuscular parameters constitute the main criteria that ACL reconstructed patients have to achieve in order to safely return to sports[3,26,29] pre-previous research showed that asymmetries of the single hop test correlate with knee muscle strength asymmetries, but not with kinematic and kinetic asymmetries.[16]

The findings of the present study need to be interpreted in light of its limitations. The rehabilitation protocol and compliance were not strictly controlled for the patients throughout the post-operative period. The findings of the present study cannot be generalized to all ACL reconstructed patients, as the participants were all male, athletic and had a patellar tendon graft. Thus, the results cannot be generalized to females or patients who received hamstrings grafts or allografts. However, since hop testing and self-reported knee function are crucial for the holistic assessment of the ACL reconstructed knee, our findings emphasize the importance of including all three single hop tests in the battery of tests aiming to reduce re-injury risk after return to sports.

In conclusion, single, triple and crossover hop tests were significant predictors of knee function 6 to 9 months after ACL reconstruction. It is of importance that 25% of the variability of ACL reconstruction perceived function can be explained by the single hop test alone, which can be very helpful for clinicians, as a quick means to identify functional deficits. However, prediction of functional competency after ACL reconstruction can be enhanced by using all the three hop tests, as shown in this study.

ΠΕΡΙΛΗΨΗ

Συσχέτιση μεταξύ αλτικών δοκιμασιών και της αυτοαναφερόμενης λειτουργικότητας του γόνατος σε ασθενείς μετά την ανακατασκευή του πρόσθιου χιαστού συνδέσμου

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ΣΚΟΠΟΣ Η αξιολόγηση των ασυμμετριών των δοκιμασιών μονού, τριπλού και τριπλού διαγώνιου μονοποδικού άλματος (single, triple και crossover hop) ως προγνωστικοί παράγοντες λειτουργικότητας χρησιμοποιώντας τη διεθνή κλίμακα αξιολόγησης λειτουργικότητας γόνατος (IKDC 2000) σε ασθενείς μετά από ανακατασκευή του πρόσθιου χιαστού συνδέσμου (ΠΧΣ) 6–9 μήνες μετά τη χειρουργική αποκατάσταση. **ΥΛΙΚΟ-ΜΕΘΟΔΟΣ** Είκοσι τέσσερις άνδρες (μέση ηλικία 26,4±9,16 SD) 6–9 μήνες (7,0±2,55 SD) μετά την ανακατασκευή του ΠΧΣ, ολοκλήρωσαν τις δοκιμασίες single, triple και crossover hop και τη φόρμα IKDC 2000. Για κάθε δοκιμή υπολογίστηκαν οι πλευρικές ασυμμετρίες μεταξύ των χειρουργημένων και των υγιών κάτω άκρων. Μετά την αξιολόγηση της πολυσυγγραμμικότητας (multicollinearity), εφαρμόστηκε μια δοκιμασία πολλαπλής παλινδρόμησης προς τα πίσω (backward) με το IKDC ως μεταβλητή έκβασης και την πλευρική ασυμμετρία κάθε δοκιμής άλματος (hop) ως προγνωστικοί παράγοντες, με όρια για την εισαγωγή στο μοντέλο παλινδρόμησης στο 0,05 και για την αφαίρεση στο 0,15. **ΑΠΟΤΕΛΕΣΜΑΤΑ** Η πολυσυγγραμμικότητα δεν αποτελούσε σοβαρή απειλή για την εγκυρότητα του τελικού μοντέλου. Και οι τρεις δοκιμές άλματος διατηρήθηκαν στο τελικό μοντέλο (προσαρμοσμένο R^2=0,33, p=0,012). Η χρήση ενός περισσότερο συντηρητικού μοντέλου όπου οι μεταβλητές αφαιρέθηκαν στο επίπεδο 0,10 οδήγησε σε ένα μοντέλο το οποίο περιλάμβανε μόνο τη δοκιμασία single leg hop, που αποτέλεσε το πιο προγνωστικό για το IKDC (προσαρμοσμένο R^2=0,25, p=0,008). **ΣΥΜΠΕΡΑΣΜΑΤΑ** Οι ασυμμετρίες στις δοκιμασίες single, triple και crossover hop μπορεί να προβλέψουν τη λειτουργικότητα του γόνατος 6–9 μήνες μετά τη χειρουργική αποκατάσταση του ΠΧΣ. Οι ασυμμετρίες στη δοκιμασία single hop συνιστούν ισχυρό προγνωστικό παράγοντα της αυτοαναφερόμενης λειτουργικότητας του γόνατος.

Λέξεις ευρετηρίου: Αλτικές δοκιμασίες, Ανακατασκευή πρόσθιου χιαστού συνδέσμου, Λειτουργικότητα γόνατος

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