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SYSTEMATIC REVIEW

THE CLINICAL UTILITY OF FUNCTIONAL PERFORMANCE TESTS WITHIN ONE-YEAR POST-ACL RECONSTRUCTION: A SYSTEMATIC REVIEW

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ABSTRACT

Introduction: A tear of the anterior cruciate ligament (ACL) represents a significant injury for an athlete that requires substantial time away from sport, and significant rehabilitation after reconstruction. The physical therapist is responsible to determine when a patient is capable of tolerating the physical demands of daily activities and to attempt to prevent re-injury. Physical or functional performance tests (FPTs) are one mechanism used to evaluate the athlete's physical skills and capabilities prior to returning to sports participation. The purpose of this systematic review is to critically examine the clinical utility of functional performance tests used with patients less than or equal to one year post ACL reconstruction.

Methods: A systematic review of the relevant literature was performed using PRISMA guidelines. A total of twelve studies were included for analysis.

Results: Two independent blinded reviewers then analyzed and rated the final included articles (n = 12) utilizing the Newcastle-Ottawa Scale (NOS). Percent overall agreement between raters for the NOS was 88% with a fixed-marginal kappa (κ) of 0.80. Of the 12 included articles, the FPTs were utilized as an outcome measure within the study design (41.7%) or studied as a measure of function (58.3%). Among those studies that used FPTs as a "measure of function" 71.4% studied a battery of FPTs, while 28.6% studied a single test. None of the studies utilized FPTs as a measure to determine readiness to return to sport.

Discussion: FPTs are being utilized with patients, less than or equal to one year post ACL reconstruction, either as an assessment of functional performance or as an outcome measure. No studies identified a FPT or test battery that has construct or predictive validity for "return to sport" in athletic population one-year post-ACL reconstruction. The identification of the critical elements within the return to sport construct may allow lower extremity performance tests to be developed or test batteries assembled to incorporate the appropriate tests to examine all of these elements deemed critical. Additionally the current FPTs should undergo content and predictive validation to assist the sports physical therapist in determining the readiness of the athlete for return to sport.

Key Words: ACL reconstruction, athlete, physical performance measure

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INTRODUCTION

A tear of the anterior cruciate ligament (ACL) represents a significant injury for an athlete that requires substantial time away from sport. The injury requires significant rehabilitation, creates anxiety for an athlete regarding the potential for return to sport at the previous competitive level, and often requires surgical intervention.[1,2,3] Between 43% and 92% of athletes return to sports after ACL reconstruction and an extended rehabilitation intervention (6 to 12 months).[4] In clinical practice, it is often the responsibility of the physical therapist to determine when a patient is capable of tolerating the physical demands of daily activities or sports participation, and to prevent re-injury after proper care.[5]

Determining an individual's ability to participate in sporting events requires careful evaluation of the rigors and demands on the athlete within his/her designated sport.[6] One mechanism used to evaluate an athlete's ability to safely return to sport post ACL reconstruction is the use of physical or functional performance tests (FPTs). FPTs are designed to evaluate a variety of skills that are necessary to participate in higher level functions such as sport or recreation.[6] Functional performance testing requires the ability to move through up to three planes of movement. FTPs are assessed by means of qualitative and quantitative information related to specialized motions involved in functional activities.[6] The tests are often utilized for assessment of the athletes' pain, muscle strength and power, lower extremity joint stability in multiple planes of movement, endurance, muscle flexibility, balance, proprioception, speed, agility, and level of aerobic and anaerobic condition.[6-9]

Some of the identified FPTs pertaining to the knee following ACL injury and reconstruction include the single-leg hop test, the single leg squat, the active straight leg raise, the in-line lunge, and the deep squat.[6,10] Others, such as the shuttle run, side-step[10], resisted knee extension, resisted knee flexion, and leg press[11], may be used in combination as a test battery to include a variety of constructs that when combined resemble function.

There are numerous FPTs used in the rehabilitation of athletes who suffer a lower extremity injury, such as an ACL reconstruction. The authors are unaware of a comprehensive review of the literature that has examined utility of the FPTs in clinical practice. The authors anticipate that the FPTs are being used clinically as outcome measures to evaluate recovery, to define recovery in terms of function, and to determine if a patient is able to return to sport. Therefore, the purpose of this systematic review is to critically examine the clinical utility of functional performance tests used with patients less than or equal to one year post ACL reconstruction.

Methods

Literature Search

This study was a descriptive systematic review that utilized the PRISMA guidelines[12] during the literature search and final reporting phases of the systematic review process. Two authors (EN and AW) independently reviewed titles, abstracts, and keywords of retrieved publications to assess their eligibility. Inclusion criteria were established prior to initiating the search. Articles were included if they were written in English, written within the last two decades (1991-2011), case controlled, randomized control trials, or cohort studies, subjects who were post ACL-reconstruction within one year[4], and must have at least one lower extremity/knee functional performance test as the primary measure of the article. Articles were excluded from the review for the following reasons, the study was conducted on healthy subjects, patients over 1 year post reconstruction, if the functional performance measure was used as an intervention and not assessment, and/or if the study population had an ACL deficient knee. The time frame of 12 months was chosen secondary to a study that determined that athletes, on average, met return to sport criteria 6-12 months after surgery.[4]

The computer-based search utilized was completed on MEDLINE (MeSH terms), PubMed (keywords), along with a multi database search of CINAHL, MEDLINE, HealthSource, and SPORTDiscus. A cross-reference search of key terms was also performed in order to find research evaluating PPTs of the knee for return to sport in a post-operative ACL reconstructed patient population. A MeSH search was conducted using the terms "knee" AND "athletic injuries" OR "athletic performance" AND "sports" AND "exercise test/instrumentation" OR "exercise test/methods." The keyword search was also performed on PubMed

utilizing the key terms "anterior cruciate ligament" AND surgery AND injury AND physical performance measures and "lunge" OR "hop test." To ensure a detailed and comprehensive search strategy, the authors also performed an additional search within academic textbooks and chapters that contained an extensive review of functional performance tests.[6]

Two authors independently reviewed each study to determine inclusion. Two reviewers independently assessed the methodological quality of all the included studies and recorded their findings.

Newcastle Ottawa Quality Assessment Scale

The ability to assess the quality of study is a critical component of any systematic review. Unfortunately, there were no randomized controlled trials or clinical trials that met the inclusion criteria, which eliminated many validated literature assessment tools. The study designs of case-control and single cohort research designs are appropriate for the population being investigated in this study; therefore appropriately assessing that type of research design becomes important. The NewCastle-Ottawa Scale (NOS) provides an objective assessment of the quality of the type of studies that are included in the current descriptive systematic review.

Wells et al[14] proposed a scale for assessing the quality of published non-randomized studies called the Newcastle-Ottawa Scale (NOS). This tool can either be used as a checklist or scale. The NOS was developed using a Delphi process and thereafter was tested on systematic reviews and further refined. Separate NOS scales were developed for cohort and case-control studies. The NOS contains eight items, categorized into three dimensions including selection, comparability, and—depending on the study type—outcome (cohort studies) or exposure (case-control studies). For each item a series of response options is provided. A star system is used to allow a semi-quantitative assessment of study quality, such that the highest quality studies are awarded a maximum of one star for each item with the exception of the item related to comparability that allows the assignment of two stars. The NOS applies to and separately assesses cohort and case-control study designs, whereas other assessment tools do not separate the assessment of these designs.[14]

Results

PRISMA

A literature search utilizing the PRISMA guidelines yielded a total of 272 articles. After 10 duplicates were removed, a total of 242 were immediately excluded based on title or abstract revealing a lack of relevance to subject matter, non-English language, or that they met exclusion criteria (article included only healthy subjects, the subjects were greater than one-year post-operation, the FPT was used only as an intervention, and/or the ACL deficiency meaning ligament laxity only). A full text review was conducted on 30 articles. A total of eighteen of the 30 full text studies were excluded. Six of the studies were excluded secondary to the studies utilization of subjects that were ACL deficient and not ACL reconstructed,[9,15-19] 8 studies were excluded based on the incorporation of subjects that were greater than one-year post-ACL reconstruction,[7,20-26] and 4 studies were excluded for using healthy subjects only.[29-32] A total of 12 studies met the inclusion criteria and were assessed for quality using the NOS.

Inter-rater reliability

The kappa (κ) statistic was used to determine the agreement between raters throughout the PRISMA process. Two independent reviewers then examined the all of the articles during the screening process to identify articles meeting the inclusion and exclusion criteria and to remove duplicates. Agreement was 100% kappa ($\kappa = 1$) for the full text articles that were included for evaluation.[33]

The 12 included studies were evaluated based on study design (Appendix 1). There were no randomized clinical trial studies that met the inclusion criteria. There were only cohort and case series studies included for review. The method of critical article appraisal was completed using the NOS. Two independent blinded reviewers assessed the quality of the 12 included studies utilizing the NOS scoring guide for case control (Table 1) and cohort studies (Table 2). The percent overall agreement between raters based on the total summary score of each article on the NOS was 88%, with a fixed-marginal kappa (κ) of 0.80.[34] This implies that the raters demonstrated substantial to almost perfect agreement in their ability to rate the included studies with this tool.[33,34]

Table 1. *NOS scores for included case control studies.*

Author for Case Control Scoring	Selection (0-4 Stars)		Comparability (0-2 Stars)		Outcome (0-3 Stars)	
	Rater 1	Rater 2	Rater 1	Rater 2	Rater 1	Rater 2
Paterno et al 1996[8]	***	*	**	**	***	***
Colby et al 1999[33]	***	***	**	**	***	***
Bjorkland et al 2006[36]	***	***	**	**	**	***
Gustavsson et al 2006[34]	****	****	**	**	***	***
Neeter et al 2006[11]	****	****	**	**	***	***

Star (*) Indicates score given to study according to NOS standard assessment scale. The more stars (*) awarded indicate a higher quality study.

Table 2. *NOS scores for included cohort studies.*

Author for Cohort Study	Selection		Comparability		Outcome	
	Rater 1	Rater 2	Rater 1	Rater 2	Rater 1	Rater 2
Wilk et al 1994[40]	**	**	**	**	0	0
Keays et al 2003[39]	***	***	**	**	**	**
Reid et al 2007[37]	**	**	**	**	**	**
Bjorkland et al 2009[10]	**	**	**	**	*	**
Lentz et al 2009[3]	***	***	**	**	***	*
Orishimo et al[38] 2010	**	**	**	**	0	0
Ardern et al 2011[37]	***	***	**	**	***	***

Star (*) Indicates score given to study according to NOS standard assessment scale. The more stars (*) awarded indicates a higher quality study.

After careful synthesis of each included article, it became apparent that FPTs were utilized as outcome measures within the study design for data collection, and as a measure of function. None of the articles utilized FPTs for determination of return to sport. Table 3 identifies the specific performance test from each study, establishes how tests were utilized, and gives a brief description of each study. Some studies use the FPT for more than one purpose. A majority of the included studies utilized the PPTs as a measurement of function (n = 7; 58.3%). Fewer studies utilized the FPT as an outcome measure within the study design (n = 5; 41.7%). There were no studies that evaluated return to sport.

The 7 articles that fell within the category 'assessment of construct validity as a measure of function' utilized FPTs as a single test or within a battery. The majority of articles were identified as using FPTs as a measure of function within a battery (n = 5; 71.4%), while fewer used a single test (n = 2; 28.6%) and are identified in Table 4.

Table 3. *Purpose of performance test in included studies.*

Purpose of performance test	Frequency (%) n=12
Outcome measure	41.7%
Measure of Function	58.3%
Measurement to determine readiness to return to sport	0%

Table 4. *How performance tests were used within the category 'measurement of function'*

Performance test	Frequency (%) n=7
Battery	71.4%
Single Test	28.6%

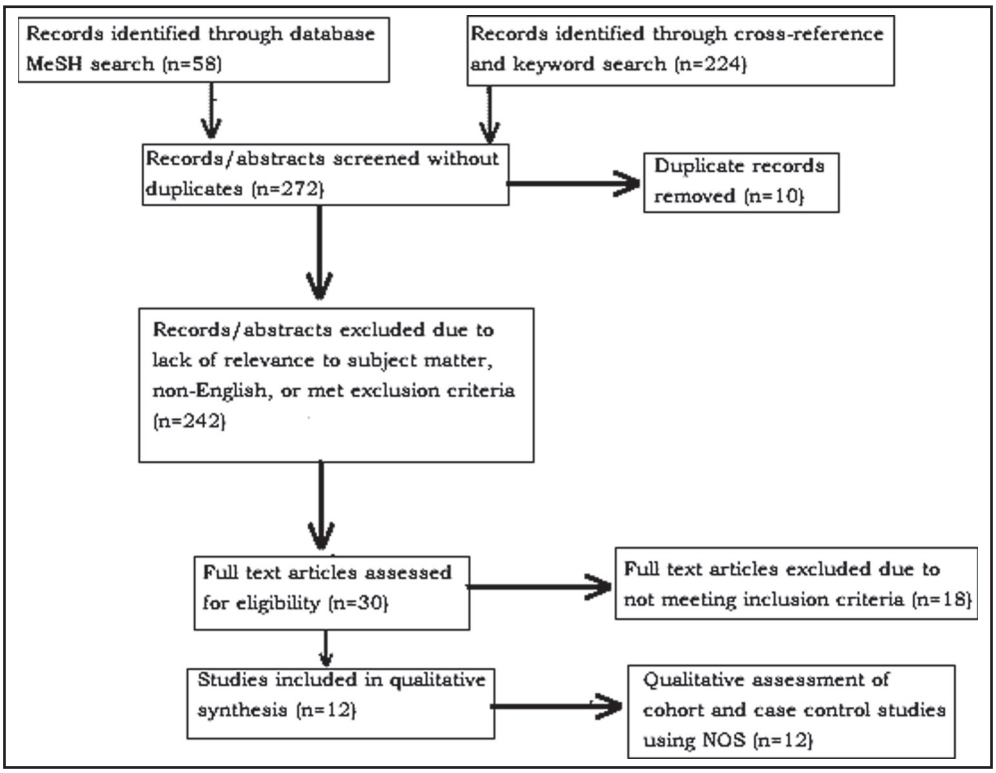

Figure 1. *PRISMA diagram for study selection.*

DISCUSSION

The purpose of this systematic review is to critically examine the clinical utility of functional performance tests used with patients less than or equal to one year post ACL reconstruction. Of the included articles, seven[8-11, 33-36] assessed the construct validity of FPTs as a measure of function. These articles looked at FPTs, whether alone or in a cluster, in terms of development, responsiveness, reliability, and overall validity in different patient populations following ACL-reconstruction. In evaluating the construct of the FPTs, the tests mentioned in Table 3 appear to be well validated in terms of assessing function for return to everyday life, and measuring general functional ability. For example, the single leg hop test and was the most commonly encountered FPT within these studies, alone or clustered with other FPTs. The single leg hop test, which measures maximal distance scored for each limb, is often clustered with double leg hop test, jogging straight forward, cross over hop test, and double legged squat test.

In practice, several FTPs are often grouped into test batteries that are used and supported in the literature to measure power, speed, balance, and single lower extremity control of the athlete.[6] However, there are other measures, such as the Tests for Athlete's with Knee Injuries (TAK)[10,36], which demonstrate a more detailed assessment of functional performance. The TAK is a battery of 8 tests that measures strength,

stability, pain, endurance, coordination, active range of motion, and balance.[10,36] The TAK incorporates many of the necessary components of FPTs, and may arguably have components that may be used for assessing readiness to return to sport. However the TAK has not been studied to ensure validation of content or whether its outcomes can predict ability to return to sport. The authors were unable to find studies that examined the clinical utility of FTP tests or test batteries ability to successfully or unsuccessfully predict return of the athlete to sports beyond the rehabilitative period.[8] Specifically, the battery or test do not measure an athlete's performance of the previously mentioned variables necessary to ensure a safe, injury free return to sport.

No studies found to meet the inclusion criteria for this systematic review discussed functional performance tests or battery to examine all of the concepts related to return to sport. It may be clinically important to have physical performance tests that have been validated with in the return to sport construct, which may differ between varied sports. Clinically it may help the practitioner decide which test or test battery to use for assessment and assist in the decision making when returning an athlete back to a high demand sport. The current lack of literature to guide clinical decisions may suggest that clinicians rely on their intuition or clinical experience when making this determination.

The remaining five[3,37-40] articles utilized FPTs an outcome measure within the respective study design. This allowed the authors to determine the effectiveness of the FPT as a means of assessing the athlete's projected results. These studies utilized scores obtained from the hop test to measure biomechanical adaptations in the post-ACL reconstructed patient, and found that compensations by other joints can suggest protective adaptation mechanisms to avoid loading through the reconstructed knee.[38] A positive correlations has been identified with the three variations of the hop test and knee extension torque. A significant correlation was found between quad strength and functional stability.[39,40] The single limb hop for distance and the cross-over hop test scores were found to serve as an indicator of an athlete's likelihood to return to sport.[37] The single limb hop test as an outcome measure has been validated to measure multiple concepts with in the functional performance testing construct, including strength, stability, and patient subjective report of performance.[6] Functional performance testing has been used to identify progress, discover weak components in an athletes' performance, and guide treatment progression in the clinical setting.[6] Although, functional performance testing is valuable in the assessment of ACL injured patients, this systematic review did not identify any clinical test or battery of tests that predicts the athletes' ability to return to play sports.

Further research is needed to identify what specific components of physical performance are required for an athlete to return to sport after sustaining a lower extremity injury. The identification of the critical elements or components within the return to sport construct may allow lower extremity performance tests or test batteries to be developed to incorporate the appropriate tests to examine all of these elements deemed critical. Future research should be conducted in order to examine the predictive ability of FPTs or whether a given test battery predicts the athletes' ability to return to play sports. This type of research could aid in the decision making for clinicians when attempting to return an athlete back to sport safely within one-year post ACL reconstruction.

Limitations

As previously described, the utilization of the New Castle Ottawa Scale to evaluate studies in this literature review poses a limitation within the study. The NOS is in the developmental phases of defining study quality as poor to good, but was the only scale found to separately assess the included cohort and case-control study designs. However, the use of this scale in the current study may add to the literature that utilizes the NOS for assessment. Recall that minimal variability was found in the authors assessment of the actual quality of articles included in this systematic review with an inter-rater reliability of 88%.

An additional limitation may have been the exclusion of studies that included subjects that had an ACL reconstruction more than one year previously. This may have allowed the authors to miss some additional characteristics of the FPTs used on a population with delayed healing. However, the literature review conducted for this systematic review suggested that many athletes met return to sport criteria on average 6-12 months post-surgery.[4] While study results have

shown that the typical individual will return to sport within 6-12 months, there is not a definitive objective measure that determines if this time frame is appropriate.[4] Therefore, studies that included subjects greater than one-year post ACL reconstruction may have utilized functional tests in order to determine readiness to return to sport in those athletes. Consequently, a more thorough analysis using those studies that examine athletes greater than one year post-operatively could potentially generate additional results, which may assist a clinician in making a judgment regarding readiness to return to sport.

CONCLUSION

There is a lack of literature that examines the clinical utility of functional performance testing in relationship to return to sport one-year post-ACL reconstruction. The clinical utility of FPTs identified in this review suggests that they are used as a measure of function or as an outcome measure. Based on the authors findings, one isolated functional test may be insufficient to assess the dynamic functional capacity of an athlete required to return to playing sports.[6] A functional performance testing battery may incorporate multiple performance variables (i.e. strength, power, proprioception, balance, endurance, flexibility, speed, agility, aerobic conditioning, and lower extremity joint stability in multiple planes of movement) that more broadly address the necessary sport specific demands. The identification of physical performance measures (i.e. cutting, stability, power, etc.) of the lower extremity for the athlete to successfully return to sport is needed may be needed. This may allow additional performance tests to be developed or test batteries developed to incorporate the appropriate tests to examine all of these elements deemed critical. Additional validation studies in this area should be performed in order to guide a safe return to sport following an ACL re-injury in the first year following reconstruction.[41]

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APPENDIX: DESCRIPTIONS OF THE 12 INCLUDED STUDIES.

Author	Subject Population	Focus of Study	Performance Test(s) Utilized	Purpose of PPT Within Study
Wilk et al 1994[40]	N=50 patients ≤ 6 months post ACL reconstruction	To find a correlation between three clinical tests: knee isometric testing, single leg hop, and subjective knee score in ACL repaired knees	Single Leg Timed Hop Test, Compared Bilaterally	Outcome measure
Paterno et al 1996[8]	N=20 subjects with no history of lower extremity injury; N=13 subjects 20-52 weeks post ACL reconstruction	Determination of the test-retest reliability of a functional one legged hop test for distance in individuals with and without ACL reconstruction	Single Leg Hop for Distance x1	Measure of Function (Single Test)
Neeter et al 1996[11]	N=13 subjects with no history of lower extremity injury; N=23 subjects with 6 months post ACL injury; N=24 subjects 6 months post ACL reconstruction	Development of a test battery of lower extremity strength tests with high ability to discriminate between leg power development	Knee Extension Power Test; Leg Press Power Test; Knee Flexion Power Test	Measure of Function (Test Battery)
Colby et al 1999[33]	N=11 subjects post 158±31 days ACL reconstruction; N=13 subjects with ACL deficiency	Development of a functional test measuring dynamic stability that can differentiate between injured and uninjured limb and it's reliability	Single Leg Hop Onto Force Plate starting from the patients leg length away; Single Leg Step Down Test onto Force Plate	Measure of Function (Test Battery)
Bjorklund et al 2006[36]	N=31 subjects post ACL reconstruction; N=14 subjects with ACL injury; N=14 uninjured subjects	Evaluation of intra-rater and inter-rater reliability of the 'Tests for Athletes with Knee Injuries'	Jogging straight forward; fast running straight Forward; one-leg standing flexing the knee; rising on one leg from a seated position; squatting down with equal weight; one-leg hop for distance; one leg vertical jump; cross over one-leg hop	Measure of Function (Test Battery)
Gustavsson et al 2006[36]	N=30 subjects 11 months post ACL injury; N=35 subjects mean 6 month post ACL reconstruction; N=15 healthy subjects	Test battery of hop tests with high ability to discriminate between hop performance of the injured and uninjured side	Drop Jump followed by a Double Hop for Distance; Single Leg Hop for Distance (Hands Behind Back); Single Legged Vertical Hop (Hands Behind Back); Side Hop; Square Hop	Measure of Function (Test Battery)

Bjorkland et al 2009[10]	N=35 subjects tested 4 and then 8 months post ACL reconstruction	Evaluation the validity and responsiveness of the 'Tests for Athletes with Knee Injuries'	Jogging straight forward 2 x 20 m and then in a figure of eight; Fast running straightforward 2 x 20 m with acceleration to full speed; one-leg standing flexing the knee x 3; Rising on one leg from a seated position with the knee flexed in 90° x 3; squatting down with equal weight on both legs x 3; One-leg hop for distance; 10 hops in rapid succession hopping as far distance as possible; One-leg vertical jump in rapid succession: jumping as high as possible, using the stretch shortening cycle x 5; crossover one-leg hops in rapid succession.	Measure of Function (Test Battery)
Orishimo et al 2010[38]	N=13 subjects 4-12 months post ACL reconstruction	Comparison of take off and landing biomechanics between legs in patients post ACL reconstruction	Single Leg Horizontal Hop Off Of Test; Single Leg Horizontal Hop Onto Test	Outcome Measure
Reid et al 2007[35]	N=42 subjects testes 16 weeks and 22 weeks post ACL reconstruction	Investigation of the reliability and longitudinal validity of data obtained from the hop test after ACL reconstruction	Triple Hop For Distance	Measure of Function (Single Test)
Keays et al 2003[39]	N=31 subjects tested 1 week pre- and 6 months post ACL reconstruction	Assessment of the relationship between muscle strength and functional stability in pre- and post-operative ACL reconstructed knees	Carioca Test; Side Step; Shuttle Run	Outcome Measure
Lentz et al 2009[3]	N=58 subjects 6-12 months post ACL reconstruction	Investigation of the association of knee impairment and psychological variables with function in subjects with ACL reconstruction	Single-Legged Hop Test	Outcome Measure
Ardern et al 2011[37]	N=503 post-ACL reconstructed athletes	Investigating return to sport rate and participation level after ACL reconstruction surgery	Single hop for distance; triple cross over hop	Outcome Measure