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FUNCTIONAL PERFORMANCE MEASURES USED FOR RETURN- TO-SPORT CRITERIA IN O' DONOGHUE'S TRAIID: REVIEW OF LITERATURE

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ABSTRACT

Background: O'Donoghue's triad or the so-called "Unhappy Triad" is an extremely debilitating condition. It mainly affects athletes, excluding them for a long time from their sports activities.

As sport participation increases globally, so will injury-related risks. The process used to determine return-to-sport following injury is vital to future sport participation and injury prevention. Early specialization along with poor management of sport participation causes an increase in injury risk and potential long-term health consequences for youth athletes. Dynamic instability of the knee joint is restored over a long period of time. For functional assessment and monitoring of the dynamics of recovery and rehabilitation intervention, it is necessary to make an analytical selection of a test battery from functional indicators and tests corresponding to the dysfunctions of the operated knee.

Objective: The purpose of this study is to develop a diagnostic system for functional assessment of patients after surgical treatment of the O'Donoghue Triad for assess sport-specific functional performance. Previous injury is a common intrinsic risk factor for new injuries. Identifying functional performance deficits, defined by return-to-sport criteria, minimizes these risk factors and provides athletes with guidelines to return safely to sport.

Methodology: A literature review was completed using numerous databases, where 22 articles were included in this commentary. Of the 22 articles using functional performance measures for return-to-sport criteria, 6 were specific to youth, 12 had mixed populations of adults and youth, and 4 were normative samples for specific youth populations.

Conclusions: Due to the inconsistencies in terminology, definitions, and standardization of clinical assessment tools, it seems necessary to create a comprehensive functional performance test battery for the lower extremity that can be used as return-to-sport criteria.

Keyword: _unhappy triad; O'Donoghue's triad; sports injuries, agility, collegiate athlete, functional performance test, return-to-play

I. INTRODUCTION

The unhappy triad, named due to the hard time the injured faces in order to return to his pre- injury functional status, is a combination of 3 disrupted knee structures due to one single initiating factor. First described by Campbell in 1936, the triad consisted of injuries to the medial collateral ligament (MCL), the medial meniscus, and the anterior cruciate ligament (ACL). In 1950, O'Donoghue played a major role in bringing this injury to light, having reported a 25% incidence of the triad in acute athletic injuries. Thus, it was named O'Donoghue's triad (Jad Mansour, M. D, 2022). Immediately after the injury there is static and dynamic instability of the knee joint, which hides a high risk of dislocation of the knee and damage to other tissues: rupture of the joint capsule, rupture of the chondral tissue, rupture of the lateral collateral ligament, damage to the lateral meniscus and others (Gramatikova, M, 2021).

The treatment is surgical and solves the problem of static instability immediately after surgery. Dynamic instability of the knee joint is restored over a long period of time by applying an analytically designed physiotherapy rehabilitation program to patients after surgical treatment of the O'Donoghue Triad (Gramatikova, M, 2021).

Return-to-sport/play is the process of deciding when an injured athlete may safely return to practice or competition. Currently, time-based criteria found in postoperative and rehabilitation protocols are often used for return-to-sport, but after injury, many athletes are not fully recovered and return to play prematurely (Christie Powell, J.J, 2018). Common intrinsic risk factors for lower-extremity injuries are previous injury in the same body region and compromised function. Previously injured athletes often lack the neuromuscular control, balance, proprioception, and muscular strength to return-to-sport safely.

For functional assessment and monitoring of the dynamics of recovery, it is necessary to make an analytical selection of a test battery from functional indicators and tests corresponding to the dysfunctions of the operated knee. Athletes must possess some degree of agility (the ability to change direction and/or speed) to be competitive in sport. In recent decades, sports-medicine professionals and strength coaches have used functional performance tests to assess agility in athletes (Scinicarelli, G, 2021). A functional performance test is an assessment tool that is reported to closely simulate a given sport or activity.

As sport participation increases globally, so will injury-related risks. The process used to determine return-to-sport following injury is vital to future sport participation and injury

prevention (Manske R, R.M, 2019). Early specialization along with poor management of sport participation causes an increase in injury risk and potential long-term health consequences for youth athletes.

NEED OF STUDY

The purposes of this clinical commentary and literature review are to provide a summary of current concepts and clinical practices and to identify functional performance measures as clinical assessment tools for return-to-play criteria in the youth population.

AIM OF STUDY

To determine the Functional Performance Measures Used for Return-to-Sport Criteria in O' Donoghue's Traid.

OBJECTIVE

- Identify the components of a functional test.
- Discuss the current literature regarding lower extremity functional testing.
- Discuss how functional testing fits into the decision to return an athlete to sport.
- Identify specific functional tests to utilize in a clinic setting.
- Be able to implement a functional test in a clinic setting.
- Be able to perform, instruct, and critique each functional test.

OPERATIONAL DEFINITIONS

UNHAPPY TRAIID- The unhappy triad, named due to the hard time the injured faces in order to return to his pre-injury functional status, is a combination of 3 disrupted knee structures due to one single initiating factor. The triad consisted of injuries to the medial collateral ligament (MCL), the medial meniscus, and the anterior cruciate ligament (ACL). The unhappy Traid often occurs in contact and non-contact sports, such as basketball, football, or rugby, when there is a lateral force applied to the knee while the foot is fixated on the ground. This produces an abduction-external rotation mechanism of injury ("pivot shift" in non-contact sports).

REVIEW OF LITERATURE

Christie Powell, et al., (2018) The purposes of this clinical commentary and literature review are to provide a summary of current concepts and clinical practices and to identify functional performance measures as clinical assessment tools for return-to-play criteria in the youth population. As sport participation increases globally, so will injury-related risks. The process used to determine return-to-sport following injury is vital to future sport participation and injury prevention. Early specialization along with poor management of sport participation causes an increase in injury risk and potential long-term health consequences for youth athletes.

MIGLENA T-G, et al., (2022) To study the dynamic balance of lower extremities and to measure the proprioceptive force sense (FS) in healthy, untrained man (n=15) and women (n=15), ages 30–50 years; - To check sex differences, leg differences and to study the correlation among proprioception and balance.

Öznur Akyüz (2022) This study aimed to determine the Single Leg Hop Tests (SLHT) and Limb Symmetry Index (LSI) and to examine possible injury risks in football players with lower extremity strength differences. The study group of the research consisted of 21 male football players between the ages of 18-35 who had at least 10 years of active football training and were regularly trained. Participants had 3 different SLHT on dominant (DS) and non-dominant (NDS) sides; Single Leg Hop for Distance (SL), Crossover Hop for Distance (CHD), and Medial Side Triple Hop for Distance (MSTH) tests were applied.

Jason B, V. Wilson, et al., (2018) The primary purpose of this study was to examine the ability of the LEFT to discriminate injury occurrence in D III athletes, in order to validate or refute prior findings. It was hypothesized that female and male D III athletes slower at completion of the LEFT would be at a greater risk for a non-contact time-loss injury during sport. Secondary purposes of this study are to report other potential risk factors based on athlete demographics and to present normative LEFT data based on sport participation.

George J. Davies, et al., (2017) Purpose of Review Because of the epidemiological incidence of anterior cruciate ligament (ACL) injuries, the high reinjury rates that occur when returning back to sports, the actual number of patients that return to the same pre-morbid level of competition, the high incidence of osteoarthritis at 5–10-year follow-ups, and the effects on the long-term health of the knee and the quality of life for the patient, individualizing the return to sports after ACL reconstruction (ACL-R) is critical. However, one of the challenging but unsolved dilemmas is what criteria and clinical decision making should be used to return an athlete back to sports following an ACL-R. This article describes an example of a functional testing algorithm (FTA) as one method for clinical decision making based on quantitative and qualitative testing and assessment utilized to make informed decisions to return an athlete to their sports safely and without compromised performance. The methods were a review of the best current evidence to support an FTA.

Gao Z, F. G, et al., (2022) The objective of this study was to examine the effects of running fatigue on the symmetry of lower limb biomechanical parameters in eighteen male amateur runners. The marker trajectories and ground reaction forces were collected before and after the running-induced fatigue protocol. symmetry angles (SA) were used to quantify the symmetry of each parameter. Normality tests and Paired sample T-tests were carried out to detect bilateral lower limb differences and SA of parameters between pre- and post-fatigue. Keryn H, R. S, et al., (2017) The aim of this study to establish the reliability and face validity of the Functional Lower Extremity Evaluation (FLEE). The FLEE is a 45-minute battery of 8 standardized functional performance tests that measures 3 components of lower extremity function: control, power, and endurance. The reliability and normative values for the FLEE in healthy athletes are unknown.

Gramatikova, M. (2021) The purpose of this study is to develop a diagnostic system for functional assessment of patients after surgical treatment of the O'Donoghue Triad. One of the most severe and slowly recovering injuries of the musculoskeletal system is the "O'Donoghue Triad" or the so-called "Unhappy Triad". It mainly affects athletes, excluding them for a long time from their sports activities. For functional assessment of the condition of the knee joint, a selection of functional tests has been made, prepared as a diagnostic system for functional assessment and for monitoring the dynamics of recovery of the knee complex in patients with "O'Donoghue's Triad" treated surgically.

Giordano S, et al., (2021) The main aim of this study was to determine the test–retest reliability of an experimental functional test battery: Y-balance test (YBT), single-leg countermovement jump (SLCMJ), single leg hop for distance (SLH), side-hop (SH), speedy-jump (SJ), agility-T (AT), and lower extremity functional test (LEFT). Secondary aims were (1) to determine the mean range for the limb symmetry index (LSI) and (2) to detect significant differences in performance between test–retest sessions. Twenty-two healthy adults (14 males, 8 females; age 23.3 ± 3.9) were tested by the same rater during two different sessions (T1–T2), with a seven-day interval, under the same conditions.

Mariya G, et al., (2016) The publicly accessible information sources contain no research on the effectiveness of manual-soft tissue mobilization on the degree of movement of the knee joint of patients after O'Donoghue's Triad. This has necessitated the development of an experimental physiotherapy program, which also includes manual-soft tissue mobilization by the method of J.C. Terrier. The physiotherapy, which is applied with the aim of recovering the motor function of the knee, its active flexion, and the complete elimination of the limited mobility of the joints in cases of O'Donoghue's Triad, is directed towards neutralization of its hindering factors- such as reduced elasticity of the soft tissues, shortenings and contractures of the corresponding to the injury muscles and capsular -ligament structures.

Jerrold J. H, et al., (2017) Clinician-friendly lower extremity physical performance measures in athletes: a systematic review of measurement properties and correlation with injury. Part 1: the tests for knee function including the hop tests. Six tests were examined for the best evidence of methodologic quality: (1) 1-legged single hop for distance, (2) 1- legged triple hop for distance, (3) 6-m timed hop, (4) crossover hop for distance, (5) triple jump, and (6) 1-legged vertical jump. A summary of the methodologic properties of the 6 tests showed fair/poor reliability, fair/poor hypothesis testing, good criterion validity, and good/poor responsiveness.

Jason Brumitt, et al., (2016) The studies show that the Lower-Extremity Functional Test (LEFT) has been used to assess readiness to return to sport after a lower extremity injury. Current recommendations suggest that women should complete the LEFT in 135 s (average; range 120– 150 s) and men should complete the test in 100 s (average; range 90–125 s). However, these estimates are based on limited data and may not be reflective of college athletes. Thus, additional assessment, including normative data, of the LEFT in sport populations is

warranted Brumitt J, H B, et al., (2013) Functional tests have been primarily used to assess an athlete's readiness to return to sport. The purpose of this prospective cohort study was to determine the ability of the standing long jump (SLJ) test, the single-leg hop (SLH) for distance test, and the lower extremity functional test (LEFT) as preseason screening tools to identify collegiate athletes who may be at increased risk for a time-loss sports-related low back or lower extremity injury. We expected that athletes with shorter jump and hop distances and slower LEFT scores would be at greater risk for injury.

Manali S. Desai, et al., (2016) The aim of this study was to determine time taken to complete square hop test in young asymptomatic individuals and to observe the effect of dominance on square hop test. Functional Performance is one's ability to participate and move through different planes of movement in safe and timely manner without functional limitations. Square hop test, type of Functional Performance test aims to measure neuromuscular coordination by placing combined frontal and rotational stress on the lower extremity. Sedentary population may develop significant bilateral asymmetry in lower limbs due to constant overload on the jumping leg depending upon different kind of daily activities. Clinicians often use functional performance test (FPT) in lower extremity rehabilitation without taking limb dominance into consideration.

Caleb D. Bazyler, et al., (2014) The purpose of this investigation was to determine what effect a bilateral strength training regimen has on iso-metric force production symmetry and if changes in force production symmetry can be accounted for by differences in pre-intervention strength levels.

Jacqueline C, et al., (2011) The aim of this study to determine injuries resulting from athletic participation have been extensively researched in an attempt to identify causative factors. Lower extremity injuries account for the greatest proportion of athletic participation injuries. Traditional medically based pre-participation screening lacks a performance assessment from which to determine athletic preparedness. The purpose of this study was to develop a reliable functional screen in order to identify biomechanical faults in a female athletic population.

Hadas Ofek, et al., (2019) The aim of this study was to develop a quantitative, easy to use and inexpensive tool, for assessing proprioception of the lower extremity of older population, to evaluate its test-retest reliability in young and older adult population and examine its known-groups validity.

Celil KAÇOŞLU (2019) The aim of this study was to investigate the relationship between contralateral inter-limb strength asymmetry (ILSA) values and jump and sprint performances. Forty-eight individuals (21.5 ± 2.8 years, 1.74 ± 0.1 m, 67.3 ± 9.7 kg) voluntarily participated in this study. All participants participated in squat (SJ), Countermovement jump (CMJ), 40m sprint run tests and right and left isokinetic concentric knee flexion and extension strength (IS) test at low ($60^\circ \cdot s^{-1}$) and high ($300^\circ \cdot s^{-1}$) angular velocities. The symmetry angle formula was used in order to determine the isokinetic knee strength asymmetry values between inter-lower limb.

KYUNG-MI P, et al., (2013) This cross- sectional was to investigate the interrater reliability of movement-quality ratings for the forward step-down (FSD) test and to compare hip muscle strength and lower extremity joint range of motion and muscle flexibility among asymptomatic women with different levels of movement quality.

José F.S. D. L, et al., (2022) O'Donoghue's triad is an extremely debilitating condition. Although there are many conventional treatments available, there is still no consensus regarding the most effective rehabilitation protocol for a full recovery. Surgical interventions have become an ordinary consideration, but problems may still persist even after the surgical procedure. Orthobiologics, however, have gained considerable popularity in regenerative medicine.

METHODOLOGY

STUDY DESIGN

Review of Literature

SELECTION CRITERIA

INCLUSION CRITERIA:

1.Evidence-based articles after 2010.

2.Article in which following keyword are used

O'Donoghue's triad, Criterion-based progression return-to-play, assessment, functional performance test.

EXCLUSION CRITERIA:

1.Articles that are not related to return to sports.

2.Articles before 2010.

SOURCE OF STUDY

The method in the study was review of literature i.e., search and evaluation of the available literature related to Functional Performance test in O'Donoghue's Traid through online data base google scholar and PubMed and the research results included in the study are of last 13 years which is 2010-2023, the result of the research was then described in brief. Thus, a final conclusion was drawn.

PROCEDURES

LEFT PROTOCOL

The Lower-Extremity Functional Test (LEFT) is a functional performance test that has been used as a component of a return-to-sport rehabilitation testing algorithm. The LEFT was initially designed to quantitatively and qualitatively assess the injured athlete's ability to perform sport-specific movement patterns. The LEFT test involves 8 agility drills performed on a diamond-shaped course. In addition to assessing an athlete's ability to perform sport-specific movements, Davies and Zillme suggest that the test also evaluates cardiovascular fitness. Average reported time for men to complete the LEFT is 100 seconds (range 90–125 s) and 135 seconds (range 120–150 s) for women.

Despite its use in clinical rehabilitation, there are few reports available providing normative data or efficacy for the LEFT in assessing athletic readiness in different sport populations.^{13–15} Thus, the 2 purposes of this study were to present normative data and relationships between LEFT scores with off-season training practices and injury incidence. Hypothesized was made that athletes who reported greater levels of off-season training would complete the LEFT significantly faster than those who reported less time training. They also hypothesized that the male athletes would complete the LEFT significantly faster than their female counterparts.

A final purpose of this study was to prospectively examine the LEFT's ability to discriminate sport-related injury occurrence. They hypothesized that athletes with slower LEFT times would have a significantly greater incidence of time-loss lower-quadrant (LQ) injury than athletes with faster LEFT times.

STUDY QUESTIONNAIRE

Athletes completed a questionnaire including age, years enrolled at university, age starting their primary sport, and hours spent training per week during the 6 weeks before the start of the season (eg, sanctioned practice) in the following activities: weightlifting, cardiovascular exercise, plyometric exercise, and time spent scrimmaging.

TEST PROTOCOL

Each athlete completed a dynamic warm-up before performing the LEFT, consisting of 3 or 4

widths of forward walking, backward walking, heel walking, tip-toe walking, forward lunging, backward lunging, and high-knee marching (approximately 5 min). The warm-ups were performed between sidelines on a gymnasium court or across the width of a tennis court. The LEFT course measures 9.14 m in a north-south direction and 3.05 m in a west-east direction (Figure 1). Equilateral triangles consisting of 0.305-m (1.0 ft) strips of athletic tape were placed at the ends of each axis. The LEFT consists of 8 different agility tasks, with each task being performed twice.

Each athlete started the test positioned behind the "A" triangle. Because of the multidirectional requirements of the test and variety of tasks performed during the LEFT, subjects were told that they would run in a forward

direction from cone A to cone C and back. Verbal instruction of subsequent movements was provided throughout the test. As a subject neared completion of the first task (as well as with each subsequent task) an investigator would provide verbal instructions describing the task and the direction of movement. Each athlete performed 1 trial of the LEFT.

Injury Surveillance. The operational definition for an AE [athletic-exposure] was participation in practice or a game where the athlete was at risk for an injury. Only time-loss LQ (LQ = low back and lower extremities) injuries were recorded for analysis. Records of AEs and time-loss- injury data were reviewed weekly by a study investigator to ensure that data were being collected in a timely fashion, as well as to ensure record completeness. An initial injury was the first time- loss LQ injury experienced during the season. A subsequent injury was any additional LQ time- loss injury experienced during the remainder of the season. Injury severity was categorized as minor (time loss from sport $t \geq 8$ d).

TABLE 1.

THE 16-STEP SEQUENCE OF MULTIDIRECTIONAL SKILLS INVOLVED IN THE LOWER EXTREMITY FUNCTIONAL TEST.

Step	Skill	Direction	Skill description	Target Sequence
1	Forward run	Forward	Subject forward runs between targets, turning at C.	A, C, A
2	Retro run	Backward	Subject backpedals between targets, turning at C.	A, C, A
3	Side shuffle	Right	Subject performs a side-shuffle maneuver to the right, facing the center, around the outside of A, D, C, B, A the entire course	A, D, C, B, A
4	Side shuffle	Left	Subject performs a side-shuffle maneuver to the left, facing the center, around the outside of the A, B, C, D, A entire course	A, B, C, D, A
5	Carioca	Right	Subject performs a carioca maneuver to the right, facing the center, around the outside of A, D, C, B, A the entire course.	A, D, C, B, A
6	Carioca	Left	Subject performs a carioca maneuver to the left, facing the center, around the outside of the A, B, C, D, A entire course.	A, B, C, D, A
7	Figure-8 run	Right	Subject forward runs around targets D and B and circles targets A and C from inside out	A, D, C, B, A
8	Figure-8 run	Left	Subject forward runs around targets D and B and circles targets A and C from inside out	A, B, C, D, A

9	45° cuts	Right	Subject forward runs to the right, plants the outside foot, and cuts 45° toward the next target.	A, D, C, B, A
10	45° cuts	Left	Subject forward runs to the left, plants the outside foot, and cuts 45° toward the next target.	A, B, C, D, A
11	90° cuts	Right	Subject forward runs to the right, plants the outside foot, and cuts 90° toward the next target.	A, D, B, A
12	90° cuts	Left	Subject forward runs to the left, plants the outside foot, and cuts 90° toward the next target.	A, B, D, A
13	90° Cross-over cuts	Right	Subject forward runs to the right, plants the inside foot, crosses the outside foot over 90°, and runs toward the next target.	A, D, B, A
14	90° Cross-over cuts	Left	Subject forward run to the left, plants the inside foot, crosses the outside foot over 90°, and runs toward the next target.	A, B, D, A
15	Forward run	Forward	Subject forward runs between targets.	A, C, A
16	Retro run	Backward	Subject backpedals between targets.	A, C, A

PHYSICAL PERFORMANCE TEST

Physical performance tests (PPTs), also referred to as functional tests, are used by clinicians to determine patients' injury risks and return-to-play readiness. The authors of this study investigated 6 PPTs that are easy to use, are low in cost, require minimal training to perform, and have a minimal time commitment. Despite numerous studies designed to research exactly what these tests offer clinicians, much of the data remain limited and conflicting.

Functional and sport-specific conditioning tests play an important role for clinicians when making return-to-sport decisions. Before returning a patient to activity, a clinician must assess the individual's functional ability. To better quantify this functional ability, researchers have designed various functional performance tests, some of which simulate the stress the knee endures during physical activity. Additional information gained from these tests pertaining to functional performance would enhance the clinical decision-making process (Jerrold J. Harrison et al., 2017).

STUDY QUESTIONNAIRE

Studies were included if they involved a test that met the operational definition for a PPT. The included studies assessed components of sport function (eg, speed, agility, and power), determined readiness for return to sport, or predicted injury to the lower extremity. All PPT measures could be performed on the field, courtside, or in a gym with affordable, portable, and readily available equipment. Studies were excluded if they made use of

3-dimensional motion capture, force platforms, timing gates, treadmills, stationary bikes, metabolic charts, or another nonportable, costly testing device (Jerrod J. Harrison et al., 2017)..

TEST PROTOCOL

The 1-legged hop for distance was the most studied test of the 6 examined in the present study. The 1-legged hop test has been shown to differentiate between the anterior cruciate ligament (ACL)-deficient knee and the uninvolved knee in an age-matched control group, in addition to detecting differences in the ACL-repaired knee and the uninvolved knee in the same person. The 1-legged hop test should be performed barefoot, while standing on 1 leg. The patient is asked to jump forward as far as possible. The clinician then measures and records the distance from the patient's toes (starting point to the end of the jump) to the nearest 0.01 meter. If the patient loses balance or falls during the test, the trial is considered invalid and must be repeated.

Limb symmetry index (LSI) scores have been examined in healthy and ACL-injured populations. The 1-legged hop-for distance test, crossover hop-for-distance test, triple hop-for distance test, and 6-m timed hop test have all been studied in relation to ACL injury. The 1-legged hop test had an LSI greater than 90% in healthy recreational athletes, and 73% of these participants had an LSI greater than 95%. Another study⁸ identified a difference in LSI scores greater than 15% as abnormal in patients with ACL injury. Patients with significant limb-to-limb deficits should engage in therapeutic exercises aimed at decreasing these deficits.

The crossover hop-for-distance test provided discriminating information to the clinician at 4 and 8 months after reconstruction. This test detected decreased performance and function in the ACL-repaired limb compared with the uninvolved limb. However, the results of this test did not correlate with the patients' self-rated function or identify differences in the ACL-deficient population. This test can be useful after surgery to identify functional differences between limbs. To perform this test, the clinician must place a line 6-m long and 15-cm wide on the floor. The patient then completes 3 hops over the line. When starting with the right leg, the patient stands to the left of the line and then hops laterally to the right, back to the left, and finishes to the right of the line. This test is conducted on only 1 leg at a time. The distance is measured from the starting line to the heel of the patient at the final hop position.

FUNCTIONAL TEST BATTERY

A test battery consists of an evaluated and standardized protocol combining single and complementary subtests, which do not require sophisticated equipment and can be carried out multiple times. Test batteries are an efficient screening tool to assess functional movement patterns as well as to provide a multidimensional, objective, and quantitative analysis for the evaluation of functional performance. In sports therapy, functional test batteries are widely used to assess sport-specific functional performance, to establish prevention strategies (such as pre- injury screenings) for anterior cruciate ligament injury (ACL-I), and to plan specific training interventions for the lower extremities. Furthermore, they are regularly used in monitoring and decision-making processes of rehabilitation after ACL-I, for return-to-sport clearance, and for movement quality assessments.

In general, functional inter-limb asymmetries in performance are associated with sport activity limitations and might be an injury risk factor for uninjured athletes. Clinically, the limb symmetry index (LSI) can be calculated easily and rapidly. It can provide valuable baseline data for pre-injury screenings or for rehabilitation progression purposes. In order to allow side-to-side performance comparisons, functional tests can be performed unilaterally (on one leg) and the LSI can be detected

Generally, a valuable test battery should include sport-specific movement patterns (e.g., balancing, landing, sprinting and cutting), in order to provide sport-specific functional performance outcomes in terms of imbalances/weaknesses related to muscle power, dynamic balance, proprioception, speed and agility. In particular, an effective test battery should encompass several functional tests structured into different levels, gradually organized from simple (less demanding) to complex (more demanding) tests. Thus, the design should be primarily based on the assessment of postural control, dynamic balance, and joint stability.

TEST PROTOCOL

This study was conducted with a test-retest design, which allowed repeated measures for reliability analysis. A test-retest interval should have adequate time to recover between testing sessions as well as reduce the influence of learning effect and of physical/fitness status changes. Two identical testing sessions (T1 and T2) were performed with a seven-day interval time under the same conditions: subjects were tested twice by the same rater (a sports physical therapist with six years of scientific experience in the field); the same indoor laboratory was used for sports therapy purposes; and both sessions were performed in the afternoon. For the sake of consistency, a predefined order of the experimental test battery was applied in both testing sessions, as follows: (1) Y-balance test (YBT); (2) single leg countermovement jump test (SLCMJ); (3) single-leg hop for distance test (SLH); (4) side hop test (SH); (5) speedy jump test (SJ); (6) agility-T Test (AT); and (7) lower extremity functional test (LEFT).

TEST BATTERY STANDARDIZATION AND DESCRIPTION

It is divided into four levels: (1) return to activity (RTA); (2) return to sport (RTS); (3) return to play (RTP); and (4) return to competition (RTC). Each level comprises two tests, which are organized from the simplest to the most complex level of difficulty in terms of effort and execution. In this context, the following seven tests were selected and included in the present study. The Y-balance test (YBT), a reliable and predictive measure for lower extremity injuries in high school basketball and American football players, which is also related to chronic ankle instability in normal population. The single-leg counter movement jump test (SLCMJ) is a reliable and appropriate measurement for determining muscle power functions of the lower extremities in healthy or rehabilitated athletes and a useful test for the evaluation of knee function after surgery (Christie Powell, et al., 2018). The agility T-test (AT) is recommended in clinical and sport practice [33] and is a reliable measurement in determining low or high levels of sports participation in college athletes. The lower extremity functional test (LEFT) is a reliable measurement in identifying competitive athletes at risk for lower back/lower extremity injuries [32]. In the present study, the first level comprised only one test because the step-down test was not performed and not included in the reliability analysis, since it does not provide any quantitative performance data as it is usually used to analyze the quality of movement.

1) Step-Down Test (SD)

According to Park et al., the SD test is performed without shoes and the starting position is on a 20 cm high step. Subjects stand upright on one leg with the toes of the standing leg close to the edge of the step. The free leg is extended in front of the step with the ankle in maximum dorsiflexion. With as much control as possible, subjects are asked to bend the knee of the standing leg until the heel of the extended leg touches the floor and then immediately return to the starting position. During the test execution, the following criteria should be used to mark invalid attempts: single-leg balance is not fully maintained, the trunk is not kept straight, the standing leg does not remain in contact with the step with the whole foot and the hands do not remain fixed at the hips. Subjects have one trial attempt and one valid attempt per leg.

2) Y-Balance Test (YBT)

The YBT is a valid, reliable test to assess postural control and balance capacities. The Y-Balance Test Kit (Move2Perform®, Evansville, IN, USA) was utilized. The subjects started in a standing position on one leg, with the toes of the standing leg positioned at the red line marked on the central platform of the instrument. The sliding elements had to be pushed with the toes of the contralateral leg as far as possible in three directions (anterior, posteromedial, and posterolateral). For correct execution, the standing leg keeps a full stance on the platform and the contralateral leg keeps constant contact with the sliding elements. After that, subjects had to return to the starting point and keep the final balancing position (on one leg) for three seconds (measured with a stopwatch) to be considered as a valid attempt. The following criteria were used to mark invalid attempts: leaving the arms from the hips, loss of balance, contact of the contralateral leg with the ground, lifting up the heel of the standing leg, kicking the sliding element or standing on top of it. For the normalization of the scores, the limb length had to be measured. The performance was then computed as a “composite score” in percentage using this predetermined formula: $\text{composite score} = (\text{anterior} + \text{posteromedial} + \text{posterolateral performances in cm}) / 3 \times \text{limb length in cm} \times 100$.

3) Single-Leg Countermovement Jump Test (SLCMJ)

The SLCMJ is a valid and reliable test that measures proprioception and neuromuscular control abilities [4,30]. The OptoJump Kit (Version 1.12.1.0—Microgate®, Bolzano, Italy) was utilized. The subjects started in a standing position on one leg, performed a countermovement flexion with the standing leg and then explosively jumped as high as possible [54]. To be considered as a valid attempt, the landing with the same leg had to be maintained stable for three seconds (measured with a stopwatch). The following criteria were used to mark invalid attempts: leaving the arms from the hips, multiple jumps while landing, flexing the jumping leg during the flight phase, a contact with the ground or a swing of the contralateral leg.

4) Single Leg Hop for Distance Test (SLH)

The SLH is a valid and reliable test useful to assess muscle strength and power deficits. The subjects started in a standing position on one leg, with the toes positioned at the starting line marked on the therapeutic mat. The subjects had to jump as far as possible, landing on the same leg. The landing had to be maintained stable for three seconds (measured with a stopwatch), otherwise, the attempt was marked as invalid. The following

criteria were used to mark invalid attempts: leaving the arms from the hips, a swing of the contralateral leg, using the contralateral leg as a support, loss of balance or multiple jumps at landing. The jumped distance was then measured in centimeters (cm) with a measuring tape, from the starting line marked on the mat (jump take-off) to the heel of the subjects where the landing took place.

5) Side-Hop Test (SH)

The SH is a valid and reliable test to assess strength resistance under fatigue state through controlled, fast, and repetitive lateral jumps. The subjects started in a standing position on one leg with their hands on the hips, jumping sideways over two parallel lines (40 cm apart) painted on the therapeutic mat. Subjects performed as many jumps as possible in 30 s, recorded using a stopwatch. After the last jump, a controlled landing had to be maintained for three seconds (measured with a stopwatch), otherwise the attempt was marked as invalid. The following criteria were used to mark invalid attempts: jumping on the painted line with the tested leg, performing extra/double jumps, supporting of the contra-lateral leg, or leaving the arms from the hips. The number of successful jumps (score = total jumps – error jumps) were counted live by the test leader.

6) Speedy-Jump Test (SJ)

The SJ is a valid and reliable test to estimate power, dynamic knee stability, and coordination of the lower extremities while jumping as fast as possible through different plane directions. A predetermined Speedy Basic Jump Set (TST—Trendsport®, Grosshöfle, Austria) was utilized. Subjects started in a standing position on one leg. The subjects executed three jumps on each of the four red bars (jumping forward, backward, and forward) and one jump on each of the four blue bars (jumping sideways), performing sixteen jumps in total. After the last jump, a controlled landing with the same leg had to be maintained for three seconds (measured with a stopwatch), otherwise the attempt was marked as invalid. The following criteria were used to mark invalid attempts: leaving the arms from the hips, a contact with the test instrument and a swing or ground support with the contralateral leg. The execution time was computed in seconds (s) with a stopwatch, from the moment of the first jump (take-off phase) to the moment of the last jump (landing).

7) Agility T-Test (AT)

The AT is a valid and reliable test for the measurement of agility and change of direction speed by maximum start, side steps, and running backwards. The layout is a combination of four cones in T-shape (5 m × 5 m). Subjects started in a standing position behind the starting point at cone A. After the start signal, subjects sprinted to cone B, touching it with their right hand. Then, they performed a side-shuffle to the left to cone C, touching it with their left hand. Next, they performed a side-shuffle to the right to cone D, touching it with their right hand. Then, they performed a side shuffle to cone B, touching it with their left hand. After that, they performed a backward run to cone A. Attempts were considered invalid if the subjects did not touch the cones, performed the side-shuffle crossing their legs or did not face forward while sprinting or side-shuffling. The execution time was computed in seconds (s) with a stopwatch, from the moment of the first sprint as soon as subjects left cone A to the moment of the last sprint as soon as subjects passed cone A.

8) Lower Extremity Functional Test (LEFT)

The LEFT is a reliable and valid test for the measurement of athletic fitness, fatigue resistance, and speed by performing a series of 16 specific maneuvers as fast as possible (including forward and backward sprinting, sidestepping, cross-stepping, 45° and 90° cutting). The layout is a combination of four cones in a diamond shape (9.14 m × 3.05 m). Test execution was performed in accordance with previously described methods [4,32]. Subjects started in an upright standing position with both feet behind the starting point at cone A. On the command of the instructor, the subjects performed eight different agility tasks, with each task being performed twice (once to the right and once to the left direction). Because of the multidirectional requirements of the test and variety of tasks to be performed, verbal instruction of subsequent movements was provided throughout the test. As such, subjects were required to respond to the external stimuli. Attempts were considered invalid if participants failed to perform the designated maneuvers or dropped a cone by contact. The execution time was computed in seconds (s) with a stopwatch, from the moment of the first sprint after the starting signal as soon as the subjects left cone A to the moment of the last sprint as soon as the subjects passed cone A.

RESULT

LEFT PROTOCOL

Men had significantly faster LEFT scores than their female counterparts. There were no significant within-group differences for male athletes in LEFT scores by age group, age starting primary sport, years enrolled in college, or prior history of a time-loss sports injury. Female athletes who reported performing >3 to 5 h/wk of plyometric exercises had significantly slower LEFT scores than those who reported >1 to 3 h/wk or 0 to 1 h/wk of plyometric training. There were no other significant within-group differences for female athletes in LEFT scores and the other off-season training practices. The overall injury incidence rate for female athletes was 4.5/1000 AEs. The incidence of an initial time-loss LQ injury was 3.8/1000 AEs and 10.4/1000 AEs for those who experienced a subsequent injury. Most injuries were of minor severity (3.2/1000 AEs). Female athletes with slower LEFT scores were twice as likely to incur 1 or more (total) time-loss injuries than those with faster LEFT scores. Female athletes with slower LEFT scores were as likely to have at least an initial injury as those with faster LEFT scores; however, the risk was not statistically significant. Women with slower LEFT scores were 6 times more likely to incur 1 or more subsequent injuries than those with faster LEFT scores (RR = 6.4, 95% CI = 1.0, 146.0, P = .05). Women with slower LEFT scores were also 6 times more likely to incur a minor LQ time-loss injury (RR = 6.2, 95% CI = 2.1, 18.1, P ≤ .0001) than those with faster LEFT scores. Conversely, women with faster LEFT scores were more likely to incur a moderate/major LQ time-loss injury than those with slower LEFT scores.

The overall injury incidence rate for male athletes was 3.7/1000 AEs. The incidence of an initial time-loss LQ injury was 3.2/1000 AEs with those experiencing subsequent injuries at 8.5/1000 AEs. While male athletes with faster LEFT scores were more likely to incur 1 or more (total) time-loss injuries than those with slower LEFT scores, the protective effect was not statistically significant. The risks for initial, subsequent, or severity between faster and slower male athletes were also not statistically significant.

PHYSICAL PERFORMANCE TEST

The authors of the systematic review determined that it remained unknown whether knee performance tests can predict the risk of knee injury in an athletic population. Isolated performance tests lack the necessary reliability, validity, and known meaningful change to serve as discriminating outcome measures during sport rehabilitation after injury or surgery. Clinicians should use PPTs in conjunction with other tests to examine the patient's overall function (range of motion, strength, etc.) and determine readiness to return to sport (patient-reported outcomes). No studies included in this systematic review identified a minimal clinically important difference for any of the tests. Once these values are identified, clinicians will have useful information to guide the progression of their patients and recognize important changes in function and performance.

FUNCTIONAL TEST BATTERY

The range of percent of respondents who rated tasks as being of high importance was 58% to 71%, whereas the range of percent of respondents who rated tasks as being frequently used was 26% to 45%. The ICC values for test-retest reliability ranged from 0.71 for the leap and catch test to 0.95 for the triple hop test. The interrater reliability ICC values ranged from 0.83 for the lateral step-down test to 1.00 for the single-leg, triple, and crossover hop tests. Average limb symmetry indices ranged from 98.6% for the triple hop and timed hop to 114.4% for the lateral step-down.

DISCUSSION

O'Donoghue's triad is a highly debilitating condition that causes major pain and significant decreases in an individual's quality of life. The incidence of these injuries among young sportsmen has increased significantly in the last two decades, yet there is almost no consensus regarding the most effective rehabilitation protocols for the achievement of complete physical recovery (Lana, J.F.S.D.2022). Surgeries have become an ordinary alternative for athletes, whereas the initial conservative strategies concerning physical therapy are usually applied in the general population. This creates additional challenges including prolonged pain, reduced physical capacity, and financial burden. Weakness in the distal lower extremities is a common consequence that is attributed to ACL injury and reconstruction; it often persists even after the post-operative rehabilitation period. Ligament reconstruction is known to improve knee stability in ACL-deficient knees; however, it does not restore regular knee kinematics. This can, in many cases, increase the risk of post-traumatic OA development. ACL disruption initiates a cascade of pathogenic processes, including elevated turnover of aggrecan and Type II collagen in a matter of days (Lana, J.F.S.D.2022).

The goal of this descriptive review was to determine useful clinical measures of function used in the youth population and to assess injury risk as it relates to return-to-sport/play criteria following lower-extremity injury. Using 3 common databases, "return-to-play" search terms yielded a total of 22 articles. To establish the condition of various aspects of the knee recovery process, after analysis of literature sources and expert assessment in the diagnostic system for functional assessment include: the LEFT protocol, Physical Performance Test, Functional Test Battery. Isolated performance tests lack the necessary reliability, validity, and known meaningful change to serve as discriminating outcome measures during sport rehabilitation after injury

or surgery. Clinicians should use functional tests in conjunction with other tests to examine the patient's overall function (range of motion, strength, etc.) and determine readiness to return to sport (patient-reported outcomes). No studies included in this systematic review¹ identified a minimal clinically important difference for any of the tests. Once these values are identified, clinicians will have useful information to guide the progression of their patients and recognize important changes in function and performance. Clinicians can also use these tests to measure quantitative differences between the injured and uninjured limbs in order to target rehabilitation programs with the goal of decreasing limb-to-limb differences. As indicated, further studies involving strong methodologic characteristics are needed to identify the clinical usefulness of these tests, especially for the knee.

These articles were difficult to find due to the inconsistencies in terminology and the focus for return-to-sport criteria on concussions and head injuries, not lower-extremity injuries. It is imperative for functional performance measures to evaluate neuromuscular control and sports-specific or explosive movements, and to identify compensatory movements or lack of quality of movement within the demands of the activities. With the limited number of articles for review on this topic, clinicians and adjunct medical professionals have limited evidence-based options to determine return-to-play criteria following injury.

CONCLUSION

Although there are many recent publications indicating criteria for return to sports following reconstruction, there is no predictive validity of any of the studies at the present time. Therefore, based on the present literature and clinical experiences of the authors, we recommend the following:

- A battery of varying tests examining different psychometric properties.
- A battery of tests based on the measurement of impairment in addition to the examination of strength and power.
- Specific quantitative and qualitative criteria for assessment of performance and function. Examination via proactive and reactive activity to simulate a real-case sport activity scenario.
- A fatigue factor in the terminal phases of clinic testing.
- Psychological testing to evaluate for potential kinesiphobia.
- Patient-reported outcomes.

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