Functional Performance Measures Used for Return-to-Sport Criteria in Youth Following Lower-Extremity Injury

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Context: 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. **Objectives:** 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. 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. **Evidence:** A literature review was completed using numerous databases, where 154 relevant articles were reviewed and 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. **Acquisition:** The gaps in the literature pertaining to functional performance measures in the youth population are addressed, and future research needs for return-to-sport criteria are identified. **Evidence Synthesis:** This descriptive literature review identifies 22 articles that meet the search criteria for the youth population discussing the use of clinical functional performance measures in order to identify return-to-sport criteria for lower-extremity injuries. **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.

Keywords: return-to-play, pediatrics, assessment, pre-screening

Context

Sport participation and physical activity have physical, social, and psychological health benefits for children and adolescents.¹ These benefits have dramatically increased participation in organized youth sport in recent years.^{2,3} In 2008, the National Council of Youth Sports estimated 60 million children 6–18 years of age participated in organized sport.⁴

Although the benefits are clear, the negative side effect to increased sport participation has been an increased rate of injury, as Monroe et al⁵ approximate 4 million sports and recreational injuries may occur in school-aged children in the United States. Sport is the main cause of injury in adolescents annually, with 8% of injured adolescents failing to return to recreational or organized sport due to injury.²

As sport participation increases globally, so will the number of injury-related risks. The process used to determine return-to-sport following injury is vital to future sport participation and injury prevention. Emery's⁶ literature review on sport-related injury concluded that injury prevention in youth sport is becoming a public health priority. Early specialization along with poor management of sport participation causes an increase in injury risk and potential long-term health consequences, including burnout, growth plate injuries, and osteoarthritis.⁷ Following an injury, identifying functional performance deficits, defined by return-to-sport criteria, minimizes injury risk factors and provides athletes with guidelines to participate safely in sport.^{8–10}

Return-to-sport/play is the process of deciding when an injured athlete may safely return to practice or competition.^{11,12} 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. Common intrinsic risk factors for lower-extremity injuries are previous injury in the same body region and compromised function.^{3,6} Previously injured athletes often lack the neuromuscular control, balance, proprioception, and muscular strength to return-to-sport safely.^{8,13–17}

Currently, guidelines have not been established for return-to-play in youth athletes, as the medical and coaching community cannot reach a consensus. Several authors have addressed this problem with a return-to-sports algorithm to determine a criteria-based progression,^{18–20} a decision-based model for return-to-play,^{21–24} and a Physical Performance Assessment Checklist.²⁵ Outside of Myer et al,^{18–20,22} very few studies have specifically applied these tools to the youth population as they relate to return-to-play. Numerous authors agree return-to-sport training protocols and testing criteria incorporating quantitative measures, including functional performance testing, should be used to determine lower-extremity function postinjury.^{12,26–28} However, reports on the application and outcomes of these protocols and tests for the youth or high school athlete are few.^{23,24}

Manske and Reiman²⁹ defined functional performance tests/measures as assessments used to qualify and quantify specialized movements in sport and exercise. They can objectively measure rehabilitation progressions and determine limb asymmetries and a safe return-to-sport.²⁹ These movement assessments are used by physicians and clinicians to determine when an athlete can safely return-to-sport following a rehabilitation program or as a

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preparticipation screening tool. The American College of Sports Medicine Summit in 2014 discussed the utility of functional movement assessments used to identify musculoskeletal injury risk and return-to-play/duty.²⁸ The expert panel established the need for using functional movement assessments to determine readiness or return-to-play following injury and rehabilitation.²⁸ A standardized approach to movement assessment was suggested as an effective method for injury prevention and return-to-play criteria.²⁸

With the concept of functional movement assessment in mind, anterior cruciate ligament (ACL) injuries have received considerable attention in the last 20 years. The focus has been on preventative strategies and rehabilitation programs. Renstrom³⁰ states that the greatest prevalence for ACL injuries exists in the female youth athlete 14–18 years of age, and considers this to be a major problem in sports medicine and an increasing clinical challenge. Numerous authors have investigated functional outcomes and deficits associated with this debilitating injury in the youth population, but they are infrequently used to determine return-to-play status.^{15,18–20,24,31–33} In a systematic review of adult patients with anterior cruciate ligament reconstructed (ACLR), Barber-Westin and Noyes²⁷ found the research lacking in objective criteria for return to unrestricted sports activities. Only 4% (10/264) of the studies reviewed included functional performance measures as return-to-sport criteria. In a systematic review of ACLR, Narducci et al³⁴ found no studies identifying movement assessment, functional performance measures, or test batteries with construct or predictive validity for return-to-sport. Teyhen et al²⁸ found scant evidence of movement assessment and screening tools that assess functional movement, balance, and neuromuscular control deficits for both the military and the general athletic population.

Objective

This literature review discusses the necessity of functional measurement, rather than generalized time references, usually denoted in weeks or months following injury or surgery, for determining when youth athletes following lower-extremity injuries are ready to return to play. The current criteria for return-to-play are often vague, and inconsistent time-based goals inaccurately represent the athlete's functional ability to return-to-sport.³⁵ A health professional's opinions are used to determine return-to-play status, but they often are conflicting and are not consistently founded on evidence-based research.³⁶ The purpose of this literature review is to identify functional performance measures as clinical assessment tools for return-to-sport/play criteria in the youth population. This process of identifying functional performance deficits, defined by return-to-sport criteria, will provide the health care team with quantitative data to determine an athlete's preparedness to return-to-sport. The gaps in the literature pertaining to functional performance measures in the youth population will be addressed, and future research for return-to-play criteria will be identified.

Evidence Acquisition

This descriptive review includes studies that discuss return-to-sport/play criteria using functional performance measures to quantify lower-extremity function for youth athletes. Inclusion criteria were (1) functional performance measure(s) used as *objective criteria* for return-to-sport/play after lower-extremity injury in youth (not measures used to determine kinematics or physical performance, or used as an intervention or outcome measure), (2) English language, and (3) published in a peer-reviewed journal.

Exclusion criteria were (1) conducted on the adult population only, (2) return-to-play criteria were used for concussions, upper-extremities, or other nonmusculoskeletal issues, (3) return-to-play was referenced as the actual time an athlete returned to sport, and (4) functional performance measures were used as an intervention. Abstracts and unpublished articles were also excluded. Two reviewers (C.P. and S.J.) independently reviewed titles and abstracts. Citation tracking of primary articles and literature reviews further determined pertinent articles.

Study and Search Selection

Data sources were found with electronic and manual literature searches. CINAHL, Academic Search Complete, SPORTDiscus, Health Source: Nursing Academic Education, and MEDLINE were considered and supplemented by the personal library of the authors. Publications selected were from 1990 to January 2016 for the youth population, and Boolean logic phrases and search terms were used for inquiry. "Return to Play" yielded N = 5413, "Return-to-Sport" yielded N = 2065, "Return to Athletics" yielded N = 989, but when "youth" was added to the search terms, "Return to Play AND youth" yielded N = 157, NOT concussions N = 32, NOT upper extremity N = 5, and no articles met the inclusion criteria. "Return-to-Sport AND youth" yielded N = 140, NOT concussion N = 19, NOT upper extremity N = 1, and no articles met the inclusion criteria. "Return to Athletics AND youth" yielded N = 5, NOT concussion N = 2, NOT upper extremity N = 0, and no articles met the inclusion criteria (Figure 1). All titles and abstracts were reviewed to determine the relevance. After searching these keywords/phrases with and without hyphens, a manual search was conducted by the authors to determine if any abstracts contained functional performance measures. Articles were manually reviewed to ensure the population included youth and adolescent athletes defined as ages 5–14 years old or "high school" age (15–19 y). Articles were included if they had mixed age groups (adults and children or high school age).

Data Extraction

Using "Return-to-Play/Sport/Athletics AND youth NOT concussion" Boolean logic phrases yielded 7 combined relevant articles, and no articles met inclusion criteria; therefore, a new search using the same Boolean phrases without "youth" AND lower-extremity NOT concussion was conducted. All titles and abstracts (N = 227) without duplicates were reviewed by C.P. and S.J. to determine inclusion criteria. A total of 22 articles fulfilled the inclusion criteria for pooled analysis (Tables 1–3), but many were found not through database searches but through citation tracking. Additional information was gathered from related articles to gain a broader perspective on youth injuries and return-to-sport concepts.

Components of Functional Performance Measures and General Use

The most common functional performance measures used are the single-leg hop for distance,^{8,13,14,16,22,23,26,32,37–40,42,43,45,46,48,50,51} single-leg hop for time,^{8,16,23,32,42,45,48} single-leg triple hop for distance,^{8,16,23,32,37,39,42,45,48} single-leg triple crossover hop for distance,^{8,16,23,32,40,42,45,48} and vertical jump activities.^{23,24,31,37–40,44,47} Several authors have found that functional measures cannot detect specific lower-extremity deficits, yet can be clinically useful in assessing overall gross lower-extremity function.^{13,26,52} Functional

Figure 1 — Article selection using Boolean logic with primary search terms (with and without hyphens). Databases: MEDLINE, CINAHL, SPORTDiscus, Academic Search Complete, Health Source: Nursing Academic Education from 1990 to Jan 2016.

performance measures incorporate numerous variables of lower-extremity function, including neuromuscular control and coordination,³¹ muscular and dynamic strength,^{29,39} and overall dynamic joint stability.⁵¹ Many functional performance measures have been validated and demonstrate reliability, specifically the various single-leg hop tests.^{13,14,45,50,51}

The most common clinical practice guideline for assessing functional performance measures is the limb symmetry index (LSI). The original authors, Barber et al and Noyes et al,^{13,14} established a cutoff point of 80% used to determine injury risk and the side-to-side differences in performance of the injured and noninjured limbs. The LSI cutoff value has been raised to 90% to 95%, indicating less variance between limbs, thus reducing injury risk.^{8–10,32,39} Clark⁵³ supports the use of hop tests as clinical tools in the absence of sophisticated laboratory equipment because in a

controlled environment, they best replicate the forces encountered during sport. Haines et al²⁵ developed a Physical Performance Assessment Checklist for athletes with lower-extremity injuries in preparation for return-to-sport. The Physical Performance Assessment Checklist describes numerous constructs agreed on by an expert panel, including a battery of tests evaluating stability, neuromuscular control, and balance prior to return-to-sport.²⁵

Return-to-Play/Sport Criteria Studies for Youth and Combined Youth/Adult Populations With Lower-Extremity Injuries

Determining when an athlete is ready to return to play following lower-extremity injury is a difficult and complicated decision for physicians and the rehabilitation team (Tables 1 and 2).

Table 1 Articles From 1990 to Jan 2016 Using Functional Performance Measures/Objective Criteria for Return-to-Sport/Play for the Youth Population (N = 6)

Author	Age/gender	Injury/diagnosis	Functional performance measure/objective criteria used	Level of evidence	Sample size
Greenberg et al ³⁷	8 y/male	Epiphyseal ACLR	(1) SLHD (2) SLTHD (3) SLVJ (4) SL lateral hop 12" × 20 s (LSI = 90%)	Case study Level 4	N = 1
Racouillat ³⁸	16 y/female	Patellar dislocation	(1) SLHD (2) VJ (3) Sprint test (LSI calculated)	Case study Level 4	N = 1
Greenberg et al ³⁹	8–15 y mean age: 12.28 y male/female	ACLR	(1) SLHD (2) SLTHD (3) SLVJ (4) SL lateral hop 12" × 20 s (LSI = 90%)	Retrospective case series Level 4	N = 16
Myer et al ²³	14–19 y mean age: 16.9 y male/female	ACLR	NFL combine: (1) Broad jump (2) Vertical jump (3) Modified pro shuttle run (4) Modified agility-T (5) SLHD (6) SLTHD (7) SLTCHD (8) SLHT (LSI = 90%)	Case control Level 4	N = 18 + 20 controls
Myer et al ²⁴	15–19 y mean age: 17.4 y male/female	ACLR	(1) VSH for 10"	Controlled lab study	N = 33
Paterno et al ³¹	13–19 y mean age: 16.4 y male/female	ACLR	(1) DVJ (2) SLS balance	Cohort study (prognosis) Level 2	N = 56

Abbreviations: ACLR, anterior cruciate ligament reconstruction; DVJ, drop vertical jump; LSI, limb symmetry index; SL, single leg; SLHD, single-leg hop for distance; SLHT, single-leg hop for time; SLS, single-leg stance; SLTCHD, single-leg triple crossover hop for distance; SLTHD, single-leg triple hop for distance; SLVJ, single-leg vertical jump; VJ, vertical jump; VSH, vertical single-leg hop.

Table 2 Articles From 1990 to Jan 2016 Using Functional Performance Measures/Objective Criteria for Return-to-Sport/Play for a Mixed Sample: Youth and Adults (N = 12)

Author	Age/gender	Injury/diagnosis	Functional performance measure/objective criteria used	Level of evidence	Sample size
Björklund et al ⁴⁰	15–50 y male/female	ACLR/ACL injuries nonsurgical	TAK—tests for athletes with knee injuries (1) Jogging straightforward (2) Fast running straightforward (3) One-leg standing flexing the knee (4) Rising on one leg from a seated position (5) Squatting down with equal weight (6) SLHD (7) VSH (8) SLTCHD	Reliability/validity study	N = 59
Clagg et al ⁴¹	13–27 y male/female	ACLR; healthy subjects	(1) SEBT modified	Prognosis Level 2b	N = 113
Fitzgerald et al ³²	15–57 y male/female	ACLR	(1) SLHD (2) SLTCHD (3) SLTHD (4) SLHT (LSI = 85%)	Decision-making scheme	N = 93

(continued)

Table 2 (continued)

Author	Age/gender	Injury/ diagnosis	Functional performance measure/ objective criteria used	Level of evidence	Sample size
Gardinier et al ⁸	(13–55) male/female	ACLR	(1) SLHD (2) SLTHD (3) SLTCHD (4) SLHT (LSI = 90%)	Descriptive laboratory study	N = 29
Hartigan et al ⁴²	13–55 y male/female	ACLR	(1) SLHD (2) SLTHD (3) SLTCHD (4) SLHT (LSI = 90%)	Randomized clinical trial Level 2b	N = 40
Herbst et al ¹⁰	(13–29) male/female	ACLR	Back in action (1) TL-ST (2) OL-ST (3) TL-CMJ (4) OL-CMJ (5) OL-SY (6) TL-PJ (7) TL-QFT	Pilot study Level 3	N = 69
Hildebrandt et al ⁹	Youth: 10–19 y adults: 20–50 y male/female	ACLR; healthy subjects	Back in action (1) TL-ST (2) OL-ST (3) TL-CMJ (4) OL-CMJ (5) TL-PJ (6) OL-SY (7) TL-QFT	Reliability/normative data Level 4	N = 434
Jang et al ⁴³	(16–30) y/male	ACLR	(1) SLHD (2) Co-contraction agility test (3) Carioca test (4) Shuttle run (20 ft × 4 s)	Retrospective comparative study Level 3	N = 67
Paterno et al ⁴⁴	10–25 y male/female	ACLR; healthy subjects	(1) DVJ (30-cm box) (LSI % calculated)	Controlled laboratory Cross-sectional cohort design	N = 98
Paterno et al ¹⁵	10–25 y males/female	ACLR; healthy subjects	(1) Dynamic postural sway	Controlled laboratory Cross-sectional cohort design	N = 98
Reid et al ⁴⁵	15–45 y male/female	ACLR	(1) SLHD (2) SLTHD (3) SLTCHD (4) SLHT (LSI % calculated)	Prospective Observational Repeated measures	N = 42
Schmitt et al ¹⁶	14–25 y mean age: 17.3 y male/female	ACLR; healthy subjects	(1) SLHD (2) SLTHD (3) SLTCHD (4) SLHT (LSI 85–90%)	Cross-sectional study	N = 90

Abbreviations: ACLR, anterior cruciate ligament reconstruction; DVJ, drop vertical jump; LSI, limb symmetry index; OL-ST, one-legged stability test; OL-SY, one-legged speedy jumps; SEBT, star excursion balance test; SL, single leg; SLHD, single-leg hop for distance; SLHT, single-leg hop for time; SLTCHD, single-leg triple crossover hop for distance; SLTHD, single-leg triple hop for distance; SLVJ, single-leg vertical jump; TL-PJ, 2-legged plyometric jumps; TL-QFT, two-legged quick feet test; TL-ST, two-legged stability test; VSH, vertical single-leg hop.

In our review of the literature, only 1 study included was not specific to an ACL injury/reconstruction (ACLR). In the case study by Racouillat,³⁸ functional performance measures (single-leg hop for distance, vertical jump, and sprint test) were used as return-to-sport criteria for a 16-year-old female lacrosse player rehabilitating from a patellar dislocation.

A case study of an 8-year-old boy included functional performance measures during the rehabilitation process and as return-to-sport criteria after an all epiphyseal ACLR.³⁷ The patient was able to achieve 90% strength symmetry and pass all return-to-sport criteria using 90% LSI score by 9 months postoperatively.

Greenberg et al³⁹ also assessed strength and functional performance recovery for 7- to 15-year-olds following ACLR and found this population may require additional rehabilitation time prior to return-to-sport due to the important characteristics unique to growth and development.

Reid et al⁴⁵ support the use of and facilitate the interpretation of the most common functional performance measures and the associated LSI score for determining return-to-sport. They established the reliability and longitudinal validity of common hop tests, used as outcome measures after ACLR, for the youth and adult population (15–45 y).⁴⁵

Table 3 Articles From 1990 to Jan 2016 on Normative Data for Youth Using Functional Performance Measures/Hop Tests (N = 4)

Author	Age/gender	Sport	Functional performance measure/ objective criteria used	Level of evidence	Sample size
De Carlo and Sell ⁴⁶	Males: mean age = 14.5 y females: mean age = 14.2 y	Multisports	(1) SLHD (LSI % calculated)	Normative data Level 2A	N = 2508 male = 1635 female = 873
Holm et al ⁴⁷	7–12 y male/female	Physical education School activities	(1) VJ (with upper limbs) (2) VJ (without upper limbs)	Normative data Level 2A	N = 387
Myers et al ⁴⁸	Mixed sample 14–24 y mean age = 17.37 y male/female	High school athletes Collegiate athletes (basketball, soccer)	(1) SLHD (2) SLTHD (3) SLTCHD (4) SLHT (LSI % calculated)	Normative data Level 2A	N = 372
Schneiders et al ⁴⁹	Mixed sample 18–40 y	Healthy physically active	(1) FMS	Normative data Level 2A (cross-sectional)	N = 209

Abbreviations: FMS, functional movement screen; LSI, limb symmetry index; SL, single leg; SLHD, single-leg hop for distance; SLHT, single-leg hop for time; SLTCHD, single-leg triple crossover hop for distance; SLTHD, single-leg triple hop for distance; VJ, vertical jump.

A decision-making scheme for returning youth and adult ACL-injured patients (15–57 y) to high-level activities, including sports or manual labor occupations, was created by Fitzgerald et al³² using common functional performance measures. This study was designed to determine candidates for nonoperative treatment of ACL injuries and create return-to-play/work criteria after an extensive rehabilitation program. The original LSI score of 80% was used, but Fitzgerald et al³² found that this needed revision to ensure a higher success rate for patients returning to high-level activities.

Clusters of functional performance measures are often used to assess the athlete as a whole and reveal deficits associated with a variety of athletic challenges. Björklund et al⁴⁰ developed an extensive functional test battery—tests for athletes with knee injuries, using a mixed age range (15–50 y)—that has shown good interrater reliability and acceptable intrarater reliability. This criterion-based test was created so the physical therapist and patient could independently and simultaneously assess performance using 8 functional performance measures frequently used in rehabilitation when returning to sport following knee injuries.⁴⁰ Myer et al^{18–20,24} have also published numerous studies with the youth population and high school athletes, investigating clinical correlates to laboratory measures and objective test batteries establishing return-to-sport criteria for use in ACL injuries. Myer et al²³ utilized a modified National Football League combine test battery to identify functional deficits in athletes following ACL surgery and determined using unilateral hop tests that could identify deficits in performance for athletes attempting to return-to-sport. There is no association of time from surgery for ACLR high school athletes and deficits in unilateral force production (vertical jump height) and absorption (vertical ground reaction forces), revealing persistent side-to-side differences.²⁴ The authors agree that there is a need to develop objective, performance-based, on-field assessment methods that can be used to determine when an athlete is safe to return-to-sport.^{23,24}

The drop vertical jump is often used by investigators to evaluate lower limb asymmetries and neuromuscular control after ACLR to determine risk of reinjury and return-to-sport status in athletes (10–25 y). Paterno et al⁴⁴ used the drop vertical jump, finding compensatory landing patterns still noted in patients at the

time of return-to-sport, and was able to predict a second ACL injury after a previous ACLR.³¹ Out of 56 athletes with ACLR, 13 athletes between the ages of 13 and 19 years suffered a subsequent second ACL injury. Altered neuromuscular control, asymmetry in the limbs during the drop vertical jump task, and postural stability deficits were the greatest predictors of injury recurrence after a return-to-sport.³¹

Hartigan et al⁴² advise using stringent return-to-sport criteria and not time-based guidelines for athletes participating in cutting, pivoting, and jumping sports. Seven functional performance measures with strict limb symmetry scores of 90% or greater determined if athletes with ACL injuries (ages 13–55 y) could return-to-sport without surgical intervention (copers vs noncopers).⁴² Hartigan et al⁴² found the time required to pass all objective criteria varied greatly and found some high-level athletes were unable to pass the higher standards necessary for a safe return-to-sport 1 year following injury.

The impact of quadriceps strength deficits on 4 common functional performance measures at the time of return-to-sport on 14- to 25-year-olds has been studied.¹⁶ Individuals with more symmetrical quadriceps strength (side-to-side differences of 10% or less and quadriceps index score of 90% or greater) demonstrated functional performance similar to that of uninjured individuals.¹⁶ It was also noted that despite being “cleared” for return-to-sport, quadriceps weakness and functional deficits were still present in these young active patients with ACLR, reiterating the need for more difficult return-to-play criteria.¹⁶

Jang et al⁴³ included rotational stability testing in their return-to-sport criteria using the carioca, co-contraction, and shuttle run tests in conjunction with the single-leg hop for distance test. Based on this study of male athletes (16–30 y) with ACLR, functional performance measures addressing dynamic rotational stability more closely mimicking sporting activities of cutting and pivoting were advised.⁴³

Patients between the ages of 13 and 55 years with ACLR demonstrated abnormal knee contact forces during gait and return-to-sport testing with significant and meaningful joint contact force asymmetries noted during single-leg hop testing.⁸ These patients failed return-to-sport criteria at 6 months after ACLR, indicating increased risk for reinjury or long-term chronic knee pathologies for patients returning to sport prior to these asymmetries being addressed.

The development of a test battery, “back in action,” using functional assessments for decision making regarding return-to-sport following ACLR has been established by Hildebrandt et al.⁹ This was the first step in creating a standardized, easy-to-use objective evaluation of knee function to facilitate the decision regarding return-to-sport. Normative data categorized by age and moderate to high reliability were established.⁹ Countermovement jumps, plyometric jumps, speed jumps, and agility tests were included in the functional performance test battery. Herbst et al.¹⁰ then studied the clinical application of the “back in action” test battery using a 90% LSI score, establishing that most ACLR athletes did not exhibit the neuromuscular abilities, when compared with healthy controls, required to return-to-sport at 8 months postoperatively. The “back in action” test battery takes 45 minutes to complete and requires little equipment and space.

Dynamic balance and postural sway have also been used as functional performance measures determining return-to-sport criteria. Balance deficits and decreased dynamic stability have been associated with ACL injuries. Paterno et al.¹⁵ used a single limb stance with eyes open on a Biodex to test dynamic postural sway and found it was significantly altered for 10- to 25-year-old patients with ACLR compared with healthy controls. Performance on the modified star excursion balance test was also assessed for 13- to 27-year-old patients with ACLR at the time of return-to-sport.⁴¹ Clagg et al.⁴¹ found the ACLR group had lower anterior reach distances on the injured and noninjured limbs compared with the control group. The star excursion balance test has been used as a clinical tool to assess neuromuscular control deficits and dynamic stability in patients with ACLR, but the modified star excursion balance test is still being investigated.

Normative Data for Youth Using Common Functional Performance Measures

Having age-appropriate healthy normative values for a variety of functional performance measures is necessary to determine return-to-play criteria for injured and noninjured limbs. De Carlo and Sell⁴⁶ found normative ranges for 2508 high-school-age males and females in a single-leg hop for distance with associated normal side-to-side variations. Abnormal functional test scores can assist medical staff in clinical decisions about returning an athlete to sport. Holm et al.⁴⁷ looked at muscular power in 2 different standing vertical jumps for 387 males and females between the ages of 7 and 12 years. Normative data for a battery of hop tests (single-leg hop for distance, single-leg hop for time, single-leg triple hop, and single-leg triple crossover hop) were found by Myers et al.⁴⁸ for a mixed population of high school and college, male and female, soccer and basketball players. They concluded that separate hop test standards should be based on participant sex and level of competition and found no clinically relevant differences between dominant and nondominant limbs.⁴⁸

Normative data were established for the “back in action” test battery developed by Hildebrandt et al.⁹ and Herbst et al.¹⁰ in a 2-part study using 434 participants. The subjects were categorized according to age: children (10–14 y), youth (15–19 y), young adults (20–29 y), and adults (30–50 y). Each of the 7 tests is reliable and simple to perform, and represents an important foundation for return-to-sport criteria in the clinical setting.^{9,10}

The functional movement screen instrument has been thoroughly studied, and normative values were established in 2011.⁴⁹ Functional movement screen reference values were provided for healthy, young, active individuals ranging from 18 to 40 years.⁴⁹

This test is often used to screen athletes for musculoskeletal injury and performance factors, and has been integrated into some return-to-play criteria test batteries. Determining normative values for the most reliable and valid functional performance measures can establish standardization of return-to-play criteria.

Discussion

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 5 common electronic databases, “return-to-play” search terms yielded a total of 5413 articles and “return-to-sport” yielded another 2065 articles (with some redundancy). Of the 5413 articles on “return-to-play,” 157 (<3%) of the articles were on youth, and none of the articles met the inclusion criteria of this study. The same was true of the 2065 articles found using the search term “return-to-sport.” Of these articles, only 140 (<7%) were on the youth population, and none of these articles met the inclusion criteria of this study. It is clear that the topic of return-to-play is well established in the literature, but when applying to the youth population and isolating lower-extremity injuries, we found only a handful of articles using a variety of search terms. The literature search yielded 22 studies from 1990 to January 2016 that described various functional performance measures or test batteries used in the youth and adult populations as return-to-sport criteria for lower-extremity injuries. 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. Numerous other studies investigated kinematics, kinetics, and intervention programs of the lower-extremity using functional performance measures; therefore, these articles were not included.

In 2013, Haines et al.²⁵ conducted a Delphi study that was used to develop a consensus statement on the critical constructs necessary for a comprehensive functional performance or physical performance assessment tool. The development of an instrument used to fully assess an athlete’s ability to return-to-sport safely following a lower-extremity injury is essential for reducing injury risk.²⁵ 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.²⁵ 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.

Inconsistencies in the Literature and Limitations

A limitation of this paper is that many articles were found by manual review; therefore, it is possible that some articles were missed. Numerous articles also measure the same performance task, such as single-leg hop for distance, but the terminology used to describe this clinical measure was not consistent. Many studies that investigated functional performance measures were not found through a database search, but by manual search within an abstract, reference list, or methodology section of other articles. For example, in the articles found manually, the terms used by the various authors that were deemed synonymous with each other include the following: functional performance tests, physical performance measures/tests, clinical outcome measures, performance outcome measures, athletic performance measures/tests,

athletic assessments, field-based measures, field-expedient tests, functional screening tests, functional stability tests, function testing, neuromuscular indices, lower limb function, lower limb assessment, performance indices, performance aspects, physical performance tasks, task performance, motor function, motor activities, dynamic stability, performance-based functional outcome, functional determinants, and functional capacity. As there is no consensus on terminology, definition, or standardization among researchers, physicians, clinicians, coaches, and athletic trainers, a single-leg hop test (the most popular functional performance measure) could fall under any of the above-stated phrases. This makes it difficult for investigators to find appropriate literature on the topic of functional performance measures and creates confusion and inconsistencies in the administration of these measures.

Recommendations for Future Research

It is imperative to agree on definitions and terminology when describing performance measures in research, so we can accurately relay results and information and develop generalizable conclusions. Inconsistency in language makes it difficult to find information and leads to errors in interpretation.

Developing normative databases using a variety of functional performance measures is necessary to truly assess lower-extremity deficits. Currently, the LSI is commonly used to determine side-to-side limb differences postinjury,^{13,14,23} but recently Larsen et al¹⁷ found that the noninjured limb was also impaired when compared with healthy controls 9 to 12 months after ACL surgery. This would suggest that having age-appropriate healthy normative values for a variety of functional performance measures could be used to determine return-to-play criteria for the injured and noninjured limbs. In this literature review, we found 4 articles (Table 3) describing normative data for a variety of functional performance measures in the youth population.^{46–49}

There is a consensus about the need for further research to develop a comprehensive test battery using functional performance measures to assist in return-to-play decisions for lower-extremity injuries. Future research should focus on validating these measures and assessment tools and then extend them to the youth population.

Conclusion

This descriptive literature review identifies 22 articles that meet the search criteria for the youth population discussing the use of clinical functional performance measures used to identify return-to-sport/play criteria for lower-extremity injuries (Tables 1–3). Injury prevention in youth sport is becoming a public health priority; therefore, it is imperative that we expand our efforts and research on this topic. There is an obvious need for further investigation into the use of functional performance measures in the youth population. Investigators using samples of collegiate athletes or adults have shown promising results using clinical measures for assessment of injury risk, return-to-play criteria, or as preparticipation screening tools. Because of 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-play criteria. This comprehensive assessment tool could be used for both the adult and youth populations, encompassing all the constructs needed to assess lower limb function and predict injury risk.

Practice Recommendations

1. Create consistent terminology and definitions related to functional performance measures and assessments.
2. Develop and validate a comprehensive functional performance test battery, Advanced Lower-Extremity Sports Assessment, utilizing various functional performance measures included in all the functional testing categories.
3. Extend future research to the youth population using the Advanced Lower-Extremity Sports Assessment or other comprehensive test batteries.
4. Determine normative values for the most reliable and valid functional performance measures used on various populations to create standardization of the Advanced Lower-Extremity Sports Assessment or other comprehensive test batteries.^{54,55}

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