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The final stage (late) of sport rehabilitation: Critical analysis of quality of movement and injury risk factors during return to sport

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Abstract

Background. *An ever increasing number of athletes incur injuries during sporting activity.*
Introduction. *A previous injury is often associated with a decrease in gestural quality. This is identified as an important risk factor for second injuries which is consistent with the results of many studies in the recent literature.* Objective. *The purpose of this article is to investigate the reliability and validity of functional tests such as FMS, AAA, LESS, TJA.*
Method. *Our research was limited to reviewing the studies published in the last 10 years in English on the PubMed database.* Results. *We found a limited literature referring to functional tests investigating the quality of movement. This allows us to affirm, also given the subjective analysis of the evaluations, their unreliability and validity in the diagnostic and therapeutic use of complex sports gestures and in rehabilitation practice. There is also conflicting and inconsistent evidence regarding the analysis of the quality of post – injury movement to determine altered patterns and postural – dysfunctional pictures linked to specific gestures.*
Conclusions. *In conclusion, further research is essential to focus on the validity of subjective evaluations, aimed at validating the quality of movement. Subjective Evaluation Tests, as such, found in the literature should be used in conjunction with additional clinical tests and evaluations to identify other sport-specific injury risk factors.*

Keywords. *Risk Factor for Injury , Return to Sport , Movement Quality, Functional Movement, Functional Tests, Movement Assessment.*

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Premise

In the analysis of research in the literature, there is little evidence that confirms a consensus on the homogeneity of risk factors, post - primary injury in athletes, correlated with individual sports.
It has been suggested by some of the literature[1,3,4,30,36,41,45,76] as an altered neuromuscular control and as a predictor of second injuries.
Previous deficits in neuromuscular control[36] lead to destructuring of motor control and gestural expressiveness[4,5,6]. This is evident during specific sporting movements such as "decelerations, jump-landing manoeuvres, sidestep cutting" [2,3,35,76].
Hagglund[1] conducted a prospective study of elite soccer players. He argues that athletes with a previous knee flexor injury or groin pain are two to three times more likely to suffer an identical injury in the following sporting season[1].
The author[1] underlines, in this work, how the overall percentages on injuries were similar between the subsequent seasons analyzed. Many of the recurrent injuries could likely be attributed to inadequate rehabilitation or an early return to after the initial injury[3,41,42].
Fulton[4] remarks, in a 2014 study, how an anterior cruciate ligament (ACL) injury is linked to a subsequent contralateral re-injury or same side. A hamstring injury is associated with subsequent “contralateral or same side muscle injuries and knee pathologies[4].
Previous injury to the achilles tendon increases the risk of a similar injury on the contralateral side. A sprained ankle is associated with a same-sided or contralateral ankle injury. Thus, the author[4] states how an injury can increase the risk of a new injury or subsequent injury[4].

Introduction

Information on the relationship between primary injury and subsequent second injury should focus not only on the study of the clinical process but also on the potential reduction of risk factors for a future second “contralateral or same side” injury.
It becomes essential to structure a specific rehabilitation protocol with follows-up based on pre-established objective criteria and indicators in relation to the objectives that occur within the phases of the return to sport process[3,76]. This process is referred to as the "Return to Sport Continuum" (RtSc)[3,76]. The approach adopted during and through the various moments of transition from injury to full participation in sport is fundamental in stabilizing the athlete at high level performance. This reduces the risk factors for re-injury or complications during training or match[3].
Unfortunately, the organization of the return to sport (RtSp) is not always managed in a systematic and objective way. This, of course, can lead both to a delay in the rehabilitation process with an increase in the risk of re-injury, and to a subsequent reduction in performance once the athlete has returned to full agonistic activity[3]. Recent systematic reviews show that the Return to Sport (RtSp) is mostly based on clinical criteria[3,47]. Dynamic functional tests (eg. Crossover hop for distance, triple hop for distance, Single Leg Triple Crossover Hop, Single leg squat ,, ... etc) are reported, in the literature, as a subjective clinical tool to validate the decision-making process of returning to sport[3,42,43,45]. Many of these tests are not oriented towards simulating a specific technical-athletic gesture. These must provide information on the level of the athlete's specific posture / functional gestural status of recovery[3,46]. These criteria are part of the functional evaluation on the analysis of the quality of movement [15,17,20,76].

Gestural expressiveness and quality of movement

Functional screenings are currently used to identify risk factors for injury in athletes, including looking for dysfunctional movement patterns [3,8,12,13,15,18,19,41].
The evaluation through functional, multifactorial tests[49], highlighted in the literature[1,3,6,12,30], often does not take into account the gestural patterns and functional movement models of

individual sports. A quality movement correlates positively with all the skills of the game, in a coherent, harmonious flow, in a continuum between gestural movements aimed at optimal sports performance.
However, it must be emphasized that the qualitative expressive fluidity of movement is an often-neglected component of sports trauma research and must be considered together with the assessment of physical performance. To this end, however, a standardized, validated, objective evaluation tool is necessary in relation to the type of individual sport.
The movement becomes non-optimal, therefore dysfunctional, due to trauma or "injuries" along the kinetic chains. These are described as a loss of the “Mobility – Stability Continuum”[7] during sport-specific dynamic gesture patterns.
It is stated[8] that, in athletes, the quality of dynamic movement (Jump, Cutting Manoeuvres, etc.) after an injury is significantly impaired[1,2,4,8], which leads to an increase in the risk factors for further injuries and re - injury during the rehabilitation process and the return to sport[3,53].
To date, there is no standard consensus on procedures for assessing the quality of post - injury movement. Non-homogeneity, however, entails diversified evaluation protocols which alter, with different results, the clinical / rehabilitative path which must be based on objective criteria and scientific evidence[3,53].

Second injuries and risk factors

Sports with repetitive activities such as "Jump, landing, cutting manoeuvre, change of direction sprints" can predispose athletes to different types of acute and chronic injuries and re-injuries to the upper and lower limbs[33].
The high percentages, highlighted by the literature, of second injuries are often caused by an improper and inopportune timing relative to the return to sport[42,43,45].
Arden[43] points out that the return to sport varies according to certain and different factors. In this 2014 work, it is highlighted that only 55% of athletes return to competitive sport after an anterior cruciate ligament reconstruction surgery[43].
Zebis[50], for example, states that at 12 months, after an ACL reconstruction, there is insufficient neuromuscular control during specific technical and athletic gestures and skills.
Others[44,45] point out that post-injury changes are present in terms of side-to-side force asymmetries, proprioception and kinematics, which may have led to general changes in motor control and gesture function with increased risk factors for injury. Thus D'Onofrio[42], recently in a Patient Reported Outcomes Measures (PROm) study of a Survey[42] underlines, how high levels of Kinesiophobia can represent a clear factor that influences the expression of sports movement by increasing the risk factors of re - injury.
For Fulton[4], an ACL lesion correlates with a re-inury and other lesions within the functional kinetic chain. Hamstring injuries are associated with subsequent ipsilateral injuries and injuries to the knee joint[77]. A previous Achilles tendon injury increases the risk of a similar injury on the contralateral side. A sprained ankle is associated with a new ipsilateral or contralateral ankle injury.
Hagglund[1] highlights how a primary injury is the most important risk factor for a re-injury. The Author[1] points out that Swedish Male Football Teams athletes who suffered an injury during one season increase their injury risk factors in the following season[1,4]. Thus it is underlined how a previous injury to the hamstring or a groin pain can increase the risk of a “delayed recurrence” [3], in the same limb in the following season.
Recent research from 2017 confirms what Hagglund[1] previously pointed out. A prospective cohort study[54] of male footballers showed that 10.5% of players with a previous knee flexor injury and 4.6% of players without a previous injury to the same muscle district suffered a “late relapse”[3] a new injury during the season, indicating that athletes with previous knee flexor injuries are more than twice as likely to suffer a new injury[54].

However, these risk factors are not considered when determining when to return to sport. The criteria used are based on clinical pathways and stereotyped functional models.
Almost no objective criteria exist to ensure safe and effective rehabilitation modulated in a progressive therapeutic continuum aimed at ensuring a return to sport at the levels prior to the injury.
One of the most important factors in the decision-making process related to return to sport, is the quality of simple and complex gestural movement[53].
Functional Tests are currently present in the scientific literature to assess the quality of gestural movement, aimed at facilitating the decision-making process relating to the injured athlete's RtSp[3.48].

Typology of functional screenings

It is suggested that posture-satisfactory asymmetries linked to sport-specific movement patterns are risk factors for injury and re-injury[75,76].
Knowledge of these changes can foster rehabilitation models aimed at reducing re-injury rates[3].
After an injury, athletes often have reduced functional capacity[3,41,75]. Several authors [1,3, 53,60] have described a previous injury as the greatest risk factor for a subsequent secondary injury to functional biomechanical changes related to gestural expression.
Movement quality capability is an often-overlooked component of sports rehabilitation research. This must be considered in conjunction with the clinical evaluation. To achieve this, evaluation tools are needed that we have a scientific consensus. To date, almost no standardized test for assessing the quality of movements has been validated according to objective criteria. Specific functional tests, present in the international orthopaedic literature, can help determine the status of the athlete's rehabilitation level[41]. The design of the tests[3,41,58] must reflect the gestural complexity in high-performance sports. Movement quality assessment should include several unilateral, bilateral and high intensity functional tests in order to create comparable physical needs as those specific to the sport being practiced.
The screenings[76] present in the clinical-scientific literature are:

a) *The FMS, Functional Movement Screen* [18,19,20] (Functional Movement System, Chatham, VA, USA), is the one that finds greater applicability in practice. The seven functional tests of the FMS[10,19] are: a) Shoulder Mobility (SM) b) Active Straight Leg Raise (ASLR), c) Trunk Stability Push Up (TSPU) d) Rotary Stability (RS) e) Deep Squat (DS), f) Hurdle Step (HS) g) In Line Lunge (ILL).
The tests were performed three times each, and the subject's movement was rated on a scale of 0–3 points[19]. [(0 points; movement performed with pain, (1 point; Unable to perform movement, (2 points; Perform movement with compensation (3 points; Complete movement without any compensation[19]. The maximum possible score from the FMS is 21 points The FMS ™ protocol may not meet the perceived needs of the professional working in elite sport[76].

b) *The Athletic Ability Assessment (AAA)* was designed to assess the gestural movement of athletes at higher levels of complexity. McKeown[15] reports that the AAA selects exercises to evaluate functional movements that are most closely aligned with the gestural skills underlying sports performance. Athletes are evaluated in sequential order through an exercise protocol which is as follows:
a) prone hold, b) side hold (left), c) side hold (right), d) overhead squat, e) single leg squat (left), f) single leg squat (right), g) walking lunge (BB on shoulders), h) hop (left), l) hop (right), m) bound (left) n) o) bound (right), p) push ups q) chin ups.
Each movement is assessed using scoring criteria consisting of three main assessment points per exercise. The scoring criteria are: [(1 point = poor, unable to perform a specific activity [(2 = inconsistent execution of a specific activity or slight compensation] [(3 = perfect performance of

a specific activity. The sum of the three points Assessment includes the score for each individual exercise. The maximum score for each movement is 9. Separate scores are given for exercises performed unilaterally and the total of all tests gives the individual a composite score out of 117.

c) *The Landing Error Scoring System (LESS)*[17] is relatively well known in practical applicability; First introduced in 2009, the Landing Error Scoring System (LESS) is a clinical tool used to assess jump-landing biomechanics[17,22].
It was developed to identify athletes at risk of an anterior cruciate ligament injury. Test [22] a Jump Drop-Vertical (DVJ) (from a 30cm box), is analyzed on the frontal and sagittal plan (17 evaluation items). The experience of the evaluator in the examination is crucial to avoiding errors of clinical / functional interpretation. A higher LESS score indicates more mistakes and, therefore, a poorer landing-jump technique. LESS scores are categorized for the specific observed population and are defined as excellent (range 0–3 errors), good (range 4–5 errors), moderate (range 6 errors) and poor (≥7 errors). Being a simpler, faster and cheaper variant expressed in the field[23] than a complete biomechanical evaluation it can be performed without expensive laboratory equipment.

d) *The Qualitative Analysis of Single Leg Loading (QASLS)* is a lesser known analysis and evaluates the quality of movement only during single stance movements; The qualitative analysis of single leg squat (QASLS) is a new scoring system designed to identify suboptimal segmental behaviour following performing a single leg squat. The QASLS scoring system is a segmental method of analysis and a series of tests[28].
The motion analysis is divided into six categories[28]: a) Arm strategy, b) Trunk alignment c) Pelvic plane, d) Thigh motion, e) Knee position f) Steady stance to evaluate the load on single leg loading in particular, which focuses on knee impairments.
The patient is rated[29] between 0-10, with a higher score indicating a higher risk of injury or worse performance. The score was defined as zero for the appropriate strategy without compensation and one point for each inappropriate movement that occurred, for each body part with the best overall score of 0 and the worst 10 points or else zero for quality movement or a maximum of 10 errors or incorrect movements.

e) *The Tuck Jump Assessment (TJA)* introduced by Myer[34] is another clinical screening tool. The use of the tuck jump assessment is designed to identify “neuromuscular imbalances”
[34]. It can provide indications for identifying the risk factors of ACL injury both in the healthy athlete and as an evaluation screening during the rehabilitation process. The clinician expert in the evaluation can effectively identify the athlete's biomechanical dysfunctional pictures.
The Tuck Jump[13] test consists of continuous jumps for ten seconds on the spot and analyses ten elements related to the main neuromuscular risk factors associated with contactless ACL injury. These are identifiable in: a) Ligament dominance, b) Quadriceps dominance, c) Leg dominance, d) Trunk dominance, e) Feedforward mechanisms deficits and Neuromuscular fatigue[34]. Participants are assigned a "0" if they meet the specified criteria and a "1" if they do not meet the specific criteria[31]. This simple assessment method is often crossed with other screening tools.

f) *The Vail Sport Test* ™ is a test to be used during the rehabilitation period and the process of returning to sport. It incorporates a series of functional "multiplanar dynamic against resistance" activities of a sportcord®[38] the test includes 4 evaluation moments which include: a) single-leg squat for 3 minutes for 3 minutes b) lateral bounding for 90 seconds and c) forward / backward jogging for 2 minutes. After each component, the patient is given 2.5 minutes of rest before proceeding with the next activity.

The patient is evaluated based on the ability to perform the test while maintaining adequate quality of movement without compensation and compensation. The potential scores for the individual components are as follows: The single leg squat and lateral bounding both have a maximum score of 15 points and the forward and backward jogging have a maximum score of 12 points each for a total composite score of 54 points.
For movement assessment to be effective, assessment must not only assess dysfunction in a standardized set of movements, but also identify differences in side-to-side ability to perform these movements.
They act as a guide for monitoring progress, modulating the rehabilitation process and structuring the objectives to be achieved. Clinical / functional follow-ups should be structured up to 36 months after reconstructive surgery. This is to optimize the rehabilitation process and the consequent return to sport and performance in contact / contrast sports, pivoting, cutting, jump, and landing[41].

Quality and accuracy of measurement

The tests selected and described are subjective evaluations. Compared to objective methods, these subjective tests are workable and efficient in terms of time, budget and convenience. Existing subjective tests can be further enhanced by objective measures to increase accuracy, validity and reliability.
Professionals conducting screening tests, presented without any technological help, must have experience in monitoring specific movements in general and have excellent knowledge of biomechanics and receive specific training within the selected test method. This improves the reliability of the evaluation.
In order to increase the quality criteria and the accuracy of the measurement, the evaluation of the athlete should ideally be carried out using an analysis on the different planes for example in the frontal and sagittal plane, transverse and longitudinal axis of rotation since these values may not be homogeneous and request further study with supplementary tests for a diagnostic interpretative quality of the final results.
Within the literature, it is also possible to objectively evaluate dysfunctional pictures using what has been considered the three-dimensional "gold standard" 3-D motion capture [30]. These systems, although accurate, are expensive and the evaluations require long application and processing times and very experienced and highly specialized personnel. 3D motion analysis qualifies as a reference standard for objectifying movements; however they are very elaborate and therefore improve the quality of a diagnostic evaluation[49,61].

DISCUSSION

The high rates of re-injury suggest that an adequate analysis of clinical-rehabilitative reasoning should be supported to validate the injured athlete's return to sport process.
On the basis of current evidence, functional tests are proposed to help clinicians in the decision-making process in assessing fitness for competitive sport after injury.
In this context, the functional tests proposed are based on subjective assessments aimed at verifying movement patterns and posture / functional dysfunctions, which could highlight the status of the rehabilitation process during periodic follow-ups.
The subjectivity, however, of these assessments limits their reliability.
These tests are generally simple, quick and repeatable and require very little equipment and the ability to develop them in a healthcare setting for their implementation [41].
Studies[10,11,12,13,16] present in the literature have verified the reliability, validity and objectivity of the selected tests (FMS, AAA, Hop test, SLS, etc.).
Our analysis clearly highlights that none of the functional tests have yet been explicitly validated by the literature. This is due to a small amount of scientific research of the tests listed by us and the contradictory results on their validity and reliability given the subjective evaluation. Due to

the nature of subjective assessments based on observational processes, it is difficult to satisfy the investigation criteria relating to dysfunctional pictures related to gestural expressiveness.
So:
a) Recent studies [10,11,12,18] have verified the reliability and objectivity of the Functional Movement Screen (FMS). Given the minimal evidence in the scientific literature (166 articles on PubMed, in the last 10 years), to date, it is not possible, in our opinion, to validate its applicability especially in elite athletes given the type of tests included in the FMS20. Parchmann[20] also points out that the FMS is not an adequate field test for the prevention of injuries as it cannot be correlated to any specific sport-relative dynamic gestures. In order to use the FMS in high performance sports, it can be considered its integration with further dynamic tests such as the TJA[13] which better identify the risk factors for injury or re-injury in footballers[1]. Moore[21] in a recent work from 2019 highlights how athlete's age, gender and type of sport explained some of the varying results of prospective injury risk studies assessed through the FMS. Functional Movement Screen (FMS) composite scores and asymmetry were more useful in estimating the risk of injury in senior athletes than in junior athletes. Questions have been raised about the ability of the FMS™ to characterize significant changes in movement quality during multiple test sessions and the relationship between FMS™ scores and improvement in sports performance[73]. The FMS™ was originally developed to evaluate the normal function of basic movement skills of daily living[74]. A level of assessment that takes into account sporting needs and movement under load is still required.

b) The Athletic Ability Assessment (AAA) is the result of a further development of the FMS[15]. It contains several functional tests that are relatively dynamic and demanding from the point of view of execution. The disadvantage of the AAA is the complex evaluation panel of the versatile functional tests included. The AAA's goal is to become a reliable movement assessment protocol targeting specific sports populations[15]. Since the AAA is a recently applied tool, further research may requalify simplified and modified versions. Good reliability and objectivity of the AAA is present in only one study[15].

c) The Landing Error Scoring System (LESS) is a valid and reliable tool to identify biomechanically [17,30,33,36] high risk movement patterns during a jump-landing activity[24]
Beese[24] recommends using LESS to identify people with impaired lower limb mechanics, which may lead to an increased risk of lower limb injury[24]. Gokeler[26], found significant differences in pre-fatigue and post-fatigue LESS scores. fatigue. Personalized rehabilitation programs that consider specific neuromuscular features with and without fatigue status should be developed in rehabilitation after ACL reconstruction[26] For Padua[22], the consensus search for screening tools to identify athletes at high risk of ACL injuries is an important step in the prevention of these traumatic pathologies. The author[22] highlighted how elite-level youth soccer athletes with a score> 5 were at greater risk of incurring an ACL injury than other athletes with LESS scores <5 [22]. Athletes with scores> 5 or higher should be referred to supplemental LCA injury prevention programs.
LESS tests include a more comprehensive assessment of multi - planar biomechanics than other clinical assessments. Padua[17] states that LESS is a valid and reliable tool for identifying subjects with errors in the executive technique of landing after a jump on the different planes of space. However, more research is needed to determine the predictive ability of LESS for ACL injuries.

d) The Qualitative Analysis of Single Leg Loading (QASLS) can be used to evaluate single-leg squats. So far only two pilot studies have analyzed QASLS[64.65]. This test is applicable for preliminary assessment when only a limited time is available. In the late rehabilitation phase the TJA (Tuck Jump Assessment) could be performed in addition [27,29]. Impaired neuromuscular control[4,22,33,36,59], has been suggested as a mechanism of injury in soccer players. Evaluation of

kinematic variables during jump-landing activities as part of a pre-season screening is useful for identifying the risk of injury.

e) The Tuck Jumps, Assessment (TJA) analyses the execution of bipodalic jumps. Since the TJA includes an important executive performance for which the test allows, also the evaluation of the quality of the movement under, “Fatigue status” [26,33].
Although TJA has been developed over 10 years to date, only a few studies (PubMed 12 articles over the past 10 years) have analysed TJA[13,14,31,32,34,37]. Consequently, TJA can be recommended only partly as a preliminary assessment and as an additional test.
It must be stated that the TJA[34] has limitations associated with the analysis and the traditional scoring system [31]. The current dichotomous scoring system does not allow the clinician to assess the severity of the dysfunctional picture within objects[31].
This limitation makes it difficult to detect both the posture / biomechanical pictures [17,30,33,36] of the high-risk movement models deriving from neuromuscular training and the increase of the same, high-risk, "post-fatigue" movement models [26,33].
Intuitively, by changing the scoring system from the original scale (0-1) to a modified scale (0-2), it may be possible to provide more objective information about an individual's risk of ACL injury[31].
Research[31] has shown that the modified version[32] (new scoring methodology) of the TJA test shows good to excellent intra- and inter-rater reliability for most articles using retrospective video analysis[32]. Furthermore, the benefits of neuromuscular deficit assessment may be of particular relevance for athletes whose activity involves gestural movements such as sidestepping, cutting manoeuvres, and deceleration tasks all related to a high incidence of injuries[5].
Future research should focus on determining the validity of this test. In particular, further information is needed to examine whether a higher TJA score is associated with risk factors related to neuromuscular control [4,22,45,50,60], but also about the consequential increase in ACL injury risk factors[14,34].
In conclusion, Smith[32] found that TJA is clinically valuable in clinical practice. We suggest more details on the application and training methodology of test[34] for adequate reliability in raters with modified TJA[32].
According to Read[37] although Tuck Jump Total Score can be reliably assessed in elite male youth soccer players, caution should be exercised in interpreting the composite score only due to the high variation within the subject in a set of individual criteria.
For Hewett[30], the analysis of knee movements during landing after a jump are predictive factors of the risk of injury to the anterior cruciate ligament in athletes. The search for valgus moments of the knee during Jump - landing[30] can be used reliably to identify athletes at high risk of ACL injuries.
Screening methods aimed at analyzing movement quality can help develop rehabilitation protocols aimed at improving neuromuscular control[4,22,45,50] in female athletes.
However, the tests provided are aimed at identifying the altered gesture mechanics and consequently, through rehabilitation protocols, at reducing or eliminating the risk factors for ACL injuries in athletes[60].

f) A further test tool for assessing the quality of movement through subjective monitoring is the Vail Sport Test (VST). This includes functional tests that analyse the quality of movement on all planes of space. The Vail Sport Test ™ is a return to the evaluation of sport - relative gestures. It incorporates a series of dynamic “multiplanar” functional activities against the resistance of a sportcord. Although there are some studies on the VAIL Sport Test[66,67,68], only one experimental study shows excellent reliability and this and this can be correlated with the experience of the operator who must be very experienced in the qualitative analysis of movement[38]. The results

of this study[38] suggest that the Vail Sport Test ™ has excellent reliability when used to analyse athletes returning to sport after ACL reconstruction. Therefore, the ability of a test to identify variables that put the Anterior Cruciate Ligament at risk of injury would appear to be an important factor in determining the adequacy of returning to sport. Per the requirements of the Vail Sport Test ™, a patient must demonstrate good neuromuscular control and symmetrical expressiveness of lower limb strength during landing. Therefore, the authors believe that the Vail Sport Test ™ is a reliable tool for evaluating performance during the return to the sports rehabilitation phase. However, although the Vail Sport Test ™ measures a patient's ability to control the lower limbs in the sagittal and frontal planes, it does not take into account rotational movements that may be involved in an ACL injury mechanism [69]. Thus the inability of Vail Sport Test ™ to analyse the quality of rotational movements or during multiplanar movements is certainly a limitation of the test. Currently, the patient is required to score at least 46 out of 54 to pass the Vail Sport Test™. Unfortunately, this score has no consensus. The scientific literature underlines the lack of a numerical reference standard for assessing fitness to return to sports after the reconstruction of the LCA, which makes validation difficult. However, the Vail Sport Test ™ is capable of assessing a patient's fitness to return to sport[38] if videographers have experience in evaluative analysis[38] The Vail Sport Test ™, however, remains in the clinic, a reliable functional tool for evaluating performance in patients after ACL reconstruction during the return to the sport phase of rehabilitation. When used as a component in an outcome measure battery, this test can enable clinicians and physiotherapists to effectively assess a patient's neuromuscular control and quality of movement and address re-injury risk factors[3,5,9 12,30,36,41,42].

Paterno[36] has prospectively identified biomechanical and neuromuscular deficits as factors of second injuries, which are highlighted during a jump test. To date, the correlation between gestures and the risk of second injury after ACL reconstruction has not yet been fully described. Paterno [51] reported that 23.5% of young sports patients suffered a second ACL injury in the first 12 months after RTS following ACL. It was later reported that 29.5% of young athletes who returned to cutting and jumping sports after ACL reconstructive surgery suffered a second injury within 24 months after RtSp[52]. Another recent study by Paterno[53] confirmed a similar percentage. 37.5% of patients suffered a second ACL injury in the first 24 months after RTSp[53]. It is clear that modifiable risk factors, such as hip joint mobility restrictions[70,71] correlate with increased injury ACL and increased risk factors for hamstring muscle injury[56]. It has been hypothesized that addressing each of these modifiable risk factors within rehabilitation programs could potentially reduce the risk of injury[75]. Height, weight and body mass index have been shown to have no influence on the incidence of hamstring injuries[54]. Gabbe[57,] in a study analyzing elite level Australian football players, found that a primary hamstring injury in the previous 12 months was a strong predictor of future second injuries. Thus football players were 4.3 times more likely to incur a hamstring muscle re-injury than players without a previous history of injury. In a similar population of Australian football players and track and field athletes, 34% of hamstring injuries were recurrent and the primary injury was the most frequent reason for subsequent re-injury [72,76]. Additionally, 27% of all hamstring injuries in the Australian Football League (AFL) were caused by previous injuries to the same anatomical site, increasing the risk of recurrence by 11.6 times[72]. Malliaropoulos[62] underlines how, knowing the Active Range of Motion (AROM) of elite athletes, through functional tests, could help to establish adequate preventive strategies for sports pathologies and favor the decision-making process related to the return to sport [3]. To conclude this discussion of ours we can state how further studies on the validation of movement quality criteria in the use of objective and technical measures are essentially necessary to apply subjective measures reliably.

CONCLUSIONS

Currently we do not have substantial evidence confirming a consensus on the risk factors relating to second injuries of athletes. Recent systematic reviews show that the Return to Sport is mostly based on subjective and clinical criteria. Dynamic functional tests (eg Crossover hop for distance, triple hop for distance…) are reported in the literature as a subjective evaluation tool to validate the decision-making process of returning to sport. This subjectivity, however, does not find consensus in the literature in the validation of tests. We found a limited literature aimed at evaluating the reliability and validity of subjective tests such as FMS, AAA, LESS, TJA. Few of these, tests, correlate with the important and different dynamic gestures, both simple and complex, represented in the technical-athletic performances. Future studies should be conducted in order to determine standardized outcome tools that could be used to objectively identify changes that occur as a result of an injury that relate to the risk of future injury. Research should be conducted in order to identify the most useful interventions and strategies used to cope with changes following injury and to develop protocols to reduce the risk of injury.

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