Italian Journal of Sports Rehabilitation and Posturology

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Italian Journal of
Sports Rehabilitation and Posturology

The return to sport after muscular injury of the "Hamstring". A Systemic Review.

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ABSTRACT

Background. *There is no homogeneous consensus in the international scientific literature on how to structure the Return To Sport (RTS) after injury to the hamstring. The epidemiological framework, the diversification of classifications, rehabilitation, and the decision-making process does not find moments of expression standardization of clear evidence-based gods.* ***Objective:*** *Target Carry out a systematic review of the literature on (a) epidemiological studies on "Hamstring" lesions (b) on the terminologies and definitions of RTP functions used in hamstring research and (c) on the criteria for RTP after Hamstring injury. The secondary objective of this review is to facilitate diagnostic, therapeutic and scientific communication between clinical and therapeutic.* ***Materials and methods****. A literature search was performed for the search of articles that provided epidemiological studies, definition, classification and criteria for Return to Sport (RTS) after injury to the Hamstring. There were no limits to the methodological design or quality of the articles. The content analysis was carried out by the authors in order to identify the contents useful for the writing of this review. After consulting PubMed 2818 articles were chosen based on our design criteria. After a brief analysis, 2191 articles where removed, leaving 627 articles. Of the remaining 627, duplicates and those articles that did not meet the objective of our study were excluded resulting in five articles forming the bases of our review and discussion. In total, 85 articles met the inclusion criteria.* ***Results.*** *We have found several studies related to the classification of lesions and the criteria of return to sport that confirm our primary scientific hypothesis or a structural lack of clinical and therapeutic homogeneity. We can say that the classification: the Munich Consensus Statement, the British Athletics Muscle Classification, the ISMuLT Guidelines for muscle injuries, show that the prognostic positivity is the benchmark in the classification of muscle injuries. Thus structural injuries are associated with longer time to sports than functional disorders. These are often clinically underestimated and require further systematic study. The return to sport does not find homogeneity in scientific evidence both in the protocols and in the guidelines. However, significant areas of divergence remain both in the language and in the process of returning to sport.* ***Conclusions.*** *In our Review we did not identify in a consensus among the studies, related to the clinical / structural and return to sport criteria, for an optimal "Decision Making". These deformities go to raise significantly, the risk factors, already highlighted widely in the literature, of re - injury.* ***Study Design****. A Systemic Review.* ***Authorship credit*** *: "Criteria authorship scientific article" has been used "Equal Contribution" (EC).* ***Citation.****; Rosario D'Onofrio, Mehul Padasala, Nikos Apostolopoulos, Jaymin Bhatt, Luigi Febbrari, Bojan Bjelica, Antonio Sicignano, Vincenzo Manzi ; The return to sport after muscular injury of the "Hamstring". A Systemic Review.; Ita. J. Sports Reh. Po. 2021; 8 (17); 2; 2; 1784 - 1813; DOI: 10.17385/ItaJSRP.21.17.080202 ; ISSN 2385-1988 [online] ; IBSN 007-111-19-55; CGI J OAJI 0,101)]. Published online.*

Keyword: *"Hamstring injury", "Hamstring return to sport", "Return to sport", "Epidemiology of muscle injuries",*

INTRODUCTION

Due to the complexity and difference of muscle injuries in athletes, the classification system is still insufficiently shared among clinicians. Implementing and validating prospectively a classification of muscle injuries and assessing its predictive value for an optimal return to sport remains the primary goal for researchers. It therefore becomes essential to analyze and summarize the current Evidence, present in the literature, related to the terminology and decision-making process (Decision-Making), and to the structuring of the consequent Return to Sport, (RTS) after a muscle injury to the hamstring. We must highlight how muscle injuries are recognized as harmful events frequently encountered in the entire sports population. Their high prevalence is well documented in international literature. They constitute 31% of all injuries in elite football[1] with over 90% of the lesions affecting the 4 main muscle groups: hamstring, quadriceps, adductors, and gastrosoleus[2]**.** The epidemiological picture of injuries is well documented in the literature also in sports such as rugby[3], 10.4%, basketball[4], 17.7%, and American football[5] ,46% in training / 22% in match[5]**.** Thus the most frequent diagnosis, highlighted by a study by the International Association of Athletics Federations (IAAF), is a muscle injury to the quadriceps / hamstring anatomical district with a percentage of 16%[6]**.** Unfortunately we must also highlight how these lesions present a high level of recurrence[70,71]**.** This high percentage of re-injury 12-31%[7] suggests that athletes probably return to full competitive activity after an unsuitable process of returning to sport[20]. Thus we can affirm how the current evidence regarding the Timing necessary to return to full to the competitive activity is mainly related to the lack of a structural homogeneity based on the evidence of the terminologies, of the classifications of the rehabilitation programs. A recent systematic review of the literature by van der Horst N in 2016[15] showed that there is a great diversity in the way in which the RTS process is structured after injury to the Hamstring

EPIDEMIOLOGY

Data obtained from epidemiological studies on sports injuries are essential for the development of strategies for prevention, treatment, and rehabilitation of muscle injuries. After reviewing the literature five studies were selected and consulted (2 from 2011, and 3 from 2018). Ekstrand[1] investigated "hamstring" and "quadriceps" injuries amongst professional men's soccer. This study reported that 25 players suffered about five "hamstring" and three "quadriceps" injuries, respectively resulting in 130 football days lost in a season[1]. During each season, 37% of players did not participate in training or official competitions due to muscle injuries to the biceps femoris with an average of 90 days and 15 games lost per club[1]**.** In football, with 96% of all injuries due to non-contact situations, it was observed that 92% of all lower limb injuries were associated with lesions to the four major muscle groups: a) hamstrings 37%, b) adductors 23%, c) quadriceps 19% and d) gastro-soleus 13% [1]**.** Given the high percentage of re-injury (16%), Ekstrand underlines the fundamental importance of a correct evaluation, diagnosis and rehabilitative strategies of a muscular lesion. The study by Mallo [8] referenced four consecutive seasons (2003 – 2007) observing that the most common injuries involved the hamstring muscles (1.0 lesion/1000h) amongst semi-professional Spanish soccer players. Of the 313 injuries recorded, the average incidence of injuries was 10.9 injuries / 1000 hours (5.2 injuries / 1000 hours of training and 44.1 injuries / 1000 hours of competition), with the relevance of injuries during matches being higher (p <0.001) than in friendly matches (55 against 22.6 accidents / 1000 hours). The incidence of serious injuries (> 28 days of absence) was 0.4 lesions / 1000 hours. The quadriceps and its anatomical district was the most affected anatomical (35%) amounting for 29% of all absences per game[8]**.** Muscular lesions in the four main groups of the lower limbs (hamstrings, adductors, quadriceps and gastrosoleus) accounted for a 43% absentism[8]**.** With the data collected using a specific web-based survey, the study by Noya [9] observed that the incidence of muscle injuries in 16 first division Spanish clubs (427 players) was 53.8% during the 2008/2009 season. 1293 injuries were identified of which 145 were recurring injuries. The overall incidence of injuries was 5.65 per 1000 hours of exposure, with most occurring during competition rather than training (43.53 versus 3.55 injuries per 1000 hours of exposure, P <0.05). Most injuries (89.6%) involved the lower limbs, with muscle and tendon injuries being the most common type (53.8%). It was remarked that a higher incidence of injury in training occurred during the pre-season[9]. In the Hägglund[10] study, 13,050 injuries were recorded within 43 high-level European professional teams, with 18.8% (2449) being recurring. Of these recurring injuries, 1944 (14.9%) were first lesions with 505 (3, 9%) were recurring, with a higher proportion of recurring injuries observed to be greater in the second half of the competitive season for all cohorts. The proportions of injuries differed between the levels of play, with 35.1% in the amateur cohort, 25.0% in the Swedish elite cohort and 16.6% in the European cohort (χ (2) overall effect, p <0.001). A decreasing trend was observed in the recurrent incidence of lesions in the European Cohort, with an average annual variation of -2.9% in the study period of 14 years (95% CI -5.4% to -0.4%, p = 0.026)[10]. Similarly, a decreasing trend was also observed in the first Swedish division. With data collected by the medical staff of each club, the second study by Ekstrand J (2016)[11] recorded the incidence of hamstring injuries for 46 elite European football teams between 2007 and 2014. The MRI parameters were evaluated by two independent radiologists and correlated with the data on RTS. A total of 255 grade 1 and 2 lesions were found in this study. Return to Sport was longer for grade 2 lesions (24 ± 13, 95% CI 21 to 26 days vs 18 ± 15, 95% CI 16 to 20 days, mean difference: 6,95% CI 2 to 9 days, p = 0.004, d = 0.39), with 84% of the lesions involving the Biceps Femoris muscle (BF), while 12% and 4% affected the Semimembranosus (SM) and the Semitendinosus (ST), respectively. No differences were found in the absence times for lesions to three different muscles (BF 20 ± 15 days, SM 18 ± 11 days, ST 23 ± 14 days, p = 0.83). The recurrence rate was higher for biceps femoris lesions (BF) than for the combined Semimembranosus (SM) and Semitendinosus (ST) lesions (18% vs 2%, p = 0.009). The size of oedema at the MRI is weakly correlated with the time to RTS (r (2) = 6-12%) [11]. No correlation was found between the location of the lesion and the time for RTS. Most intramuscular lesions affected the muscle tendon junction (56% in first and second-degree lesions), but no difference was detected in the withdrawal times between the different types of lesions. The radiological degree and the size of the oedema are correlated with the time to RTS for both grade 1 and 2 lesions. No correlation was found between the time to return to agonistic activity, position and type of injury[11]**.** In 2016, Ekstrand J [12] published a work in which players from 35 clubs from 12 European countries were followed between 2001 and 2014. A total of 1614 lesions of the biceps femoris were recorded, with 22% of players suffering at least one injury to this muscle area a season. The overall ratio of injuries to "Hamstrings" within the 13-year period was 1.20 injuries per 1000 hours with the injury rate during a match (4.77) being 9 times (0.51, RR 9.4, 95% CI 8.5-10.4). The analysis of the temporal trend showed an annual average increase of 2.3% on an annual basis in the rate of total biceps injuries within this 13-year period (R (2) = 0.431, b = 0.023, 95% CI 0.006 at 0.041, p = 0.015). This increase over time was more pronounced for training injuries, increasing 4.0% per year (R (2) = 0.450, b = 0.040, 95% CI 0.011 to 0.070, p = 0.012). The mean absence for hamstring injuries was 19.7 days per 1000 hours (average annual increase of 4.1%) (R (2) = 0.437, b = 0.041, 95% CI 0.010 to 0.072, p = 0.014)[12]. In the investigation by Roe M[13], 38 datasets of 15 Gaelic soccer teams of male elite players collected between 2008 and 2015 by the National Gaelic Athletic Association (GAA) were used to assess injuries. Of these injuries, 391 lesions were observed, with 21% involving the hamstring muscle (95% CI from 20.0% to 21.7%). The incidences were 2.2 (95% CI 1.9-2.4) per 1000 hours of exposure and 7.0 (95% CI 6.5 to 7.1) times greater in games than in training. In general, each team suffered injuries of 9.0 (95% CI 7.0 to 11.0) on the biceps femoris (44%; 95% CI 39.4% to 48.7%); in the proximal muscle-tendon junction (13%, 95% CI 9.8% to 16.3%); and distal (12%; 95% CI 8.6% - 14.9%). Lesions in the semimembranosus / semitendinosus (9%; 95% CI 6.3% - 11.7%). ~ 36% (95% CI 31.5% - 41.0%) were recurrent injuries[13]. The average absence was 26.0 days, (95% CI 21.1 to 33.0) which varied according to age, type of injury, and seasonal cycle. Knee flexor injuries accounted for 31% (95% CI from 25.8% to 38.2%) of total time loss. Previously injured players (rate ratio (RR) = 3.3), players aged between 18 and 20 (IRR = 2.3) or> 30 years (RR = 2.3), in addition to defenders (IRR = 2.0) and midfielders (RR = 1.5) had greater exposure to injury to the "Hamstring". The correlations between the 2008-2011 seasons with the 2012-2015 seasons revealed a 2-fold increase in the incidence of hamstring injuries. Between 2008 and 2015 the incidence of injury in the training increased by 2.3 times and the incidence in the games increased by 1.3 times. Knee flexor injuries were the most common lesions in elite Gaelic football, with increases in incidence occurring from 2008-2011 and from 2012-2015. Adapting risk management strategies to the history of injuries, age and playing position and the quality of training can reduce the percentage of knee flexor injuries [13,27,28].

MATERIALS AND METHODS

Research strategy

The objective of this review was to identify evidences and studies of "Consensus" related to the terminology classification and RTS of muscle injuries involving the hamstring muscle group. In order to compile the data, search terms such as *"Hamstring injury", "Hamstring return to sport", "Return to sport", "Epidemiology of muscle injuries",* were used. The use of the term "strain" was not used given its non-homogeneity and the terminological generality highlighted in the literature. In all 2.818 articles were identified, on PubMed, up to and included December 2018. After a brief analysis 627 articles were selected. Subsequently duplicate publications and articles not conforming to the objective of the study, scientific consensus, reliable and quality of studies on the return to sport after injury to Hamstring , were excluded. The remaining full text articles were checked, by the first author for both the relevant content and the eligibility criteria. (Diagram 1)

Selection criteria

The first author followed each phase of the analytical process to guarantee an adequate categorization of the information and an appropriate thematic analysis consistent with the literature and structural objectives. After each phase, the coding procedures were discussed among the authors to reach a consensus on the drafting of the article. Five articles have been identified as a guide for this review. The selection priority was to search for consensus articles. The selection of articles was limited by the design of the studio. Articles using definitions adopted by other studies were excluded, as well as the evidence reporting Return to Sport (RTS) after surgery. The differences in the selection of the articles and the inclusion of the same were resolved in a consensus meeting between the authors. In total, 85 articles met the inclusion criteria.

Priorities: provide clear epidemiological definitions

Epidemiological studies, where we report the results related to the clinical / therapeutic project of RTS[20] included clear definitions of injuries sustained, adopting any pertinence related to consent and Evidence-Based Practices (E.B.P.). The importance of providing clear definitions should not be underestimated for this will create a common language from which to categorize a proper RTS after muscle injury. Clinicians / therapists should consider using the RtPe (Return to Performance) continuum as the basis for their definition.

TERMINOLOGIES AND DEFINITIONS OF FUNCTIONS RELATIVE TO RETURN TO SPORT

Unfortunately, several concepts related RTS make it difficult to analyze and compare various studies after a knee flexor injury. It is recognized that the differences in definitions and methodologies contribute to significant differences in the results and in the conclusions obtained from research on muscle injuries in athletes[13]. Furthermore, in accordance with the strategic risk assessment and risk tolerance framework, it is commonly agreed that any decision to RTS should be based on a risk assessment and an acceptable risk tolerance threshold[20]. A recent systematic review of the literature has shown that there is great diversity in the way RTS is defined after a hamstring injury and what criteria are used to improve decision-making related to RTS[15,16,17,18,20,70,71].

Although there are numerous studies [20,24,30,41,43,45,48,51,56,60,63] on the RTS these do not appear to be homogeneous in the diversified and anomalous terminological definitions used. Furthermore, there is no consensus on the criteria used to determine when an athlete can resume competitive sports. These criteria must be critically assessed, to reduce recidivism rates and thus optimize RTS. To support an optimal “Making decision concerning the RTS, a wide variety of criteria is used, none of which has been validated by the scientific community. More research is needed to reach a consensus and provide validated criteria to facilitate the management of injuries related to muscle injuries. To this end a guide used for this review was based on the work by van der Horst N.[15].

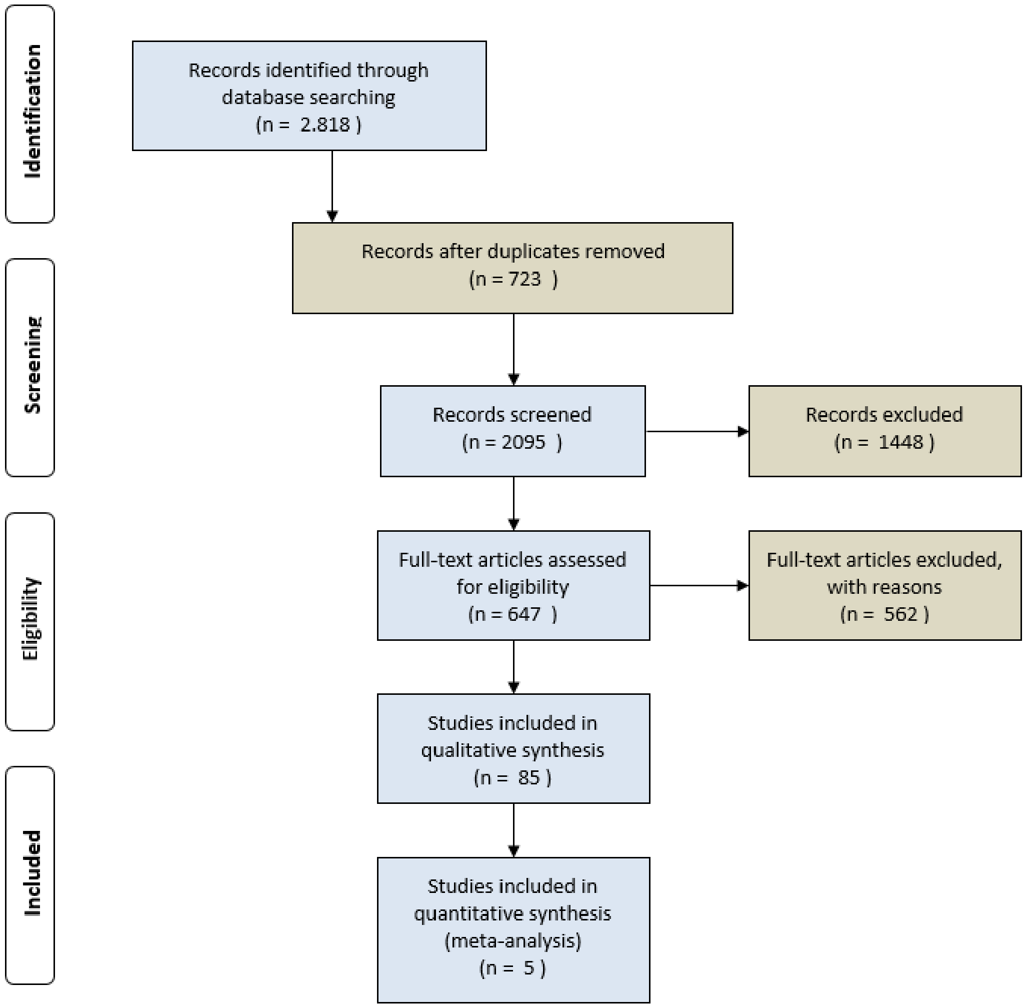

Diagram 1. Prisma Diagram of the literature search.

TERMINOLOGIES AND FUNCTIONS

Substantial and fundamental differences in the definitions and implementation of injury classifications and therapeutic strategies during the process of reorganization of the athlete's RTS with muscular injury exist. The search for a common language, based on evidence, in the diagnosis of muscular injuries as well as in rehabilitative strategies is one of the primary objectives of scientific research[20]. In theory and clinical / rehabilitative practices differences in definitions and terminologies create significant differences in the diagnosis, and during rehabilitation, possibly affecting the success of the final result (successful outcome) of the RTS. On the contrary, the homogeneity of these definitions contributes to optimizing both the scientific comparison amongst modalities and the RTS of the injured athlete[20]. The terminology of muscle injuries has not yet been clearly defined and a high degree of variability continues to exist between the terms frequently used to describe such injuries. This contributes to a high rate of inappropriate diagnoses and recurrent injuries suggestive of the importance of the development of a standardization [18,19] ensuring better communication and comparability. This will facilitate the evolution of new therapeutic and organizational strategies related to RTS.

Terminology

Although there have been numerous studies of RTS following hamstring injury in recent years, the term identified is rarely defined as explicit, with definitions such as "return to sport", "return to competition", "return to competitive play", "return at the pre lesion level "and" return to the activity to the sport activity " "return to the training", making it difficult to compare results between studies. Since no correlative consensus exists in the literature between imaging and resumption of competitive activity, coupled with the absence of clear scientific evidence, this further affirms the need to standardize RTS[19,20]. All this has aroused interest in the criteria that contribute to the decision process relating to the RTS after an injury to the "Hamstring". These criteria must be critically assessed to reduce relapse rates and optimize RTS.

The concept of sports injury

Epidemiological studies, as far as muscle injuries are concerned, are also very far from a heterogeneous terminological homogeneity in conceptual language. Hagglund[10,17] defines the sport injury as: "... a damaging event that occurs in training or in a match that prevents the player from participating in the next complete training or match".

The exposure time

Total exposure time in training is given by the sum of the values of PT and DT divided by 60 for each training session, where PT refers to the number of players participating in a training session and DT as the duration of the training session in minutes. The collection of training data based on the complete team rather than on the individual data does not consider the training exposure and the time of absence when a player does not complete an entire training session. [20] If game times are recorded where accidents occur, injuries should be collected in well-defined periods of the game, as suggested below in lines 1 & 2 for a complete game of soccer.

Line 1 : first half [0-15, 16-30, 31-45 (time + accident + minutes)] .

Line 2 : second half [46-60, 61-75, 76-90 (time + injuries + minutes)] .

Injuries during these set periods are reported as percentages with those during overtime reported in a separate time period referred to as “extra time”. The injury incidence index calculated globally and based on traumas occurring every 1000 hours of play (training + competitions) is calculated with the formula below:

a) number of traumas / hours of exposure x 1000.

According to D’Onofrio[20] the incidence affecting male elite players is between 24.6 and 34.8 events per thousand hours of competition (matches), with the damaging incidence being between 5.8 and 7.6 per thousand hours of training with some studies reporting figures outside this range[20, 21].

The concept of injury

The Fédération Internationale de Football Association Medical Assessment and Research Center (F-MARC) at the First World Congress on Sports Injury Prevention in Oslo (2005), suggested that the term "medical attention" be used to express the condition of the player unable to participate in future training or match. The word "future" is applied at any time after the occurrence of an injury, identifying the prognosis and time of absence[17,20,21]. In the summary according to Fuller[21], a sports injury was defined as "any physical complaint" sustained by an athlete resulting from a race / competition or training, regardless of the need for medical assistance or time loss from sports activities ", as well as regardless of structural damage.

Activity level

In the literature terms such as "reaching the pre-injury level" [22, 23] and "complete sports activity" [24, 25] are used to define RTS after an injury to the knee flexor muscles. Other terms include "availability for game selection or complete training" "training without restrictions"[20,25] "a complete competition" [26] and "a 100% recovery score on clinical, functional tests, as well as specific performance skills[27]. Similar to RTS, risk of injury to the hamstring was defined on the basis of medical information[20,28,29] or "absence of symptoms related to the pathological limb" [30] "authorization by medical personnel" [29] and "completion of a program of rehabilitation " were used as terms to define Return to Play[20,29]. In contemporary clinical practice, the decision of RTS should be a shared decision among all the professionals involved in the recovery process of the injured athlete. This requires a good definition of roles, and a dispute resolution system to protect the athlete from imposition then there are discrepancies in the assessment of risk factors related to the return to sport.

Progression and documentation

The most important and complex phase of a progressive rehabilitation program in sport is the decision-making process. As with all elements of the rehabilitation program, little evidence remains to support this decision. The RTS within the rehabilitation process can be referred to as a continuous parallelism in all its phases up to the return to performance[20]. With injuries being an inevitable part of sporting activities, optimal rehabilitation management planning should be carefully studied, with a full-blown diagnosis conducted as soon as the lesion occurs[20]. Clinical and rehabilitation records must contain (but not be limited to) the following:

a) daily report,

b) objectives to be achieved for the transition in the various phases,

c) definition of the protocol and rehabilitative guidelines,

d) definition of clinical and functional tests used to guide RTS decision making,

e) definition of follow-up criteria (time from surgery, type of clinical and functional assessments) designed to guide the process of RTS.

Regarding a continuum[20] of the RTS three objectives are defined with each objective being associated with a transition periods and a graded progression applicable to any sport (figure 1). These objectives are listed below:

a) *Return To Participation (RTPa).* The athlete returns to activity with restrictions and / or limitations to training, rehabilitation, or general sport training. In other words, the athlete is physically active, but not yet "ready" (clinically, physically and / or psychologically) for RTS.

b) *Return To Sport (RTS).* The athlete has returned to his/her specific sport in terms of intensity, volume and quality of the training but s somewhat limited from training and competing at a maximum level (i.e., athletic values still unsatisfactory, in the match / training. psychological problems , kinesiophobia ...)

c) *Return to Performance (RTPe*). This is the final phase of RTS. The athlete is reintroduced to his/her sport performing at pre-lesion level or greater. For some athletes this phase can be characterized by personal best performance or by progress in technical / physical performance.

Figure 1*.* The three elements of Return to Performance (RtPe) definable as a process in continuity of care (continuum.) (From: C. L. Ardern et .al. [37]). (by R. D'Onofrio, personal Lecture to SIA Arthromeeting Congress, L'Aquila 2018.)

The decision-making process:

a) decision-making

"Evaluation models can help clinicians and therapists make sense of the infinite factors influencing the final decision-making process and consequently the RTS20. Strategic Assessment of Risk and Risk Tolerance (Strategic Assessment of Risk and Risk Tolerance, StARRT)[4] is a three-step model that helps estimate the risks of short- and long-term results associated with RTS. It is essential to identify the risk factors influencing the RTS to determine the final success of the decision making[20], and to clarity who is responsible for making the decision for RTS.

b) Classification

At the beginning of the twentieth century, muscle injuries were classified either by the causative or mechanistic force or by the anatomical position of the lesion[37]. Authors classified muscle injuries as those derived from internal forces (secondary to a sudden "strained" overstress) or external forces (secondary to direct "trauma"). Anatomically, it has been recognized that the muscle can be "injured" at various points such as "where the fibers meet the tendon", the "body of the muscle" or the “tendon” itself [38]. Although these terms precede the frequently cited classification systems, they most likely provide the basis for their subsequent interpretative development39. Since the 1980s, the availability of ultrasound and MRI imaging has allowed direct visualization of the muscle lesion resulting in greater anatomical accuracy[40]. At the beginning of the 21st century, a renewed interest in the classification of muscle injuries occurred with authors classifying, defining, and distinguishing lesions according to distinct anatomical positions and structures (proximal/distal, semimembranosus/biceps femoris), highlighting for the first time a relationship between anatomical position and time for RTS[41]. Didactically, classification systems of commonly used muscle injuries were traditionally based on three degrees of muscular lesions; a) minor, b) moderate and c) complete. However, researchers have begun to address the limits of these existing systems of classifications with attempts being made to provide an evidential basis, seeking to correlate clinical and radiological assessment with the extent of the injury. With the acknowledgment of imaging in the clinical healing process providing a better evaluation for RTS, a re-formulation of the classification systems of muscle injuries was needed. With different classification systems being published in the literature little coherence between studies and their practical application in clinical settings existed [31]. To accommodate for this divisiveness, O’Donoghue devised a classification system based on the severity of the lesion related to the amount of tissue injury and associated with the loss of function. It categorizes muscle injuries into three grades, ranging from:

a) Grade 1, without appreciable laceration of fabric,

b) grade 2, with tissue damage and decreases in the strength levels of the muscle-tendon unit,

c) grade 3, with complete rupture of tendon muscle and complete loss of function.

In recent years, numerous protocols evaluating and classifying muscle injuries have been developed. Petersen J. introduced a radiological classification system for muscle lesions[25] with other authors indicating that MRIs are useful for not only verifying the diagnosis of a knee flexor injury but as well as determining "dismissal" times after injury [11,32]. The “Munich Consensus Statement" introduced a new terminology and classification system for muscle injuries classifying lesions as either functional and/or structural, with the former referring to disorders induced by fatigue or neurogenic causes with the latter referring to lesions of muscle fibers. However, although these new methods provide correlations between clinical and radiological characteristics of a muscular lesion, the decision-making processes of returning the athlete to sport are still insufficient

c) Re injury

Acute injury to knee flexors can be categorized as a non-contact muscle lesion[1,42] associated with a high incidence and risk of re-injury[43] therefore, reducing the risk of relapses is a key priority. Because of a greater recurrence, these lesions require a wider rehabilitation process than the primary lesion[1,42,44] . For instance, the recurrence rate for Hamstring injuries is between 12-33% [10.42,49], believed to be due to inadequate rehabilitation and/or an early RTS [45,46]. Of these relapses, 59% occur within the first month after RTS [10,47]. Particularly alarming is the observation that recurrence rates have not improved over the past 30 years. These could be associated with the criticality of the processes of RTS, especially with the non-homogeneity of the rehabilitation protocols[45,46]. Unfortunately, the ability to identify risk factors is compounded by the existence of diversified RTS processes making it difficult to analyze and compare various RTP studies after a hamstring injury. Therefore, with the existence of a discrepancy amongst definitions and methodologies, conclusions obtained from research may be a contributing factor to increasing the risk factors for re-injury. In accordance with the Strategic Risk Assessment and Risk Tolerance Framework it is commonly accepted that any RTS decision should be based on a risk assessment and an acceptable risk tolerance threshold [20].

d) Return to sport

For RTS we have taken as a structural reference a recent article by van der Horst N [16] published in British Journal of Sports Medicine. This study, part of the "Hamstring Injury Prevention Strategies" project, included several papers focused on the prevention of Hamstring injury [16]. The aim of the publication was to reach a scientific consensus on the terminology, and the definition of the clinical criteria related to the RTS. The study was conducted by the Department of Rehabilitation, Physical Therapy Science, and Sport at the University Medical Center of Utrecht, Netherlands[16]. Fifty-eight experts in the field of knee flexor injury management were selected from 28 FIFA excellence medical centers around the world. Each step of "Delphi" consisted of a questionnaire, an analysis, and a feedback report which remained anonymous. After four steps of "Delphi", with over an 83% response, a consensus was reached on the definition of RTS "... the moment when a player has been authorized medically to perform and is "Mentally ready" and fully available for game selection or unrestricted training[15,16,20] (Figure 1). In the article by van der Horst N. [16] on the "Delphi" procedure concerned with RTS post injury to the crests there was consensus defined by terminology such as "full activity", “a 100% recovery score on performance tests and ability", "absence of symptoms on the pathological limb", "completion of a rehabilitation program", with the concept "the achievement of the pre injury performance level" not to be included in the definition of RTS after a knee flexor injury. A consensus was reached in the third round of Delphi to include "the positive, psychological attitude of a player (athlete's readiness)" in the definition of RTS, since mental alertness was considered important for eliminating anxiety and that a positive mental attitude was associated with a decrease in the risk of re-injury and improvement in performance. Anxiety as stated above can present several issues when seeking to provide a homogenous definition and its use in RTS. It defines an affective state which is very general, considered not so much as a symptom or a delimited syndrome, but rather as a mode of existence, whose extremes enter the domain of psychopathology, originating from feelings of aggression, anxiety, and fear.

The American Psychiatric Association[84] defines anxiety as a state of apprehension, tension, discomfort, which springs from the anticipation of a danger, the origin of which is largely unknown or not recognized. Since anxiety was included in the third round of "Delphi" it is reasonable to propose that a reliable and valid psychometric tool, not excessively complicated, easy to apply and easy to interpret should be included in determining RTS. To that effect we propose the inclusion of STAI (State - Trait Anxiety Inventory-Form Y)" as part of the decision making process (Annex A in the appendix). The bio psychosocial model (Figure 2)[65] can also help guide the process of returning to sport. This model takes into account the physical, psychological and social / contextual factors that can contribute to the athlete's return influencing their performance levels. An athlete can be physically conditioned and ready to return to the sport, but if he is afraid or anxious about his injury then perhaps the process should be prolonged. There are some scales that can help measure psychological readiness such as the Injury-Psychological Readiness to Return to Sport scale (I-PRRS).

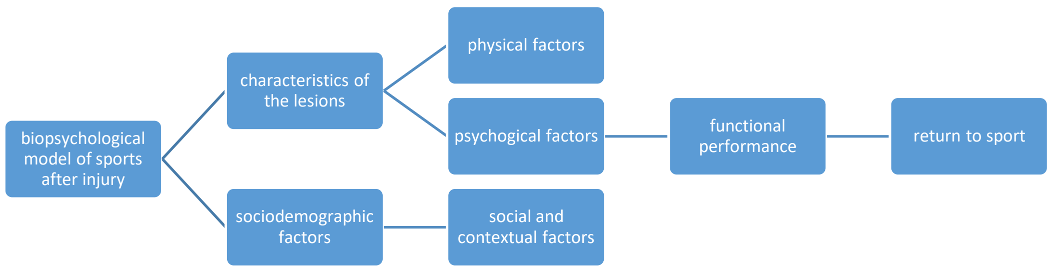

Figure 2. *Model of psychological, physical and social factors that can influence the return to sport proposed by Arden CL [65]*

In conclusion, the study by Van der Horst[16] reached a consensus that RTS should be defined as "when a player has received a medical approval based on criteria and is psychologically ready for full availability for game selection and full training ". In addition the following "consensus" parameters for RTS were highlighted:

1. Favourable opinion of the clinician

2. Absence of pain on palpation

3. Absence of pain during strength and flexibility tests

4. Absence of pain during / after functional tests,

5. Symmetrical flexibility of the Hamstrings

6. Positive field performance tests

7. Psychological preparation

The seven recommendations above suggest that RTS should be based on a shared multidisciplinary decision-making process. (Figure 3) Consensus on aspects of RTS should be clear and facilitate the assessment of when RTS is appropriate after a hamstring injury in order to avoid or reduce the risk of recurrence of injuries due to premature RTP[16,20].

e) criticality of the return to sport

Currently, there is no consensus in the literature on criteria relating to the return to sport, after muscular injury given the lack of standardization and clear objective parameters[20] . Often, the recommendations are empirical and not based on evidence. It is claimed that athletes are ready to return to sport once they, for example, have a complete Range of Motion, symmetries in expressiveness of strength and functional abilities / functional abilities that must be performed without pain[48] (Figure 3). A rehabilitation program based on progressive criteria consisting of valid and reliable assessment tools is desirable when managing athletes with crest injury. Unfortunately, specific criteria for progression through a rehabilitation program are rarely described and rarely validated. Consequently, the clinician handles injuries to the crest of the knee and a progression structure is frequently required without an adequate basis of scientific evidence Absence of pain, absence of pain (figure 4) on palpation and during performance tests[15] was used as a criterion for RTS after knee flexor injury in most of the studies present in the literature[20,28,29] in some studies; pain was tested by direct palpation of the hamstring.[51] Hamid and Askling[22,52] also stated that the "Hamstring" contraction should not cause pain (0 on the Vas scale) when tested in the final position of the Straight Leg Raise Test[22, 52] . Muyor J.M.[53] agreed that "...... a similar flexibility of the hamstring muscles" could lead to an asymmetry between the pathological leg and the non-compared leg with the pre-lesion data. The group of experts has reached a consensus that the flexibility of the hamstrings must be accessed through the passive straight leg raise test. The "end-feel" phase of the exercise was determined by 1 or both of the following criteria: (a) participants reported hamstring muscle pain (b) palpable onset of pelvic rotation. Furthermore, the ankle of the tested leg was held in maximum plantar flexion to avoid adverse neutral tensions[53] . The rationale is that the straight leg raise test is considered the gold standard for posterior chain flexibility measures, especially hamstring, in daily practice[53] and it is important to measure both active and passive components[15, 16].

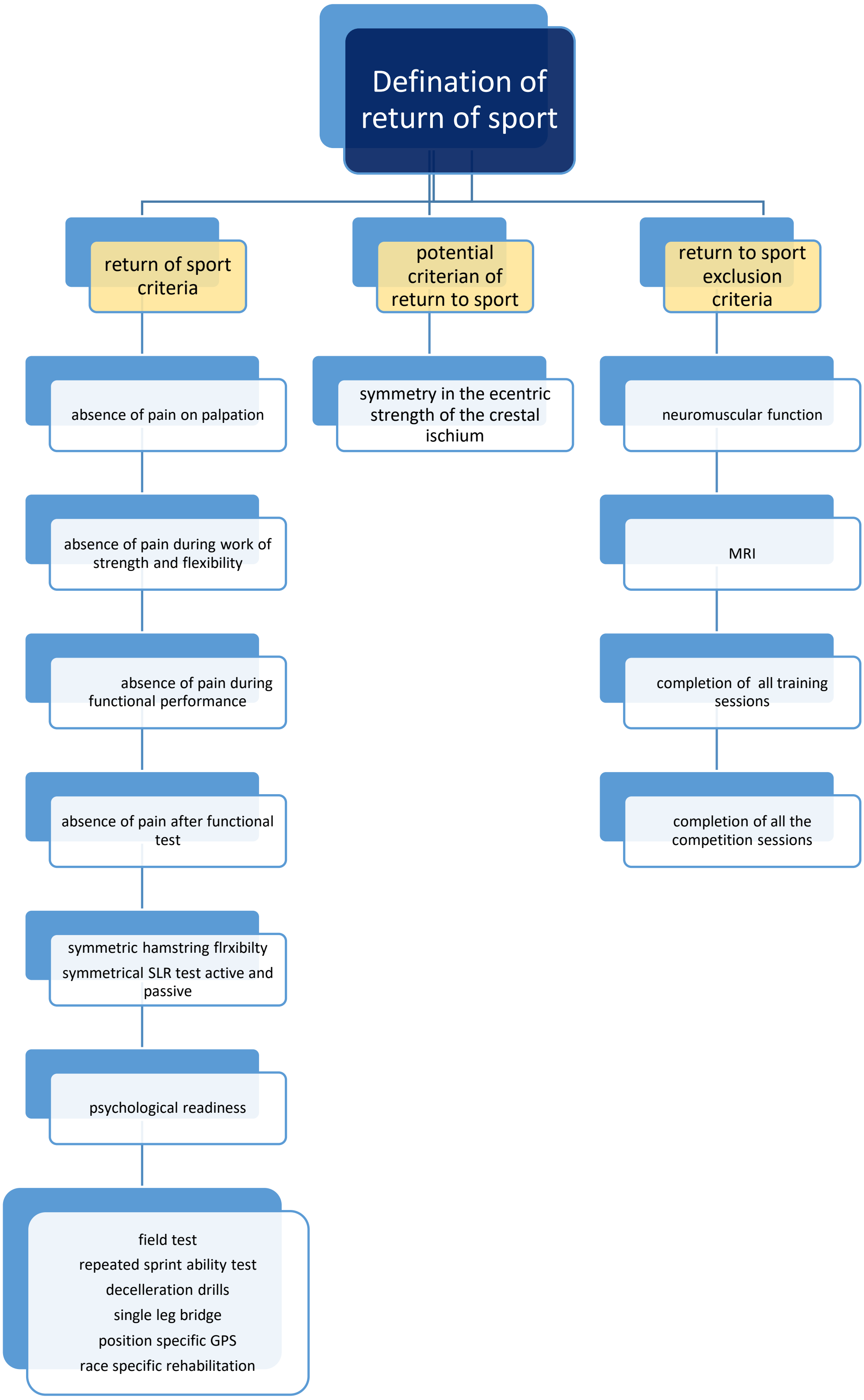

Figure 3. *The model of the return to sport for hamstring injuries. Criteria and decision-making process Delphi procedure for crest injur[16]**.***

absence of pain

- None during palpation of the affected muscle group
- No pain during a controlled sprint
- No pain during specific technical gestures
- No pain during agility drills
- No pain during strength tests
- No pain during the active and passive straight leg raise
- No pain during 3 km of endurance

Figure 4. Criteria for return to sport after hamstring injury [15] modified by D'Onofrio R. 2019

RTS rate and time to RTS

The time for 'RTS after acute knee flexor injuries varies substantially between studies, from an average of 11.3 days to 50 weeks[54,55]. The Munich classification clearly shows a difference in the return to sport between structural and functional muscle injuries. This seems logical since, by definition, structural lesions show macroscopic evidence of muscle fiber lesions and functional disorders do not show such lesions. We can say that the severity of the muscular injury directly affects the time to return to sport and the recurrence index [52,58]**.** The guidelines for RTS relative to time are categorized below [20,36] :

Direct injuries:

- Contusion:
- Slight: 2 - 5 days;
- Moderate: 7 - 15 days;
- Severe: 15 - 25 days;
- Tear: variable.

Indirect injuries:

- Non-structural: 5 - 15 days.
- Structural **-** Type 3A: 15 - 18 days; Type 3B: 25 - 35 days; Type 4: ≥ 60 days.

The ability to provide an accurate estimate of the timing of the RTS activity is a specific, fundamental skill for classifying and grading muscle injuries. However, it is well recognized that this process is multi-factorial involving not only physiopathological healing times, but also social and psychological factors. Furthermore, it seems counter-intuitive that a single assessment of the time-point of an injury, no matter how complete, provides an accurate prediction of RTS time some weeks into the future. Wangensteen[59] pointed out that the clinical examination after a hamstring injury can represent only 29% of the time variation in RTS. The complement a clinical evaluation with MRI represents only a total of 31% of the variability of the definition of the timelines related to RTS[59]**.** However, this approach based on scientific evidence does not align with expectations of athletes and coaches, who generally expect an early definition of time to RTS after an injury.

DISCUSSION

Terminology, classification, functions, and definitions of RTS following a hamstring injury were consulted when constructing this literature review. The purpose was to discuss the lack of a general “consensus” (definition, categories) regarding muscle injury and its contribution to the prevalent incoherent clinical/rehabilitative strategies related to the process of RTS[20,21,33]. Recent classification of muscle injuries such as the Munich[34], ISMuLt[36] and British Athletic Classification[63], present new approaches for classifying muscle injuries improving the diagnosis, prognosis, and management of RTS following muscle lesions. The differences between structural lesions and “functional muscular disorders” are discussed, with the latter defining an acute indirect disorder without macroscopic evidence (MRI, ultrasound). It is multifactorial and itself is grouped into subgroups reflective of a clinical origin including "neuromuscular" muscle disorders. Functional muscular disorder is affiliated with an increase in muscle tone associated with pain, which is considered as a subsequent risk factor for injury. In addition, etiological differences regarding sub-categories of this disorder were researched since these possess a distinct clinical entity often determining a functional limitation of the athlete. However, since standard diagnostic methods lack use of an MRI, which can determine any macroscopic structural damage, these methods present a problem, in contrast to indirect injuries (caused by internal forces) such as lacerations or bruises having a distinct origin (external forces) responsible for the trauma[60,61].They are classified as mild, moderate, and severe, associated with a widespread or limited bleeding displacing or compressing the muscle fibers causing pain and a loss of Range of Motion (ROM). Given the lack of standardization of clear objective criteria, no consensus currently exists in the literature concerning the RTS and *"Decision Making"*. Although studies have evaluated the loss of playing time due to RTS diagnosis with use of an MRI does not predict the amount of time needed to RTS [61,62, 63]. On the other hand, DeVos[29] found that athletes with localized palpation-induced discomfort at the time of RTS were almost[4] times more likely to sustain a relapse than athletes with no discomfort at palpation[23,50] . Often, the indications relative to RTS are superficial, with athletes deemed suitable to resume competitive activity once they have acquired a full (ROM), strength and functional skills (jumping, running, and cutting) performed without pain [16,21, 39,44,70,71]. Based on the review of literature the difficulty to assess asymmetries and imbalances with the current diagnostic methods make it very difficult to properly assess the RTS an diagnostic tool that may provide some answers is the functional H / Q ratio. The “Hamstring/Quadriceps Ratio” (H:Q ratio) is one tool used to assess RTS[70,71,85]. Functional H:Q defines the percentage ratio of peak force of the flexors during an eccentric contraction and the quadriceps during a concentric contraction (H.ecc. / Q.con.). Normal strength values between agonist and antagonist are essential for modulating the functionality and joint biomechanics of the knee during movement, described in the literature as “muscle balance”[70, 71] with a “muscle imbalance” suggestive of tensional abnormalities due to weakness and / or shortening of the same muscle [70.71]. A "shortened" muscle is associated with a decrease in ROM (Range Of Motion) and loss of harmony at the joint, and an expressiveness of its movement. The quadriceps and the hamstring manage the analytical functionality of the knee joint. An imbalance between the extensor / flexor apparatus could create an articular overstress with compensatory movement patterns, which can lead to postural syndromes (Janda's Crossed Syndromes), to acute and chronic lesions of the skeletal muscle apparatus.[70,71]

The force relationship between agonist / antagonist during knee extension and flexion can, however, be described[70,71]. better from the more functional reports during:

a) Knee extension phase: eccentric force of the hamstring and concentric quadriceps (H.ecc / Q.con).

b) Knee flexion phase: concentric force of the flexors and eccentric strength of the quadriceps (H.con / Q .ecc.).

From the final analysis of this review it is possible to state how asymmetries / imbalances in the functional H / Q ratio have been shown to significantly affect the percentages of muscle injuries. Athletes with persistent force imbalances showed a significant increase in muscle injuries of 4.66 times. Altered values of the H / Q force ratio (<0.6 by 60 ° s-1) may increase the risk factors including lesions of the anterior cruciate ligament (ACL) 70, 71. A complete, pre-season assessment of the muscular system is advisable and should include screening to identify "over activity", shortening, weakness, and quality of movement. It remains correct to point out that a recent meta-analysis [64] has found that isometric strength deficits and flexibility tend to resolve within 20-50 days after the initial lesion to the "Hamstring"; however, at the time of the RTS there were deficits of strength (conventional and functional of the ratio of H: Q)[64,70,71]. In addition, the dominant limb in football and futsal players suggests an asymmetry which needs to be considered during sports rehabilitation programs in assessing properly functional deficits resulting from lower limb injury or surgery[62]. Force asymmetries may be a risk factor for musculoskeletal injuries [69,70,71]. A study by Croiser observed that percentages of muscle injuries were significantly increased in subjects with asymmetries of strength in the pre-season (relative risk = 4.66, 95% confidence interval: 2.01-10.8)[66]. One in two players exhibited isokinetic imbalances of strength (47%), responsible for a four times increase in risk of injury to the knee flexors[66]. Athletes with force imbalances (bilateral asymmetries, conventional and mixed H/Q ratios) present with a higher risk of injury to the “hamstring” muscle (50%)[67,70,71]. As a result, bilateral asymmetries in sports have been reported with predominant unilateral movements, such as football, volleyball, basketball and handball. Bilateral asymmetry greater than 15% of the maximum force peak was associated with the risk of muscle injury. Ruas[69] measured knee strength asymmetries in football players in their different positions on the field, and their results indicated that in all players the eccentric strength of the hamstring of the dominant limb knee was greater than that of the non-dominant[69]. A study observing isokinetic evaluations in the pre-season phase reported that H: Q ratio predicted athletes who would suffer an injury in-season[72]. Ardern observed that the H/Q force imbalance affects performance in football during the season having implications for future injury risk[73]. Therefore, any physiological change in the percentage ratio of H/Q strength (<0.6 to 60° s-1) possesses a predictive value in assessing the increase in risk of a muscle injury to the hamstring [70,71]. This inherent strength ratio between the extensors and flexors of the knee estimates the functional ability of the joint and the relative balances existing between agonists and antagonists. According to Elliott[75] muscular force imbalance between the extensors and flexors of the knee, when considering peak force moment occurs when the ratio between them exceeds 10%, with Davies suggesting that the peak of the isokinetic force moment of the hamstring should be anchored around 66-69% compared to that of the extensors at an angular velocity of 60 ° / sec[76]. There appears to be a discrepancy for the ideal isokinetic force ration with one study suggesting that the H :Q should be 100:67%[70], with another implying 100:55%[77]. According to an investigation, players with an H.con./Q.con. of less than 0.61 had a substantial increase in risk of knee flexor injuries [82,85] suggested that players had substantially increased risk of knee flexor injuries when their H.con. / Q.con. were less than 0.61 in the preseason concentric isokinetic test. H.con. / Q.con. It is interesting to note that although H:Q ratio values are very important for assessing the execution of athletic movement in accordance to muscle imbalances, it is imperative that the evaluation of H:Q be performed when the muscles are not fatigued [70,71], since a fatigue state will present with different results compared to traditional H:Q conventional ratio[79]. Future studies would be needed to be done to determine the potential predictive value of H:Q fatigue. For the evaluation and analysis of the extensor/flexor ratio the following has been proposed by Daniel[80]:

a) Quadriceps index (IQ: quadriceps index = maximum force peak in extension pathological limb / healthy limb x 100).

b) Hamstring index (IH : index of the hamstring = maximum peak of force in flexion pathological limb / healthy limb x 100).

According to Witvrouw[81], a constant decrease in the flexibility of the crest in football players is due to the typical half-flexed gesture. This "shortening" contributes to an imbalance of the intra- and inter- muscular coordination moment, significantly raising the risk of a muscular lesion.. Witvrouw[81] suggests that poor flexibility of the hamstring and the quadriceps muscles in the pre-season phase is a significant risk factor in soccer players which is further compounded with muscle fatigue[45].

CONCLUSIONS

Numerous criteria are used to support decision-making regarding the RTS after a knee flexor muscle injury, but none of these has been validated by studies in the literature. Further research is needed to reach a consensus on the definition of RTS to provide clear, objective validated criteria to facilitate the management of hamstring injuries and reduce their high recurrences. The complexity of muscle injuries cited in the scientific literature does not correlate with the existent classification system, its terminology and rehabilitation processes. For instance, asymmetries/imbalances of the functional H : Q ratio have a significant impact on the incidence of muscle injuries, responsible for an increased risk of muscle injuries, especially those affecting the crest. Therefore, as indicated by this literature review, a general consensus on a unified classification system will help to identify risk factors thereby establishing proper rehabilitation process for muscle injuries, and preventing re-injuries. Numerous criteria are used to support decision-making regarding the return to sport after a knee flexor muscle injury, but none of these has been validated by studies in the literature. Further research is needed to reach a consensus on the definition of RTS and to provide clear, objective validated criteria to facilitate the management of hamstring injuries and reduce high recurrences. We can state how the complexity of muscle injuries, generally accepted in the scientific literature, does not correlate with a non-homogeneity in the terminology and rehabilitation processes associated with a classification system that is still lacking. It is evident that the asymmetries / imbalances in the functional H / Q ratio have a significant impact on the incidence of muscle injuries. It is reported in the literature as "muscle imbalance" that can increase the risk factors of muscle injuries, especially those affecting the crest. A limitation to the careful study of muscle injuries and their management has been the lack of a uniform approach to categorization, classification to rehabilitation processes of muscle injuries.

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Italian Journal of Sports Rehabilitation and Posturology

Appendix A

SHEET 1 (Spielberger's Trait Anxiety for state anxiety)

1	I feel calm	[1] [2] [3] [4]
2	I feel safe	[1] [2] [3] [4]
3	I am tense	[1] [2] [3] [4]
4	I feel under pressure	[1] [2] [3] [4]
5	I feel comfortable	[1] [2] [3] [4]
6	I feel upset	[1] [2] [3] [4]
7	I am worried about possible misfortunes	[1] [2] [3] [4]
8	I feel satisfied	[1] [2] [3] [4]
9	I feel intimidated	[1] [2] [3] [4]
10	I feel comfortable	[1] [2] [3] [4]
11	I feel confident	[1] [2] [3] [4]
12	I feel nervous	[1] [2] [3] [4]
13	I am agitated	[1] [2] [3] [4]
14	I feel indecisive	[1] [2] [3] [4]
15	I'm relaxed	[1] [2] [3] [4]
16	I feel happy	[1] [2] [3] [4]
17	I'm worried	[1] [2] [3] [4]
18	I feel confused	[1] [2] [3] [4]

19	I feel relaxed	[1] [2] [3] [4]
20	I feel good	[1] [2] [3] [4]

Score calculation Card 1 Stay X1 State anxiety

Scoring: for the following items, which contain statements indicative of anxiety, consider the score marked with the cross: 3, 4, 6, 7, 9, 12, 13, 14, 17, 18.

For the remaining items, namely for 1, 2, 5, 8, 10, 11, 15, 16, 19, 20 which do not contain statements indicative of anxiety, it is necessary to invert for the calculation the direction of the answer (in this way, for example, the score "4" becomes "1").

The total score is the sum of the scores for the individual items thus calculated.

A score higher than 30-35 reveals the presence of state anxiety, linked to transient situations.

SHEET 2 (You are Spielberger's Trait Anxiety for trait anxiety)

21	I feel good	[1] [2] [3] [4]
22	I feel tense and restless	[1] [2] [3] [4]
23	I'm satisfied with myself	[1] [2] [3] [4]
24	I wish I could be happy as others seem to be	[1] [2] [3] [4]
25	I feel like a failure	[1] [2] [3] [4]
26	I feel rested	[1] [2] [3] [4]
27	I am calm, calm and in control of me	[1] [2] [3] [4]
28	I feel that the difficulties accumulate so much that they cannot be overcome	[1] [2] [3] [4]
29	I worry too much about things that really don't matter.	[1] [2] [3] [4]
30	I'm happy	[1] [2] [3] [4]

31	I have negative thoughts	[1] [2] [3] [4]
32	I have no confidence in myself	[1] [2] [3] [4]
33	I feel safe	[1] [2] [3] [4]
34	I make decisions easily	[1] [2] [3] [4]
35	I feel inadequate	[1] [2] [3] [4]
36	I'm glad	[1] [2] [3] [4]
37	Thoughts of little importance pass through my mind and annoy me	[1] [2] [3] [4]
38	I experience disappointments with so much participation that I can't get them out of my head	[1] [2] [3] [4]
39	I am a constant person	[1] [2] [3] [4]
40	I become tense and upset when I think of my current concerns	[1] [2] [3] [4]

Scoring: a point is assigned for the following items, which contain statements indicative of anxiety, and consider the score marked with the cross: 22, 24, 25, 28, 29, 31, 32, 35, 37, 38, 40.

For the remaining items, namely for 21, 23, 26, 27, 30, 33, 34, 36, 39 which do not contain statements indicative of anxiety, the direction of the answer must be inverted for the calculation (in this way, for example the score "4" becomes "1").

The total score is the sum of the scores for the individual items thus calculated.

A score higher than 30-35 reveals the presence of trait anxiety, linked to a stable personality trait.

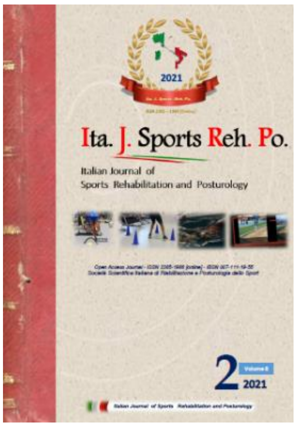
Scores on both scales can range from a minimum of 20 to a maximum of 80.

If the examinees do not answer one or two questions, of one of the scales, to calculate the overall score, proceed as follows: determine the arithmetic average of the score obtained, to the questions to which he answered; multiply this result by 20 and round it up to the nearest whole number.

If the answers to three or more questions have been omitted, the results are poorly reliable and valid.

Info Scientific article

Citation



Rosario D'Onofrio, Mehul Padasala, Nikos Apostolopoulos, Jaymin Bhatt, Luigi Febbrari, Bojan Bjelica, Antonio Sicignano, Vincenzo Manzi ;

The return to sport after muscular injury of the "Hamstring". A Systemic Review.

Ita. J. Sports Reh. Po. 2021; 8 (17); 2; 2; 1784 - 1813 ; DOI: 10.17385/ItaJSRP.21.17.080202 ; ISSN 2385-1988 [online] ; IBSN 007-111-19-55; CGI J OAJI 0,101)]. Published online.

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Declaration of interest

The authors declare that they have no financial, consulting, and personal relationships with other people or organizations that could influence the author's work.

Author's Contributions

Authorship credit : "Criteria authorship scientific article" has been used "Equal Contribution" (EC)
All authors played a significant role in this project; All authors were involved in drafting the manuscript critically for important content, and all authors approved the final version.

Info Journal

Publication Start Year : 2014
Country of Publication: Italy
Title Abbreviation: Ita. J. Sports Reh. Po.
Language : Italian/ English
Publication Type(s) : No Periodical
Open Access Journal : Free
ISSN : 2385-1988 [Online]
IBSN : 007-111-19-55
DOI : Digital Object Identifier
ISI Impact Factor: CGIJ OAJI :0,101
Index/website : Open Academic Journals Index , www.oaji.net/
Google Scholar – Google Citations
www.facebook.com/Ita.J.Sports.Reh.Po
Info: journalsportsrehabilitation@gmail.com

2021

Ita. J. Sports Reh. Po.

ISSN 2385 – 1988 [Online]