Original article

Quality assessment of muscle injury classification in sports: a systematic literature review

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Summary

***Introduction*: Muscular injuries are very common and lesion categorization is important for patient treatment and orientation. There is no study in literature that assessed methodological quality of classifications for muscle injury in sports. The objective of this study was to evaluate the quality of manuscripts that proposed a classification of muscular injury in sports.**
***Methods*: A systematic search for articles in English, Spanish and Portuguese languages containing terms related to "muscle, skeletal/ injuries", "athletic injuries", "classification", "diagnosis" and "etiology" were carried out. Articles included for evaluation proposed classifications of muscular injuries related to sports and were submitted to methodological quality appraisal from Quality Assessment of Diagnostic Accuracy Studies (QUADAS-2) protocol.**
***Results*: 1606 articles were found. From those, 17 proposed an organized system with different sorts of muscular injury. The 17 studies were graded according to methodological quality, considering risk of bias and applicability of each classification. Three studies presented very good results and one showed good results. The remaining articles presented a high or undetermined risk of bias and problems related to applicability.**
***Conclusion*: There is a wide variety of methodological quality of classification studies. Most classifications system are only a theoretical model and therefore have important limitations.**
Level of evidence: IIIa.

KEY WORDS: athletic injuries, bias (epidemiology), classification, muscle injury, review.

Introduction

Muscular injuries are among the most common lesions in physical activity practitioners[1-3]. Lesion severity categorization is a very important element for patient treatment and orientation, as well as for planning recovery time and proper rehabilitation for professional athletes and medical team department. Therefore, classification systems are important tools for guiding athletes' recovery.
Muscle injury graduation systems are mostly related to experts opinion (level of evidence V)[4]. These studies usually classify muscular injuries in a varied way by location, size, causative mechanism or other characteristics. Nevertheless, many Authors categorize the various aspects of these lesions but do not correlate it with a prognosis and thereby do not establish evidence to be used in the follow-up treatment for team physician.
Besides the lack of conformity between classification systems, ambiguity of technical definitions is usually present[5]. It disrupts communication between professionals and makes it difficult to carry out studies that evaluate the accuracy of diagnosis and prognosis provided by the proposed classification[6].
Since the 1960s, studies have been published defining and classifying types of muscular injuries[7,8]. The number of new proposed classifications has been increasing every decade with the objective of providing a better severity understanding of these lesions and to enable prognosis standardization. On the other hand, the variety of characteristics considered in these studies has raised with the several different classification systems[9,10].

There is no study in literature that assessed methodological quality of these existing classifications. No review article could identify which classification system is based on evidence provided by well-designed protocols, low risk of bias and good applicability.
Therefore, the main objective of this study is to conduct a literature review to assess muscular injuries classification methodology, as well as graduation strengths and inadequacies.

Materials and methods

This is a systematic literature review study conducted according to PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analysis) guidelines[11]. A systematic research was performed in the EMBASE, MEDLINE, PUBMED and SciELO databases from their inception to July 2017 to capture all pertinent articles investigating muscle injuries graduations. The search includes the primary and sub primary terms (MeSH) related to "muscle, skeletal/injuries", "athletic injuries", "classification", "diagnosis" and "etiology". As several characteristics can be used to assemble a classification, this search strategy sought to cover all possible relevant studies. Search limitations were made and the full text of these studies in English, Spanish or Portuguese should be available for assessment. The searches were performed in December 2016 and updated in July 2017.

Inclusion and Exclusion Criteria

The inclusion criteria for this review were as follow: studies that proposed a classification of muscular injuries in sports were selected. The articles were included if an organized categorization of some lesion-related feature were present. Classifications could contain etiology, topographic anatomy, physical exam findings, image aspect evaluation and others[9,12].
We excluded articles that did not propose a classification or graduation of muscle injury, manuscripts that defined injury graduation not related to sports and studies that just cited an existing classification. Moreover, studies based on animal models were excluded.

Study selection

The selection of articles was performed by two Authors (TLF and JPCS) as described below. The studies selected in the databases from the pre-defined terms were merged and the duplicates were removed using Mendeley Desktop (v.1.16, Mendeley Ltd., London, UK) as shown in the flowchart based on PRISMA (Fig. 1). The studies maintained were evaluated based on their abstract and were excluded articles that did not refer to muscular injuries classifications in sports or were written in a language other than specified (English, Spanish and Portuguese) or were based on animal models or did not have full text available for assessment. In the following step, full texts of selected articles were used to assessment. Studies that only presented an existing classification, such as update articles, systematic review, meta-analysis or case reports were excluded. Proposed ratings that were not related to sports were also removed.
After proposed classifications selection, a research was carried out to find which of them were submitted to some methodological validation. At this moment, EMBASE, PUBMED, SCIELO and MEDLINE databases were searched. We looked for articles validating classifications or researches citing the selected studies.

Data extraction

For each study meeting the inclusion criteria, descriptive information related to parameters used for categorization, sample size, subject characteristics, presence of outcomes and sports practiced were summarized using a spreadsheet from Excel (Microsoft Corporation, Redmond, Washington, USA). Information about each classification proposed and the validation study were collected and organized (Tab. I) to provide a structured summary. In addition, a summary of all 17 classifications proposed was prepared in a supplementary table (App. 1).
Each article that proposed a classification was evaluated for methodological quality by QUADAS-2 (Quality Assessment of Diagnostic Accuracy Studies) protocol[13]. This tool seeks to judge risk of bias in four domains (patient selection, index test performance, standard reference interpretation and patient flow) and evaluates concerns regarding to applicability of the first three domains described above. Then, 7 criteria were assessed in each study. This protocol was tailored to the research allowing more adequate evaluation[13].
In order to assess the risk of bias and applicability concern, the 7 domains were evaluated on the scale "low", "high" or "unclear". To reach this result, each domain related question should be answered as "yes", "no" or "unclear" with any response other than "yes" posing a certain risk of bias or concern in applicability. All questions used in this assessment are available in the supplemental material (App. 2).
The Authors divided the studies into three categories in order to organize their assessment: (1) classification that presented validation studies; (2) classification without validation studies but presenting a clinical outcome; (3) those that did not undergo any validation method or showed no clinical outcome.
In the cases where the classifications were validated, the study evaluated by the QUADAS-2 protocol was that carried out the validation research.
Disagreement related to the use of primary and subprimary terms, exclusion of articles and assessment of selected studies were resolved by agreement between two Authors. If there was no agreement after deliberation of disagreements, a third Author was responsible for final decision. This review was approved by the local scientific committee and filed at PROSPERO (Centre for Reviews and Dissemination, University of York, UK - CRD42016039544) repository.

Appendix 1 m Summary of all 17 proposed classifications evaluated in the review.

1. Classification based in clinical and imaging features

Author	Description				
Lopes, A. 1993.[1]	**Grading based in etiology and sonographic findings** Type I muscle injuries caused by extrinsic factors: muscle bruising Type II muscle injuries caused by intrinsic factors without show rupture of muscle fibers Type III muscle injuries caused by intrinsic factors showing rupture of muscle fibers				
Verrall, J. 2003.[2]	**Clinical parameters**			**Imaging features - MRI** Classification of Injury	
	Onset	Insidious	Sudden		
	Circumstance	Playing	Training	Positive	Negative
	Pain	(0-10) visual analog scale			
Malliaropoulos, N. 2010.[3]	**Clinical Grade - AROM Deficit**			**Imaging features (US)**	
	I	<10º		Grade 0 to 3 (according Peetrons)	Cross sectional area:
	II	10º - 19º			< 25%
	III	20º - 29º			25-50%
	IV	> 30º			> 50%

Author	Grade of injury	Description	MRI
Pollock, N. 2014.[4]	Grade 0: referred pain		
	0a	Focal muscle soreness	Normal
	0b	Generalized muscle soreness	normal or MRI characteristic of DOMS
	Grade 1: small injuries to the muscle (< 5 cm or < 10% crossn section area)		
	1a	Extend from fascia	Intermuscular fluid
	1b	Muscle or MTJ involvement	Intermuscular fluid
	Grade 2: Moderate muscle tears (5 - 15cm or 10-50% cross sectional area)		
	2a	Extend from fascia	Periphery high signal
	2b	Muscle or MTJ involvement	High signal at MTJ

To be continued

Continued from **Appendix 1.**

	2c	Tendon involvement	High signal at tendon
	Grade 3: Extensive muscle tears (> 15cm or > 50% of cross sectional area)		
	3a	Extend from fascia	Periphery high signal
	3b	Muscle or MTJ involvement	High signal at MTJ
	3c	Tendon involvement	Periphery high signal
	Grade 4: Complete muscle tears		
	4a	Extend from fascia	Periphery defect
	4b	Muscle or MTJ involvement	Defect at MTJ
	4c	Tendon involvement	Defect at tendon
Mueller-Wohlfahrt, H. 2013.[5]	**A. Indirect muscle disorder/injury**		
	<u>Functional muscle disorder</u> Type 1: Overexertion-related muscle disorder Structural muscle injury Type 1A: Fatigue-induced muscle disorder Type 1B: Delayed-onset muscle soreness (DOMS) Type 2: Neuromuscular muscle disorder Type 2A: Spine-related neuromuscular Muscle disorder Type 2B: Muscle-related neuromuscular Muscle disorder		
	<u>Structural muscle injury</u> Type 3: Partial muscle tear Type 3A: Minor partial muscle tear Type 3B: Moderate partial muscle tear Type 4: (Sub)total tear Subtotal or complete muscle tear Tendinous avulsion		

To be continued

Continued from **Appendix 1.**

<table>
<tr><td></td><td colspan="4">B. Direct muscle injury
Contusion

Laceration</td></tr>
<tr><td rowspan="3">Maffulli, N. 2014.[6]</td><td colspan="4">- Direct muscle injury
Contusion

Laceration</td></tr>
<tr><td colspan="4">- Indirect muscle injury
<u>Non-structural muscle injury</u>

Type 1: Fatigue muscular disorder

Type 1A: Fatigue-induced muscle disorder

Type 1B: Delayed-onset muscle soreness (DOMS)

Type 2: Neuromuscular muscle disorder

Type 2A: Spine-related neuromuscular Muscle disorder

Type 2B: Muscle-related neuromuscular Muscle disorder</td></tr>
<tr><td colspan="4">- Indirect muscle injury
<u>Structural muscle injury</u>

Type 3: Partial muscle injury

Type 3A: Minor partial muscle tear

Type 3B: Moderate partial muscle tear (<50%)

Type 4: (Sub)total injury

Subtotal or complete muscle tear Tendinous avulsion

Structural injuries may be proximal (P), middle (M), and distal (D)</td></tr>
<tr><td rowspan="4">Valle, X. 2016.[7]</td><td colspan="4">Clinical findings</td></tr>
<tr><td>Mechanism of injury (M)</td><td>Locations of injury (L)</td><td>Grading of severity (G)</td><td>No. of muscle re-injuries (R)</td></tr>
<tr><td>T - Hamstring direct injuries</td><td>P Injury located in the proximal third of the muscle belly

M Injury located in the middle third of the muscle belly

D Injury located in the distal third of the muscle belly</td><td>0-3</td><td>0: 1st episode

1: 1st re-injury

2: 2nd re-injury ...</td></tr>
<tr><td>I - Hamstring indirect injuries, plus sub-index s for stretching type, or sub-index p for sprinting type</td><td>P Injury located in the proximal third of the muscle belly. The second letter is a sub-index p or d to describe the injury relation with the proximal or distal MTJ, respectively

M Injury located in the middle third of the muscle belly, plus the</td><td>0 3</td><td></td></tr>
</table>

To be continued

Continued from **Appendix 1.**

		corresponding sub-index D Injury located in the distal third of the muscle belly, plus the corresponding sub-index		
	N - Negative MRI injuries (location is pain related), plus sub-index s for indirect injuries stretching type, or sub-index p for sprinting type	N p Proximal third injury N m Middle third injury N d Distal third injury	0-3	
	Magnetic resonance imaging grading			
	Grade 0	Negative MRI		
	Grade 1	Hyperintense muscle fiber edema without intramuscular hemorrhage or architectural distortion		
	Grade 2	Hyperintense muscle fiber and/or peritendon edema with minor muscle fiber architectural distortion (fiber blurring and/or pennation angle distortion) ± minor intermuscular hemorrhage, but no quantifiable gap between fibers		
	Grade 3	Any quantifiable gap between fibers in craniocaudal or axial planes. Hyperintense focal defect with partial retraction of muscle fibers ± intermuscular hemorrhage		
	(r) superscript	When codifying an intra-tendon injury or an injury affecting the MTJ or intramuscular tendon showing disruption/retraction or loss of tension exist (gap)		
2. Classifications based in imaging features				
Pomeranz, S. 1993.[8]	**MRI evaluation**			
	Muscle group involved	Cross-sectional area	Location	Superficial involvement
	Semimembranosus	< 50%	Tendinous	Yes
	Semitendinosus	> 50%	Myotendinous junction	No
	Biceps femoris	Total		
	Quadratus femoris			

To be continued

Continued from **Appendix 1.**

Study	Sonographic findings	
Takebayashi, S. 1995.[9]	Type 1	Normal findings
	Type 2	Hyperechoic infiltration
	Type 3	Mass
	Type 4	Compound lesion (infiltration + mass)

Study	Sonographic findings	
Peetrons, P. 2002.[10]	Grade 0	Sonographically Normal
	Grade 1	Hypoechoic area, <15 mm in longest axisj <5% of muscle involved
	Grade 2	5n 50% muscle involvement. Partial Muscle Rupture
	Grade 3	Full thickness tear of muscle or fascia, with extravasation of collection away from injured part of muscle

Study	MR Imaging of Hamstring Injury		
Slavotinek, J. 2002.[11]	Muscle Affected	Location	Injury cross-sectional area
	Biceps femoris	Proximal to short head of the biceps	0-100%
	Semitendinosus	Distal to short head of the biceps	
	Semimembranosus		

Study	MR Imaging of the Proximal Rectus Femoris – anatomical location
Bordalo-Rodriguez, M. 2005.[12]	Apophyseal avulsion injuries
	Musculotendinous junction injuries
	Muscle contusion and laceration Because

Study	MRI-based grading system (There is more one item related to patient age)					
Cohen, S. 2011.[13]	Item	Description	0 points	1 point	2 points	3 points
	1	N° of muscles involved	None	1	2	3
	2	Location	-	Proximal	Middle	Distal
	3	Insertion	No	-	Yes	-
	4	Cross-sectional % of	0%	25%	50%	≥75%

To be continued

Continued from **Appendix 1.**

		muscle involvement				
	5	Retraction	No	-	> 2 cm	-
	6	Longitudinal axis involvement	0 cm	1-5 cm	6-10 cm	> 10 cm

Chan, O. 2012. [14]	**Grading based in radiological finding and site of lesion**				
	Grade	MRI	US	Site of lesion
	I (strain)	Less than 5% of fibre disruption; feathery oedema-like pattern, intramuscular high signal on the fluid-sensitive sequences	Normal appearance, focal or general increased echogenicity; No architectural distortion	Proximal MTJ
	II (Partial tear)	Less than 5% of fiber disruption; feathery oedema-like pattern, intramuscular high signal on the fluid-sensitive sequences Oedema and hemorrhage of the muscle or MTJ may extend along the fascial planes, between muscle groups	Muscle fibers are discontinuous, the disruption site is hypervascularized and altered in echogenicity in and around, with no perimysial striation of the area adjacent to the MTJ	Muscle A. Proximal B. Middle C. Distal
	III (Complete tear)	Complete discontinuity of muscle fibers, haematoma and retraction of the muscle ends	Comparable with MRI	Distal MTJ

Corazza, A. 2013. [15]	**Combined US-MR assessment**		
	Grade	**MRI**	**US**
	0	no pathological findings	no pathological findings
	I	muscle edema without tissue damage	altered echotexture at the point of tenderness but no sign of disruption
	II	partial muscle tear	Tear and associated hematoma
	III	complete muscle tear	complete muscle tear

3. Classifications based in clinical findings

Bass, A. 1969. [16]	**Classify muscle injuries by etiology and location**		
	Type	Etiology	Location
	I	Direct external violence	Intramuscular
	II	Muscle contraction	Intermuscular

To be continued

Continued from **Appendix 1.**

Wise, D. 1977.[17]	**Classification based on cause, severity and location of the muscle injury in leg**						
	Indirect injuries - inflammation n						
	Direct injuries - trauma						
	Grade	Pain	Circumference difference	Range of motion	On contraction		
					Pain	Loss of power	Function disturb
	I	Minimal;	< 6 mm	100%	Minimal	None	Mildly
	II	Substantial	6 - 12 mm	50%	mild	mild	Great
	III	Intractable	> 12 mm	<50%	severe	Almost total	No bear weight
MRI, magnetic resonance image; **US**, ultrasound; **DOMS**, delayed onset of muscle soreness; **MTJ**, Musculotendinous junction							

Supplementary Appendix 1 References

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Appendix 2 – Questions from QUADAS-2 assessment. The answers were used to help the assessment of risk of bias and concerns regarding applicability in the proposed classifications showed by studies included in the review.

Domain 1: Patient Selection - Could the selection of patients have introduced bias?				Concerns regarding applicability
Was a consecutive or random sample of patients enrolled? (Yes, No, Unclear)	Was a case-control design avoided? (Yes, No, Unclear)	Did the study avoid inappropriate exclusions? (Yes, No, Unclear)	RISK OF BIAS - Could the selection of patients have introduced bias? (Low, High, Unclear)	Is there concern that the included patients do not match the review question? (Low, High, Unclear)

Domain 2: Index Test - Could the conduct or interpretation of the index test have introduced bias?			Concerns regarding applicability
Were the index test results interpreted without knowledge of the results of the reference standard? (Yes, No, Unclear)	If a threshold was used, was it pre-specified? (Yes, No, Unclear)	RISK OF BIAS - Could the conduct or interpretation of the index test have introduced bias? (Low, High, Unclear)	Is there concern that the index test, its conduct, or interpretation differ from the review question? (Low, High, Unclear)

Domain 3: Reference Standard - Could the reference standard, its conduct, or its interpretation have introduced bias?			Concerns regarding applicability
Is the reference standard likely to correctly classify the target condition? (Yes, No, Unclear)	Were the reference standard results interpreted without knowledge of the results of the index test? (Yes, No, Unclear)	RISK OF BIAS: Could the reference standard, its conduct, or its interpretation have introduced bias? (Low, High, Unclear)	Is there concern that the target condition as defined by the reference does not match the review question? (Low, High, Unclear)

Domain 4: Flow and timing - Could the patient flow have introduced bias?				
Was there an appropriate interval between index test and reference standard? (Yes, No, Unclear)	Did all patients receive a reference standard? (Yes, No, Unclear)	Did all patients receive the same reference standard? (Yes, No, Unclear)	Were all patients included in the analysis? (Yes, No, Unclear)	RISK OF BIAS - Could the patient flow have introduced bias? (Low, High, Unclear)

Results

Using the defined strategies, 1805 articles were found corresponding to primary and sub-primary terms (MeSH and DeCS) related to "muscle, skeletal/injuries", "athletic injuries", "classification", "diagnosis" and "etiology" from the selected databases.

After exclusion of duplicate items, 1606 articles were maintained and their abstracts were evaluated. 1562 texts were excluded due to not refer to muscular injuries graduation or not be related to sports, or they were written in another language different from those proposed or were based on animal model or did not have a full text available. Forty-four articles presented some classification of muscular injuries in sports and full text was evaluated (Fig. 1).

The 44 studies selected for the second stage included 17 articles that proposed a new classification. The other 27 articles presented studies of case report, reviews showing updates, overview of evaluation strategies, treatment of muscle injuries or exposed ratings related to non-sports activity.

Characteristics of the proposed classifications and some features from the studies assessed for methodological quality are showed in Table I. These features, like patient involvement, presence of target condition or clinical outcome were extracted from the data of the studies evaluated in QUADAS-2 protocol. As previously stated, in the cases where classifications were validated, we evaluated the validity study.

Among 17 studies with classifications of muscle injury in sports, two articles published by Bass et al. in 1969 and Wise et al. in 1977[8,14] presented classifications based just on clinical findings. The first classification based only on image was published in 1993 by Pomeranz et al.[15] and eight classifications in total took into account only aspects of image exam[15-22].

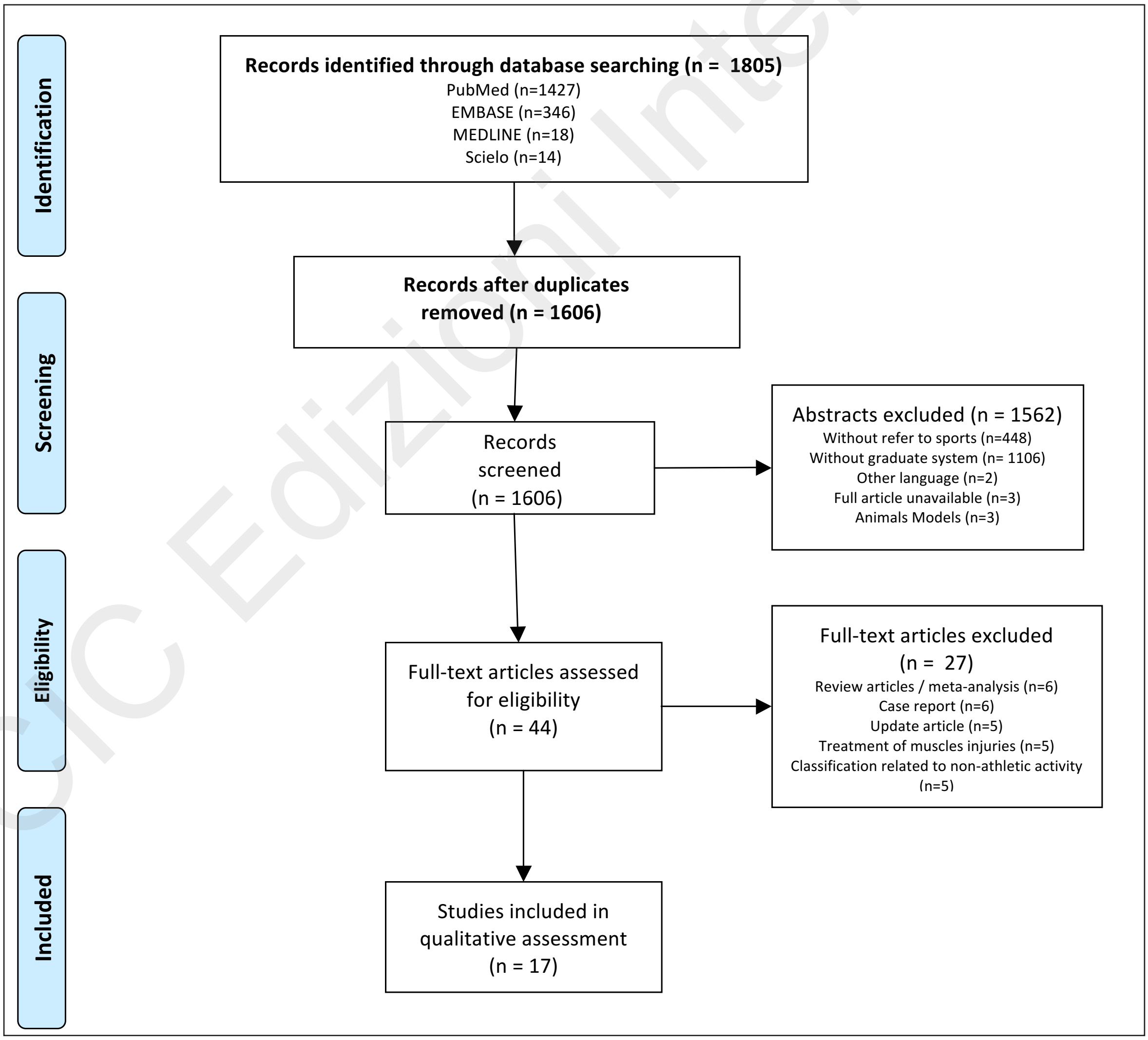

Figure 1. Flowchart of literature search process.

Seven graduation systems were based on clinical and radiological findings[6,23-28].

Regarding some features used for methodological evaluation, six classifications had no study with patients to assess whether the proposed graduation correlated with clinical and radiological findings[8,14,19,21,27,28]. Among 11 studies that evaluated patients, 4 involved soccer players[22,24,29,30], 2 included Australian football (Australian rules) players[18,25], 2 involved athletics[26,31], 1 with football (American football) players[20] and 2 involving sportsman without definition of sport[19,21].

The athletes largest study was conducted in Brazil and published in 1993 by Lopes et al.[24] in which 2670 soccer players were evaluated (Table I).

The most frequently assessed muscle group was hamstrings. Eight studies evaluated hamstring injuries isolated[15,18,20,25-27,29,31], while 3 studies included more muscle groups: Corazza et al.[22] and Ekstrand et al.[30] assessed injuries of the thigh and Takebayashi et al.[17] assessed hamstrings, quadriceps and calves. One study evaluated lesions of the rectus femoris muscle[19] and the 5 other studies did not define which muscle group were evaluated[8,14,21,24,28].

Regarding to clinical outcome, in 8 studies it wasn't assessed[8,14,19,21,24,28,31]. The other 9 studies reached a clinical endpoint and return to sports was the chosen target condition in all these research.

As described before, 17 studies were selected to be evaluated by QUADAS-2 protocol. Three classifications presented validation study in literature[6,16,23]. Ekstrand et al.[29] validated the classification described by Peetrons[16]; the Munich consensus statement[23] was validated through a study from Ekstrand et al.[30] and the British athletics muscle injury classification system[6] was validated from the study of Patel et al.[31].

The results of QUADAS-2 were summarized in a tabular presentation (Fig. 2). In patient selection domain, 7 studies[18,22,25,26,29-31] presented low risk of bias and the other 10 had high or unclear risk of bias. In each of the other 3 domains (index test, reference standard, flow and timing) less than 1/3 presented low risk of bias. Five studies with low risk of bias in index test[17,18,29-31], and 4 studies with low risk of bias both in reference standard and flow and timing domain[17,29-31]. Regarding to applicability concerns 10 studies showed low concern in patient selection domain, 11 in index test, and 5 showed low applicability concern in reference standard domain. QUADAS-2 assessment showed less than half of all proposed classifications studies had low risk of bias in all domains, whereas more than a half studies presented low applicability concern in 2 of 3 domains (Fig. 3).

When the articles were divided into the 3 groups described in *methods,* it was found 3 classifications[6,16,23] in the first group as shown above. The second group formed by graduations without validation studies but that presented clinical outcome consisted of 7 studies[15,17,18,20,22,25,26]. The remaining seven studies formed the third group[8,14,19,24,27,28,32]. The articles in the second and third groups presented a high risk of bias and problems related to applicability in almost all domains evaluated in comparison to the first group composed by validity studies as shown in the tabular presentation (Fig. 2).

Discussion

Sports muscle injury is increasingly studied and discussed in scientific publications[9]. It is verified due to 1606 articles from this present search strategy. Most studies did not meet the inclusion criteria, but these numbers show how this issue has become common.

Almost half of the evaluated graduations were published in the last decade. There were 8 different rating systems presented between 2010 and 2016[6,20,22,23,26-28,32], of the 17 articles published since the 1960s. The increase in sports practice, both professional and amateur may be one of the factors stimulating the rise of research in this field. In addition to this, the costs related to a professional athlete absence from training and matches have stimulated the study of muscular injuries. Another important reason that leads research groups to develop new classification systems may be the lack of methodological quality of previous studies.

Regarding general characteristics assessed, all classifications except two[8,14] are based on image studies. These imaging protocols have been shown to be important in diagnosis and prognosis, and new studies aim to improve the correlation findings between images and injury severity and return to sports. Most of the studies evaluated limited muscle groups, which most often were hamstrings. This delimitation is necessary and seeks to standardize research, allowing Authors to reach their outcomes properly. Furthermore, Authors classify muscle injury by many others aspects such as location, size, causative mechanism and other characteristics. The use of these different features can create misunderstanding when we try to compare muscle injuries severity trough distinct classifications.

In this review we noted 13 researchers classified muscle lesions seeking to correlate the graduation with a target condition such as return to sports activity[8,15-18,20,22-28]. But just 9 studies sought to define a clinical outcome[15-18,20,22,23,25,26]. Thus, almost half of studies did not established valid evidence that could guide the team physician in muscle injury treatment. This lack of outcome evaluation can create systems that had poor applicability.

QUADAS-2 protocol was used in this review to evaluate the methodology of the studies. As described before, we divided the studies into 3 groups. The first group, formed for researches that not just implemented or assessed a graduation system, but also validated and evaluated its predictive value for a clinical outcome, presented the best result of methodological quality, with low risk of bias in all domains evaluated. The studies of the other 2 groups (without validation

Table I. Characteristics of the proposed classifications and some features from the studies assessed for methodological quality. These features, like patient involvement, presence of target condition or clinical outcome were extracted from the data of the studies evaluated in QUADAS-2 protocol.

			Classifications features		Evaluated studies features				
	Proposed classification	**Validation study**	**Based on clinical findings**	**Based on image findings**	**Patients involved (n)**	**Sport included**	**Muscular group evaluated**	**Target condition**	**Clinical outcome**
1	Peetrons, P. 2002.	Ekstrand, J. 2012.	NO	YES	207	Football (Soccer)	Hamstrings	Return to sport	YES
2	Mueller-Wohlfahrt, H. 2013.	Ekstrand, J. 2013.	YES	YES	393	Football (Soccer)	Thigh muscles	Return to sport	YES
3	Pollock, N. 2014.	Patel, A. 2015.	YES	YES	45	Athletics	Hamstrings	Not Defined	NO
4	Bass, A. 1969.	NO	YES	NO	NO	NO	Not Defined	Return to sport	NO
5	Wise, D. 1977.	NO	YES	NO	NO	NO	Not Defined	Not Defined	NO
6	Lopes, A. 1993.	NO	YES	YES	2670	Football (Soccer)	Not Defined	Return to sport	NO
7	Pomeranz, S. 1993.	NO	NO	YES	14	Not Defined	Hamstrings	Return to sport	YES
8	Takebayashi, S. 1995.	NO	NO	YES	57	Not Defined	Hamstrings, Quadriceps and Calf	Return to sport	YES
9	Slavotinek, J. 2002.	NO	NO	YES	37	Australian Rules	Hamstrings	Return to sport	YES
10	Verrall, J. 2003.	NO	YES	YES	83	Australian Rules	Hamstrings	Return to sport	YES
11	Bordalo-Rodriguez, M. 2005.	NO	NO	YES	NO	Not Defined	Rectus femoris	Not Defined	NO
12	Malliaropoulos, N. 2010.	NO	YES	YES	165	Athletics	Hamstrings	Return to sport	YES
13	Cohen, S. 2011.	NO	NO	YES	38	American football	Hamstrings	Return to sport	YES
14	Chan, O. 2012.	NO	NO	YES	NO	Not Defined	Not Defined	Not Defined	NO
15	Corazza, A. 2013.	NO	NO	YES	84	Football (Soccer)	Thigh muscles	Return to sport	YES
16	Maffulli, N. 2014	NO	YES	YES	NO	Not Defined	Not Defined	Return to Sport	NO
17	Valle, X. 2016.	NO	YES	YES	NO	Not Defined	Hamstrings	Return to sport	NO

	STUDY	RISK OF BIAS				APPLICABILITY CONCERNS		
		PATIENT SELECTION	INDEX TEST	REFERENCE STANDARD	FLOW AND TIMING	PATIENT SELECTION	INDEX TEST	REFERENCE STANDARD
1	Ekstrand, J. 2012* (Peetrons, P. 2002)	☺	☺	☺	☺	☺	☺	☺
2	Ekstrand, J. 2013* (Mueller-Wohlfahrt, H. 2013)	☺	☺	☺	☺	☺	☺	☺
3	Patel, A. 2015* (Pollock, N. 2014)	☺	☺	☺	☺	☺	☺	☺
4	Bass, A. 1969	☹	?	?	☹	?	?	?
5	Wise, D. 1977	☹	?	?	☹	?	☺	?
6	Lopes, A. 1993	?	?	?	☹	?	☹	?
7	Pomeranz, S. 1993	☹	?	?	☹	☺	☺	?
8	Takebayashi, S. 1995	?	☺	☺	☺	☺	☺	☺
9	Slavotinek, J. 2002	☺	☺	?	☹	☺	☺	?
10	Verrall, J. 2003	☺	?	?	☹	?	☹	?
11	Bordalo-Rodriguez, M. 2005	☹	?	?	☹	?	☹	?
12	Malliaropoulos, N. 2010	☺	?	?	☹	☺	☺	?
13	Cohen, S. 2011	☹	?	?	☹	☺	?	?
14	Chan, O. 2012	☹	?	?	☹	?	?	?
15	Corazza, O. 2013	☺	?	?	☹	☺	☺	?
16	Maffuli, N. 2014	?	?	?	☹	?	?	?
17	Valle, X. 2016	?	?	?	☹	?	?	?

*Validation study ☺ Low Risk ☹ High Risk ? Unclear Risk

Figure 2. QUADAS protocol results summarized in a tabular presentation showing the high prevalence of studies with undertemined and high risk of bias.

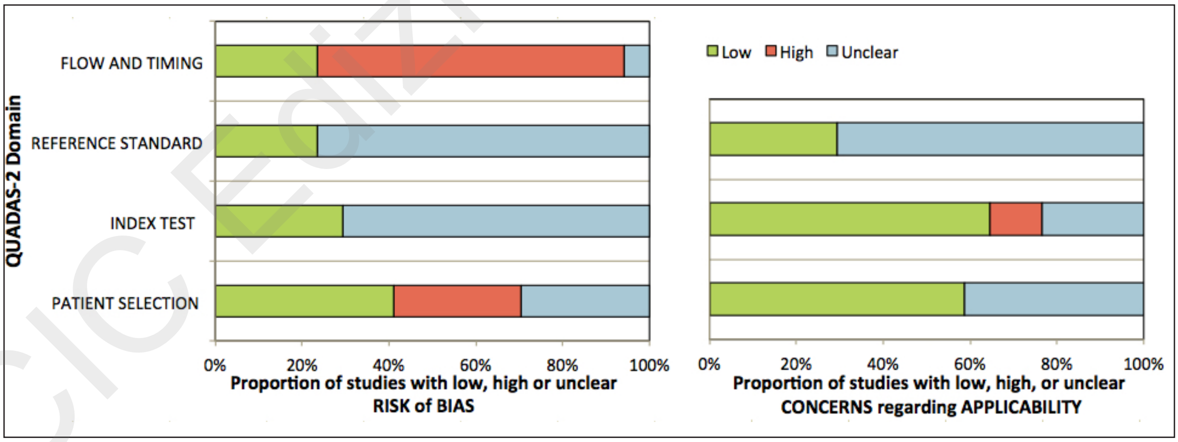

Figure 3. Percentage results of QUADAS protocol assessment shows less than half of classifications presented studies with low risk of bias in all domains. In majority of domains an undetermined or high risk of bias was present.

study) showed a risk of high bias in at least 1 of the 4 domains assessed.

It is interesting to notice that about 70% of these studies presented an undetermined bias towards the index test performance and the standard reference interpretation. This difficulty in accurately determining the risk of bias in several studies was a complication for this review article. However, it was expected that the large number of classifications created without adequate methodology to assess their reliability could lead to this limitation.

Nevertheless, the initial hypothesis that muscle injury classification studies have a low level of compliance could be confirmed. There is a wide variety of methodological quality of most classification studies. Most classifications are only a theoretical model and therefore have important limitations.

Previous reviews also shown the wide variety in how to graduate muscle injuries[5,33,34]. Two narrative reviews show the methods used for creating various classification systems chronologically[5,33]. Nevertheless, no review evaluated systematically the methodological quality of these existing classifications and sought to define which systems were based on evidence from well-designed studies with low risk of bias and good applicability.

We could conclude that excellent methodological quality is an important issue and it should be sought for every study based on diagnostic accuracy. It is proposed that studies related to muscle injury classification in sports should be performed looking for better prognosis predicting. In this study, the classifications proposed by Peetrons[16], Mueller-Wohlfahrt[23] and Pollock[6] were very well evaluated, presenting good results regarding risk of bias and applicability. In our clinical practice we use the Munich consensus statement, this system seems to be simple in its application and covers the wide range of muscle lesions found in our practice. Moreover, it is a useful tool regarding the challenging of predict return to sports for the injured player.

Finally, it is certain that most of the researchers are searching to define a graduation of muscle injury that could be used for different muscle groups. Nevertheless, the studies published so far do not allow such possibility. Each muscle groups are required in different ways and the mechanisms of injury and recovery time may vary for each group. The complexity of muscle injury appears to be the main reason for the difficulty of create a simple system with an excellent correlation to clinical outcomes. It would require plenty of clinical research with appropriate methodology and comparative analysis of the assessment of individualized sports and specific muscle group.

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Ethics

The Authors declare that this research was conducted following basic ethical aspects and international standards as required by the journal and recently update in[35].

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