Classification and grading of muscle injuries: a narrative review

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ABSTRACT

A limitation to the accurate study of muscle injuries and their management has been the lack of a uniform approach to the categorisation and grading of muscle injuries. The goal of this narrative review was to provide a framework from which to understand the historical progression of the classification and grading of muscle injuries. We reviewed the classification and grading of muscle injuries in the literature to critically illustrate the strengths, weaknesses, contradictions or controversies. A retrospective, citation-based methodology was applied to search for English language literature which evaluated or utilised a novel muscle classification or grading system. While there is an abundance of literature classifying and grading muscle injuries, it is predominantly expert opinion, and there remains little evidence relating any of the clinical or radiological features to an established pathology or clinical outcome. While the categorical grading of injury severity may have been a reasonable solution to a clinical challenge identified in the middle of the 20th century, it is time to recognise the complexity of the injury, cease trying to oversimplify it and to develop appropriately powered research projects to answer important questions.

INTRODUCTION

Muscle injuries are among the most common injuries in sport, but there remain few high-quality studies evaluating their specific management.[1] A limitation to the comprehensive study of muscle injuries has been the lack of uniformity in their categorisation and description. Reflecting this observation, the Munich muscle injury classification group stated that '...little information is available in the international literature about muscle injury definitions and classification systems.'[2] The terms classify and grade do not refer to the same process. Injury 'classification' refers specifically to describing or categorising an injury (eg, by its location, mechanism or underlying pathology). By contrast, a 'grade' provides an indication of injury severity.[3]

While it would appear logical to initially classify a muscle injury according to a system of choice (eg, by location or mechanism), and then grade the injury severity within that classification (eg, grade I, II or III), this approach has not been uniformly applied. When referring to muscle injuries, the terms classification and grading have frequently been used interchangeably and ambiguously.[4 5]

The following narrative review outlines the historical progression of the classification and grading literature for acute muscle injuries, predominantly from the English literature. We illustrate the strengths, weakness, inconsistencies and controversies in the literature to better understand the paradigm in which muscle injury descriptors have been developed, thereby facilitating future understanding.

Methodology

A retrospective, citation-based methodology was applied to search for English language literature which evaluated or utilised a novel muscle classification or grading system. Peer-reviewed journal publications were the primary source, but prior to 1970 popular sports medicine textbook sources were also utilised. No systematic search strategy was used and one author (BH) independently screened and documented the literature.

Muscle injury classifications

By the turn of the 20th century, muscle injuries were being classified by both the causative or mechanistic forces and the anatomical location of the injury (see online supplementary table S1 for a complete summary).[6–8] Specifically, authors categorised muscle injuries as either being derived from internal forces (secondary to violent exertion) or external forces (secondary to direct 'violence').[6–8] Anatomically, it was recognised that the muscle may 'rupture' in distinct locations such as 'where fibres meet the tendon', the 'body of the muscle' or in the tendon.[6] This early literature predates frequently cited classification systems, but most likely provided the foundation for their subsequent development[9–12] as minor variations of this approach were common throughout the early 20th century.[13–17]

In the 1960s, approaches to muscle injury classification expanded to include newly defined conditions such as myositis ossificans, and to incorporate mechanistic and anatomical descriptors in a single classification.[9 12] This approach of incorporating the mechanism, injury location and distinct pathologies continues to be utilised.[18] Indeed, the classification of muscle injuries by the causal mechanism (intrinsic vs extrinsic forces) and the anatomical location of the injury has remained largely unchanged with time.[10 19 20] Although not all influential authors in the past have felt it clinically necessary to separately classify internally and externally derived injuries,[11] animal injury research and imaging techniques of the late 20th century have largely validated the clinically derived distinctions of 'contusion' (external force) and 'strain' (intrinsic force).

From the 1980s, availability of imaging in the form of ultrasound (US) and MRI allowed direct visualisation of muscle injury, resulting in enhanced anatomical accuracy and an expansion of the imaging literature.[10 20–22] Initial image-based muscle injury publications were descriptive in nature, articulating the appearance of images corresponding to popular clinical classification (and grading) approaches that were in use by the 1980s.[23] Early imaging reports included only small subject numbers, limited clinical information,[10 20–24] and rarely acknowledged that the imaging descriptions of the clinical classifications had little pathophysiological or prognostic grounding.[25]

In the early 21st century, there has been renewed interest in muscle classification. Askling *et al*[26–28] have continued the history of classifying hamstring injuries by their distinct anatomical location (eg proximal/distal; semimembranosis/biceps femoris; figure 1A–C) and, for the first time, demonstrated a relationship between the anatomical location and time to return to play. The same group also proposed a subclassification of intrinsic force injury, specifically the 'stretching type' (type 2) or 'high speed running type' (type 1) related to the muscle involved.[26–28] While stretch versus high force intrinsic injuries have previously been alluded to,[9] Askling *et al*[26–28] highlighted a relationship between the specific nature of the intrinsic force and clinical prognosis. Thus, classification of injuries based on their causation may have prognostic validity. Ultimately, larger study numbers may enable further grading of injury severity within each classification (ie, Stretch (type 2) or high speed (type 1)).

'Central tendon' disruption was identified as a potential contributor to prognosis in earlier imaging studies.[20] Comin *et al*[29] recently demonstrated a distinct prognosis when the 'central' tendon was disrupted in hamstring injuries. In 1966, Bass[30] proposed that anatomical classification was clinically relevant, but only recently have Askling *et al*[31] and Comin *et al*[29] provided evidence that identifying the specific tissue involved may have clinical utility.

Historically, there was limited critique of the literature pertaining to muscle injury classification, but in the past 10 years, authors have critically evaluated the limitations of muscle injury classification.

Muscle injury grading

The 'clinical era' (c1900–1980)

The severity of any given injury may be determined by either directly identifying the underlying pathology (eg, with a muscle biopsy), indirectly by utilising a proxy representation of the pathology such as imaging or systemic (eg, serum) markers, or by the serial documentation of observed clinical outcomes related to specifically identified clinical, pathological, imaging or systemic variables.

Excluding a single biopsy report of a clinical 'grade III' injury in a patient suffering from systemic sclerosis, we are not aware of any human biopsy studies assessing muscle strain severity.[32] While a number of animal models have assessed muscle injury, few reflect either the mechanism of injury or the symptoms experienced by athletes.[33–39] As a result, clinicians employ indirect means of evaluating muscle damage severity.[25] Traditionally, this was achieved by identifying a range of symptoms and/or signs at injury presentation thought to reflect the severity of any underlying pathology, with early 20th century literature grading including variations of 'mild' or 'severe' categories.[13 15 16 40 41] By the 1960s, there were a range of categorical grading systems for muscle injury with the severity determined by a subjective assessment of function loss, assumed to reflect either the number of muscle fibres involved or the injury location.[13 15 16 40 41]

In 1966, the American Medical Association (AMA) subcommittee on the classification of sports injuries published the first comprehensive three grade system for acute muscle injuries.[23] This grading system, incorporating both clinical descriptors and a theoretical pathological correlation, provides the most detailed grading of the pre-imaging era (see online supplementary table 1 for details). While rarely cited, the AMA grading appears to have been highly influential in subsequent literature,[42 43] and almost certainly forms the clinical basis for early imaging grading;[10 44] recent literature appears to neglect this substantial work.[2 45]

While more than 1500 muscle injuries were described in the literature prior to the 1980s,[7 13 16 17 46 47] only Bass (1966), studying 72 football players, made any attempt to correlate any clinical findings to a distinct outcome.[30] As a result, there is no established prognostic validity to historical (clinical) grading systems of muscle injury, but despite this they have been recycled in various modified forms and continue to appear in the literature.[48] Traditional clinical grading of muscle injury is attractive for practitioners and patients, but the grading is based on expert opinion only and lacks any substantial empirical support.

The imaging era (c1985–2000)

From the 1980s, US and MRI allowed the indirect assessment of muscle anatomy and pathology with contemporary authors anticipating that this would provide greater objectivity to the complex clinical evaluation.[49] As with clinical grading systems, we are aware of no studies that validate imaging findings observed in muscle strain with a confirmed underlying pathology. Subsequently, as already noted with regard to the classification literature, early imaging grading literature describes the radiological appearance of a clinical presentation, which in itself lacks any pathophysiological or prognostic validity. Of the early imaging grading descriptions,[10 24 44 49–52] only Pomeranz and Heidt,[20] evaluating 14 muscle injuries, made any attempt to establish a distinct prognosis between muscle grades. Pomeranz and Heidt[20] assessed muscle injury size with MRI and then carefully followed athletes during their rehabilitation, providing one of the earliest indications of a possible correlation between the extent of imaging findings and clinical prognosis.

Recently, limited data have supported the reliability,[53] and the prognostic validity of categorical imaging grading derived from clinical evaluations.[54] A landmark study involving 207 elite European footballers failed to show a statistically significant difference in prognosis between grade 1 and 2 injuries.[54] By contrast, a subsequent investigation with a larger cohort did establish that MRI can statistically differentiate prognosis in this group of athletes.[55] It is important to note that these studies do not reflect the natural history (ie, an injury course unmodified by treatment) of any of the clinically or radiologically determined injuries. Injured athletes in these cohorts may have been exposed to a range of intensive rehabilitation and invasive treatments which may significantly impact the natural history and prognosis for any given radiological appearance.[56] Furthermore, the *timing* of any imaging is critical for prognostication as MRI findings may remain after an athlete is clinically ready to return to competition.[25 57] Finally, it is pertinent to recall that the imaging descriptions utilised (ie a 'modification of Peetrons classification'[10 54]) are based on historically derived clinical descriptions that have no established validity.

Hence, while data are emerging that in certain situations are image based, categorical grading systems may provide a valid prognosis, technical limitations and data reproduction demands that further evidence be collected.

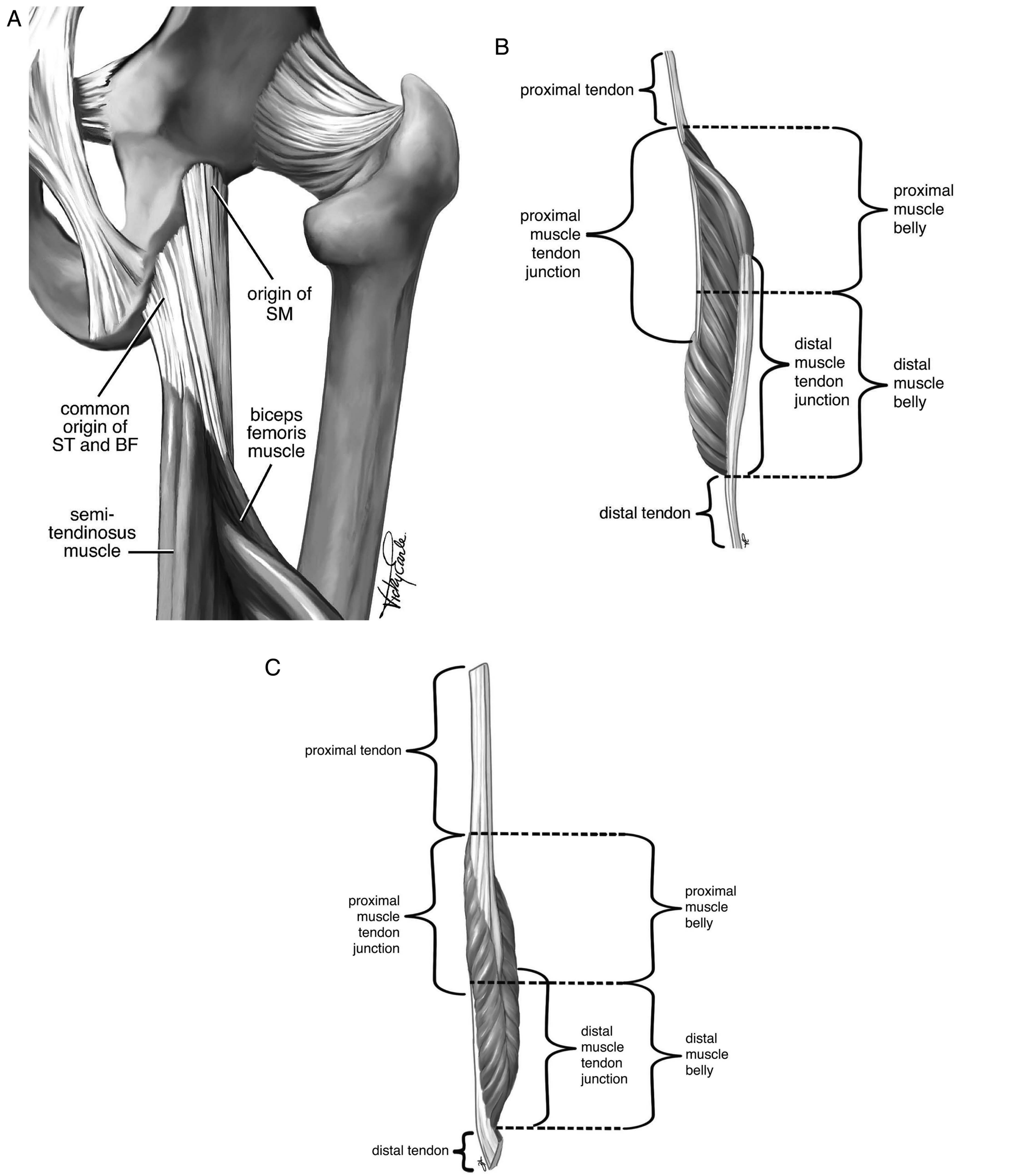

Figure 1 Part (A) proximal hamstring origin. (B) Type I ('high-strain') hamstring injuries mainly occur within the long head of the biceps and typically involve the proximal muscle-tendon junction. (C) Type II (stretching) injuries typically occur close to the ischial tuberosity and affect the proximal free tendon of semimembranosus, reproduced with permission from Askling C, Schache A. *Brukner & Khan's clinical sports medicine*, Chapter 31: posterior thigh pain.[89]

The modern era (c2000–)

Early in the 21st century, researchers began to address the limitations of existing classification and grading systems for muscle injuries. First, as illustrated above, there have been attempts to provide an evidential basis for correlating clinical and radiological grading with injury severity. Second, there has been recognition that imaging can provide continuous rather than categorical data, and that this may correlate with injury prognosis. Finally, there has been recognition of the benefits of combining clinical and radiological evaluations, and with this insight authors have begun to reconstruct classification and grading systems.

Establishing an evidence base

Despite Wise (1977) describing a clinical grading system for muscle injury incorporating both symptoms and signs,[43] until recently there was little empirical evidence for the prognostic value of either clinical variable.[19 58] In 2003, Verrall *et al* illustrated that symptoms and signs such as the sudden onset of pain and localised tenderness, respectively, may accurately reflect underlying injury to the hamstring muscle. Furthermore, both patient reported pain severity and the clinician's 'estimate' of injury severity correlated with the return to play.[58] Similarly, time taken to walk pain free (more or less than 1 day) has been noted to have a degree of prognostic merit for hamstring injuries,[59] and active range of knee joint extension has been correlated with hamstring injury severity and reinjury risk.[19 60]

By contrast, Askling *et al*[31] assessed passive straight leg raise and knee flexion strength in a cohort of injured sprinters and dancers, and found that neither of the clinical tests correlated with prognosis. Likewise, Verrall *et al*[61] found that the initial clinical examination, including the categorical finding of swelling, bruising, tenderness and pain on hamstring contraction, had no value in predicting the likelihood of reinjury. Low numbers of subjects and conflicting clinical findings necessitate further data to enable a better understanding of the merits of clinical assessment in muscle injury prognostication.

The significant role of Ekstrand*et al*[54] in correlating imaging with prognosis has been noted above. An additional finding of note, that grade 0 (MRI negative injuries) had a significantly better prognosis than all other grades of injury, supports the findings of previous authors who highlighted the prognostic relevance of a positive versus negative MRI.[25 58 62–64] Paradoxically, while US has been shown to be as sensitive as MRI in determining the presence of muscle injury,[25] a study involving 51 footballers illustrated no difference in hamstring injury prognosis based on a positive or negative initial US.[65] In the presence of a clinically diagnosed muscle injury, there remains uncertainty as to how to interpret negative imaging findings—specifically whether this reflects a muscle injury below the sensitivity of the imaging modality, or whether this is a true negative for muscle injury.[2 66]

Anatomical details now visible on imaging, such as tendon involvement, may impact on muscle injury prognosis suggesting that historical categorical approaches to grading may be oversimplistic in nature.[29] Evidence is slowly accumulating, allowing the critical evaluation of clinical and radiological variables in the assessment and prognosis of muscle injury, but data quality and quantity remain limited.

Measuring continuous variables and prognosis

Since 2002, authors have correlated injury size on imaging, using a continuous scale, with clinical outcome (table 1).[25 27 28 58 61–63 65 67 69 71 72] Of the continuous variables studied using MRI for hamstring injuries, lesion length, cross-sectional area and estimated volume all provide some predictive value—in essence, the larger the lesion, the longer the rehabilitation period required. By contrast, US has not consistently shown a relationship between muscle length and prognosis.[25 65]

Askling *et al*[28 69] found that the absolute (clinical and radiological) distance from the ischium in 18 hamstring injured sprinters correlated with prognosis. This finding was not reproduced in 15 dancers with 'stretch' type injuries of the hamstrings,[27] and previous studies have not found an association between injury location and return to play duration.[58] Furthermore, while continuously measured clinical variables such as pain at the initial injury correlate positively with return to play,[58 63] measures of hip flexibility and knee flexion strength do not.[31]

With the total data using imaging analysis of continuous variables totalling just over 200 cases, there remain limited data with which to accurately predict an individual's specific prognosis based on injury size. Furthermore, in the majority of the studies cited, bias cannot be excluded, as treating clinicians were not blinded to MRI or clinical findings. As a result, further study and larger subject numbers are required.

Combined approaches to classification and grading

The past 5 years have seen a range of publications touting 'new' muscle injury classification and grading systems, on occasion varying little from previous approaches.[2 16 45 73–79] However, only two manuscripts provide any clinical data to support the proposed systems.

In a novel approach, Cohen *et al*[76] evaluated hamstring injuries in 43 American football players, combining six radiological observations into a single injury score (see online supplementary table 1 for details). A combined score of greater than 10 points was found to have a worse prognosis. This comprehensive grading system, utilising currently available knowledge, illustrates a progressive approach and while the data have yet to be reproduced elsewhere, its clinical merit warrants further inspection.

In 2012, an experienced group of clinicians met in Munich to establish a comprehensive system for the classification and grading of muscle injuries.[2] While the authors retained the 'direct' and 'indirect' terminology first utilised as early as 1902 (then termed internal and external),[6] that is where similarities with many previous classifications end. The authors expand previous definitions of muscle injury and pain, to incorporate terms such as 'functional', 'structural', 'neuro-muscular muscle disorder', 'overexertion-related muscle disorder' and 'fatigue induced muscle disorder' in an expansive system of subclassification. In support of this classification is an extensive clinical description including delineating factors from the history, examination and imaging. The authors also grade the 'partial muscle tear' into 'minor partial muscle tear' (3A) and 'moderate partial muscle tear' (3B), on the basis of symptoms, signs and imaging.

As with previous classification systems, there remain both a limited pathophysiological and pathoanatomical basis on which to base the detailed subclassification, and limited evidence for distinct clinical outcomes on the basis of either the classification or grading. However, the Munich group implemented an expansive research programme involving European football clubs to evaluate the validity of their system.[80] This study suggested a relationship between the injury category/grade and prognosis, particularly in differentiating the return to play duration between 'functional' and 'structural' disorders. Whether this terminological distinction reflects the previously identified importance of MRI positive versus negative injury remains to be determined.[80] However, the significance of this work, and the fact that for the first time in the history of muscle injuries, large volumes of data are being utilised to test a classification and grading system, should be recognised and commended. For the first time in over 100 years of muscle injury grading, authors are testing a proposed model.

Summary and future challenges

In reviewing the evolution of muscle injury classification and grading, several themes became apparent.

1. Variability in the nomenclature utilised to classify and grade muscle injuries has resulted in limited ability to compare the few studies available. Standardisation and enhanced anatomical detail[81] of structural descriptions in manuscripts would enhance future discussion.
2. Authors have sometimes ignored, subtly adapted, or on occasion misrepresented existing muscle injury grading and classification systems, without recognising or addressing their limitations. This has resulted in widely used but unsubstantiated dogma established solely on expert opinion.
3. A historical ambivalence towards reporting clinical outcomes has meant that evidence is only beginning to appear relating clinical or imaging observations to functional outcome. To

Table 1 Clinical muscle injury research utilising continuous variables for the assessment of severity

Author	Grading/description		Outcome	Cited cases
Slavotinek *et al*[63]	*Description based on MRI findings*	Approximate volume of muscle involved; (r=0.46) percentage of abnormal muscle (r=0.70)	Association with RTP duration	30
		Subjective pain score	Association with MRI determined severity	
Verrall *et al*[58]	*Description based on MRI findings and symptoms*	Amount of pain	Positive correlation with RTP duration	83
Connell *et al*[25]	*Description based on MRI and US findings*	Injury cross-sectional area (%) Longitudinal length (r=0.58); Volume of intramuscular haematoma	US determined cross-sectional area associated with RTP duration; MRI positive correlation with RTP; haematoma, no correlation with RTP.	60
Gibbs *et al*[62]	*Description based on MRI findings*	Cross-sectional area (%); Length of lesion (cm)	Positive statistical correlation with RTP	31
Verrall *et al*[61]	*Description based on MRI findings*	MRI transverse size (%); MRI volume	Larger lesion, increased risk of injury in subsequent season	37
Schneider-Kolsky *et al*[67]	*Description based on MRI findings*	Longitudinal length of lesion on coronal views (r=0.58); Cross-sectional area (%)	Positive correlation with RTP	58
Askling *et al*[31]	*Description based on Clinical findings*	Hip flexibility (Degrees/Borg CR-10 pain scale); Knee flexion strength (dynamometer)	No data on relationship to RTP	33
Koulouris *et al*[68]	*Description based on MRI findings*	Cross-sectional injured area (mm); Injury location (muscle, location); Injury longitudinal length (mm)	Non-significant impact on reinjury risk	31
Askling *et al*[28]	*Description based on MRI findings*	Distance to ischial tuberosity (r=0.54); depth of injury (r=0.58); Volume of injury (r=0.61); Cross section of injury (r=0.70)	Positive correlation with RTP	18*
		Length of injury (r=0.51)	No statistical correlation with RTP	
		Width of injury (r=0.39)	No statistical correlation with RTP	
Askling *et al*[27]	*Description based on MRI findings*	Distance to ischial tuberosity; Length of injury; Width of injury; Depth of injury; Volume of injury	No statistical correlation with RTP	15*
Balius *et al*[69]	*Description based on US findings*	Length of lesion	Positive significant association with RTP	35
Nescolarde *et al*[70]	Grading based on changes in localised BIA	Resistance; reactance (xc); phase angle PA	Decreases with increasing injury severity	3
Peterson *et al*[65]	*Description based on US findings*	Length of lesion	No association with RTP	51

*Refers to duplication of athletes from previous manuscript.
BIA, bioimpedance analysis; PA, phase angle; RTP, return to play; US, ultrasound.

date, there remains minimal pathological or prognostic validity to the majority of classification and grading systems utilised.

4. While it may be reasonable to classify and subclassify the nature of an injury, given our current understanding of the variable healing times of different tissues, and the range of tissues involved in even a simple 'muscle' injury, it seems unlikely that any categorical grading of muscle injury severity will accurately predict an individual's healing time. While the categorical grading of injury severity may have been a reasonable solution to a clinical challenge identified in the middle of the 20th century, it is time to recognise the complexity of muscle injury, and to develop appropriately powered research projects to answer appropriate questions.

In the future, a range of novel techniques may provide further clues as to the underlying injury and prognosis, including serological biomarkers of injury,[82] advanced MR imaging,[83 84] diffusion tensor imaging[85–87] and bio-impedance techniques.[70 88] Given the incidence of muscle injuries, there remain limited injuries being incorporated into formal study protocols, and as a result there remains much to be done. Understanding the history of muscle injury classification and grading provides a foundation for the development of appropriate questions.

What are the new findings?

- Classification and grading refer to distinct elements of muscle injury evaluation, but have been used interchangeably in the literature.
- Systems for clinical classification and grading have been present in the literature for over 100 years; in many ways, current approaches offer the clinician no more than did the first efforts.
- There is limited evidence to support either the pathological or prognostic validity of clinical and radiological grading systems.

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Supplementary Table One:

Chronology of publications pertaining to categorical classification and grading of muscle injury.

RTP = Return to play ROM = Range of motion MRI = Magnetic Resonance Imaging US = Ultrasound < = Less than > = Greater than DOMS = Delayed onset muscle soreness

Author	Publication	Classification / Grading Basis	Details	Cited Cases
Marsh H.(1)	Clinical lecture on Displacements and Injuries of Muscle and Tendons.	*Classification based on force application*	**External Injury** **Forcible contraction**	5
Crowley D.(2)	Suturing of Muscles and Tendons.	*Classification based on Force application and anatomical location of injured tissue*	**Internal** (Secondary to violent exertion) **External** (Secondary to Direct violence)	Nil
Heald C.(3)	Injuries and Sport.	*Classification based on anatomical location of injured tissue*	**Traumatic Periostitis** of Attachment: Sudden onset pain, at site of attachment; **Tendon-Muscle Strain**: Progressive increase in pain, weakness and discomfort with on-going activity; **Rupture of Muscle Belly**: Sudden onset muscle belly pain, swelling and bruising. Palpable muscle "trough"; Risk of recurrence	Nil
Gilcreest E.(4)	Ruptures and Tears of Muscles and Tendons of the Lower Extremity. Report of Fifteen Cases.	*Classification based on aetiology*	1. **Senility** 2. **Pathological Changes** 3. **Physiologic Predisposition** 4. **Occupation** 5. **Fatigue** 6. **Trauma**	15

Smart M.(5)	The Principles of Treatment of Muscles and Joints by Graduated Muscular Contractions	*Grading based on clinical appearance*	**Slight** **Severe**	Nil
McMaster P.(6)	Tendon and Muscle Ruptures. Clinical and experimental studies on the causes and location of subcutaneous ruptures.	*Classification based on mechanism*	**Direct** **Indirect**	6
		Grading based on clinical appearance	**Partial (incomplete) rupture** **Complete rupture**	
Haldeman K, Soto-Hall R.(7)	Injuries to Muscles and Tendons.	*Classification based on mechanism*	**Direct trauma** **Indirect trauma** **Spontaneous rupture** **Dislocation** of the tendons **Herniation** of a muscle through its sheath	104
Lloyd F, Deaver G, Eastwood F.(8)	Safety in Athletics. The Prevention and Treatment of Athletic Injuries	*Classification based on mechanism*	**Direct blow** **Indirect Force**	Nil
Thorndike A.(9)	Athletic Injuries: Prevention, Diagnosis and Treatment	*Classification based on anatomical location of injured tissue*	**Origin** **Tendon** **Muscle Belly**	375
		Grading based on clinical appearance	**Mild** **Severe**	
Jarvis W.(10)	A Medical Handbook for Athletic and Football Club Trainers	*Classification based on source of force application and presumed pathology*	**Contusion** **Myositis Ossificans** **Strain (rupture)**	Nil

Featherstone D.(11)	Sports Injuries	*Classification based on source of force application*	**Internal Force** **External Force**	9
		Grading based on pathological findings (theoretical)	**Slight** **Severe**	
Anzel S. et al.(12)	Disruption of Muscles and Tendons. An Analysis of 1,014 Cases	*Classification based on injury mechanism*	**Lacerating Injury** **Direct Injury** **Stress Injury** **Miscellaneous**	1014
Colsen J.(13)	Strapping and Bandaging for Football Injuries.	*Grading based on Theoretical pathology*	**Minor** **Severe**	Nil
Page E.(14)	Athletic Injuries and Their Treatment.	*Classification based on source of force application*	**Intrinsic** **Extrinsic**	Nil
		Classification based upon the location of injury	**Musculo-tendinous tear** **Periosteal Tear** **Ruptured Tendon** **Fascial Sheath Rupture** **Muscle Bruising**	
		Grading based on clinical appearance and theoretical pathology	**Mild** **Severe**	
Williams J.(15)	Sports Medicine	*Classification based on source of force application*	**Intrinsic** **Extrinsic**	45

		Grading based on clinical appearance and theoretical pathology	**Pull/Strain/Tear** **Complete Rupture**	
O'Donoghue D.(16)	Treatment of Injuries to Athletes	*Classification based on pathological nature of injury*	**Contusion** **Myositis Ossificans** **Muscle Strain** **Muscle Rupture**	
		Grading based on clinical appearance, theoretical pathology and management	**Simple Muscle Strain** **Violent Strain / Musculo-tendinous injury**	Nil
Tucker W. & Armstrong J.(17)	Injury in Sport: The Physiology, Prevention and Treatment of Injuries associated with Sport	*Classification mixed, based on nature of forces involved, anatomical location and "degree" of injury*	**Contusion (Superficial or Deep)** **Strain of muscle or tendon** **Rupture of a few fibres** **Partial rupture of muscle or tendon** **Avulsion of the tendon origin** **Acute tendonitis or tenovaginitis**	Nil
		Grading based on theoretical pathology	**Strain of muscle or tendon** **Rupture of a few fibres** **Partial rupture of muscle or tendon**	
Rachun A.(18)	Standard Nomenclature of Athletic Injuries	*Grading based on clinical appearance and theoretical pathology*	**First Degree Strain** (Mild Strain; slightly pulled muscle): Trauma to musculo-tendinous unit due to excessive force or stretch. Localised pain, aggravated by movement; Minor disability; Mild swelling, ecchymosis, local tenderness; Tendency to recur. Minimal haemorrhage, predominantly inflammation **Second Degree Strain** (Moderate Strain; Moderately pulled muscle): Mechanism as above. Localised pain, aggravated by movement. Moderate disability; Moderate swelling, ecchymosis, local tenderness. Stretching and tearing of fibres, without complete disruption; tendency to recurrence. **Third Degree Strain** (Severe Strain; Severely pulled muscle): Mechanism as above. Severe pain, and disability. Severe swelling, ecchymosis, haematoma, palpable defect and loss of muscle function. Muscle or tendon rupture, including musculo-tendon junction or bone avulsion.	Nil

Bass A.(19)	Rehabilitation after soft tissue trauma	*Classification based on observed clinical outcome and theoretical pathological nature of injury*	**Intra-muscular** **Extra-muscular**	72
		Classification based on anatomical location (presumed)	**Musculo-periosteal** **Musculo-tendinous** **Tendon** **Tendo-periosteal** **Muscular**	
Hirata I.(20)	The Doctor and the Athlete	*Classification based on clinical appearance*	**Contusion** **Strain** **Tear ("pull")** **Tight (hamstring)**	Nil
Ryan A.(21)	Quadriceps strain, rupture and charlie horse	*Grading based on clinical appearance and theoretical pathology*	**Grade I**: Crushing or tearing of a very small number of muscle cells; small amount of bleeding and localised muscle spasm; **Grade II**: Greater number of muscle cells crushed or torn. Fascia remains intact, with considerable bleeding and haematoma of liquid and blood. More severe pain and spasm with palpable tenderness **Grade III**: Greater muscle involvement, fascia partially torn; considerable bleeding and loss of range of motion; **Grade IV**: Complete rupture; Intense pain and swelling; complete disability	Nil
Wise D.(22)	Physiotherapeutic treatment of athletic injuries to the muscle-tendon complex of the leg	*Classification based upon Injury Mechanism*	**Contusion** **Strain**	Nil

		Grading based on clinical presentation	**Grade 1**: Minimal pain to palpation, well localised; <6mm difference in circumference; full pain free ROM; minimal pain on contraction with no loss of power and only mildly disturbed function. **Grade 2**: Substantial pain to palpation, poorly localised; 6-12mm difference in circumference, develops within 12-24 hours; 50% loss of ROM; considerable pain on contraction with considerable loss of power and greatly disturbed gait. **Grade 3**: Intractable pain to palpation, diffuse; >12mm difference in circumference, develops rapidly within one hour; [more than] 50% loss of ROM; severe pain on contraction with almost total loss of power with flicker contractions and cannot weight bear.	
Tietjen R.(23)	Closed Injuries of the Pectoralis Major Muscle	*Classification based on clinical appearance*	**Type I: Contusion/Sprain** **Type II: Partial** **Type III: Complete** **IIIa Muscle Origin** **IIIb Muscle Belly** **IIIc Musculo-tendinous Junction** **IIId Tendon**	3
Oakes B.(24)	Hamstring muscle injuries	*Grading based on clinical history and appearance*	**Grade 1**: Athlete notices a small moderately painful "pull", but can usually continue activity. Next day "quite sore" or "stiff", able to walk and slow jog up to "3/4 pace" before discomfort. Minimal limitation of straight leg raise. **Grade 2**: "twang" while sprinting and usually has to stop and limp. Aching after warming down and limping. Straight leg raise limited and painful. Tenderness and bruising may appear after 3-6 days, usually distally in popliteal fossa. Pain with active flexion or jogging. **Grade 3**: Near or complete rupture. "Explosion" of pain while sprinting with collapse in pain. Walking not possible, straight leg raise only to low angles still with pain.	Nil
Renstrom P.(25)	Muscle Injuries in Sports. In: Sports Medicine in Track and Field Athletics	*Classification based on anatomical location of injured tissue*	1. **Origin Bone/Periosteum** **2. Muscle** **3. Musculo-tendinous Junction** **4. Tendon/Aponeurosis** **5. Insertion**	Nil

		Grading based on clinical appearance and theoretical pathology	**1st Degree Strain;** **2nd Degree Strain;** **3rd Degree Strain (tear)**	
Safran M. et al(26)	Warm-Up and Muscular Injury Prevention: An Update	*Classification based on Clinical Presentation*	**Type I**: DOMS Muscle soreness that occurs 24-48 hours after unaccustomed vigorous exercise **Type II**: Acute disabling pain from a muscle tear **Type III**: Muscle soreness or cramp that occurs during or immediately after exercise	Nil
		Graded based on presumed pathology	**Grade 1 -4**: (As per Ryan 1969)	
De Smet A. et al.(27)	Magnetic resonance imaging of muscle tears	*Classification based on injury longevity*	**Acute tear**: Injury less than 2 weeks duration **Subacute Tear**: Injury 2-5 months duration **Chronic Tear**: Injury 1-3 years duration	17
Peetrons P & Creteur V.(28, 29)	Imagerie Des Parties Molles De L'Appareil	*Classification based on source of force application*	**Intrinsic** **Extrinsic**	
		Grading based on ultrasound imaging and clinical appearance	**Grade 0**: Sonographically Normal **Grade I**: Hypoechoic area, <15 mm in longest axis; <5% of muscle involved. **Grade II**: 5-50% muscle involvement. Partial Muscle Rupture. Sudden "snap" with intense localised pain. Demonstrable hypo or an-echoic gap, with "bell clapper" sign. Typically 5-6 weeks healing time. **Grade III**: Full thickness tear of muscle or fascia, with extravasation of collection away from injured part of muscle. Associated with severe pain	Nil
Pomeranz S, Heidt R Jr.(30)	MR imaging in the prognostication of hamstring injury. Work in progress	*Classification based on MRI Findings*	**Anatomical Location** (Tendon / Myotendinous / Superficial) **Presence of Oedema** **Haemorrhage**	14

		Grading based on MRI Findings	Extent of Muscle Involvement	
Takebayashi S, et al.(31)	Sonographic findings in muscle strain injury: Clinical and MR correlation	*Grading based on clinical findings*	**Grade One** (Mild Degree) **Grade Two** (Moderate Degree) **Grade Three** (Severe Degree)	57
		Grading based on US findings	**Grade One**: Normal **Grade Two**: Hyperechoic infiltration **Grade Three**: Mass observed **Grade Four**: Compound lesion of hyperechoic infiltration and mass	
		Grading based on US / MRI lesion size	**Small:** < 20% cross sectional area **Moderate:** 20-50% cross sectional area **Large:** > 50% cross sectional area	
Rubin S. et al.(32)	Magnetic Resonance Imaging of Muscle Injury	*Classification based on source of force application*	**Penetrating and blunt trauma** Lacerations Contusions) **Exertion related** Muscle strains Overuse syndromes DOMS	8
		Grading based on clinical and MRI appearance	**Grade I**: Minimal tearing of muscle fibres, without weakness **Grade II**: Partial separation of muscle from tendon or fascia; weakness **Grade III**: Complete separation of musculo-tendinous unit; significant lack of function	
Connell D. et al.(33)	Injuries of the Pectoralis Major Muscle: Evaluation with MR Imaging	*Classification based on MRI findings of anatomical location and surgical confirmation*	**Tendon-bone interface** **Tendon** **Musculo-tendinous junction** **Muscle**	15
		Grading based on MRI findings with or without surgical confirmation	**Partial "Low":** < 30% muscle fibres **Moderate:** 30-70% muscle fibres **High:** >70% muscle fibres; Complete	

De Smet A, Best T.(34)	MR Imaging of the Distribution and Location of Acute Hamstring Injuries in Athletes	*Classification based on MRI findings of anatomical location*	**Muscle involved** **Musculo-tendinous Junction** **Proximal** **Proximal intra-muscular** **Distal intra-muscular** **Distal**	15
Jarvinen T, et al.(35)	Muscle Strain Injuries	*Classification based on pathological (imaging) nature of haematoma collection*	**1. Intra-muscular Haematoma**: Intact muscle fascia limits the size of the haematoma. Pain (due to increased pressure) and loss of function; **2. Inter-muscular Haematoma**: Rupture of the muscle fascia, with blood spreading to inter-muscular spaces. Not as much pain as intra-muscular.	Nil
		Grading based on clinical appearance and theoretical pathology	**Mild (first degree) strain:** Tear of a few muscle fibres; minor swelling and discomfort, with no or minimal loss of strength and restriction of movements. **Moderate (second degree) strain**: Greater damage of muscle with a clear loss of strength. **Severe (third degree) strain:** Tear extending across the whole muscle belly, with a total loss of function.	
Carrino J, et al.(36)	Pectoralis major muscle and tendon tears: diagnosis and grading using MRI	*Classification based on Radiological appearance*	**Subacute:** Presence of oedema or haemorrhage (at the enthesis or myotendinous junction), reflecting intra- or extra- cellular methemoglobin. **Chronic:** Absence of a substantial amount of oedema and/or haemorrhage, or muscle atrophy present.	10
		Grading based on radiological findings and Surgical outcome	**Partial Tear:** Fluid or haemorrhage at the interface (enthesis or myotendinous junction) but without substantial retraction or complete discontinuity **Complete Tear:** Discontinuity with or without retraction of either the tendon at the enthesis or the muscle at the myotendinous junction.	
Verrall G, et al.(37)	Clinical risk factors for hamstring muscle strain injury: a prospective study with correlation of injury by magnetic resonance imaging	*Classification based on MRI findings*	**MRI Positive** **MRI Negative**	32

Slavotinek J, et al.(38)	Hamstring Injury in Athletes: Using MR Imaging Measurements to Compare Extent of Muscle Injury with Amount of Time Lost from Competition	*Classification based on MRI findings*	**MRI Positive** **MRI Negative**	37
		Classification based on MRI location	**Proximal Hamstring** **Distal Hamstring**	
		Grading based on MRI findings	**< 50% muscle involved** **> 50% muscle involved**	
Verrall G, et al.(39)	Diagnostic and prognostic value of clinical findings in 83 athletes with posterior thigh injury	*Classification based on clinical location of injury*	**Upper** **Middle** **Lower** (third of hamstring)	83
		Classification based on MRI findings	**MRI Positive** **MRI Negative**	
Stoller D, et al.(40)	Diagnostic Imaging Orthopaedics	*Grading based on clinical findings, US and MRI Imaging*	**Rectus Femoris:** **First-degree**: small area muscle involved without loss of function **Second-degree**: partial tear musculo-tendinous unit +/- mass or hematoma **Third-degree**: complete tear musculo-tendinous unit +/- mass or palpable defect +/- retraction of mass or detached muscle segment **3B** = avulsion fracture from origin or insertion	Nil
Blankenbaker D, De Smet A.(41)	MR Imaging of muscle injuries	*Classification based on source of force application*	**Direct** Contusion Laceration) **Indirect** strain / tear	Nil

		Grade based on clinical and MRI appearance	**Grade 1**: Minor degree of microscopic tearing with no permanent defect; MRI: Intramuscular high signal on T2 images without disruption of muscle fibers; peri-fascial fluid tracking along the inter-muscular region. **Grade 2**: Partial tear; Incomplete disruption of muscle fibres MRI: myotendinous junction partially torn. Tendon fibres irregular and thinned with mild laxity. Muscle oedema and hemorrhage with extension along the fascial planes between muscle groups. Haematoma at myotendinous junction. **Grade 3**: Complete rupture of muscle with loss of muscle function, retraction, spasm, shortening of muscle. MRI: Complete disruption of the myotendinous junction. Extensive oedema and hemorrhage.	
Lee J. & Healey J.(42)	Sonography of lower limb muscle injury	*Classification based on injury mechanism and underlying pathology*	**Contusion** **Strain** **Delayed onset muscle soreness** **Muscle Hernia** **Myositis Ossificans**	Nil
		Grading based on clinical and US image findings	**Grade I Muscle Strain**: Stiffness, soreness. US: Normal, or focal/general areas of increased echogenicity. +/- peri-fascial fluid. Low risk of tear extension; "heal" within 2 weeks **Grade II Muscle Strain**: Intra-substance tears; Pain, loss of function. US: Discontinuity of muscle fibres in echogenic perimysial striae. Hyper-vascularity around disrupted muscle fibres. Intramuscular fluid collection. Partial detachment of adjacent fascia or aponeurosis. Risk of extension of injury. Recovery approximately 4 weeks. **Grade III Muscle Strain**: US: Complete myotendinous or tendo-osseous avulsion. Complete discontinuity of muscle fibres and associated haematoma. "Clapper in Bell" sign.	
Connell D, et al.(43)	Longitudinal Study Comparing Sonographic and MRI Assessments of Acute and Healing Hamstring Injuries	*Classification based on MRI findings*	**MRI Positive** **MRI Negative**	60
		Classification based on MRI anatomical diagnosis	**Muscle with most involvement** **More than one muscle** **Musculo-tendinous junction** **Myofascial**	

			Tendon at bone	
		Graded based on inter-muscular haematoma	**Inter-muscular haematoma:** **Absent** **Mild** (< 2cm2) **Moderate** (<6 cm2) **Large** (>6 cm2) **Absorbed**	
Gibbs N, et al.(44)	The accuracy of MRI in predicting recovery and recurrence of acute grade one hamstring muscle strains within the same season in Australian Rules Football players	*Classification based on MRI findings*	**MRI Positive;** **MRI Negative**	31
		Classification based on MRI determined number of muscles involved	**Single muscle** **More than one muscle**	
		Grading based on clinical findings	**Grade One:** Sudden onset pain posterior thigh; localised tenderness in hamstring; localised pain on straight leg raise; pain with resisted prone knee flexion; no loss of continuity, bruising or swelling.	
Cross T. et al.(45)	Acute Quadriceps Muscle Strains: Magnetic Resonance Imaging Features and Prognosis	*Classification based on MRI anatomical findings*	**Location One:** Proximal / Middle **Location Two**: Rectus Femoris Central Tendon / Rectus Femoris Peripheral / Vasti	60
		Grading based on MRI Size	**Length of injury** 1-7 cm 8-12 cm ≥ 13 cm) **Cross-sectional area** 1-14% 15-24% ≥25%)	

Rehman A, Robinson P.(46)	Sonographic evaluation of injuries to the Pectoralis Muscles	*Classification based on US Imaging determined anatomical location*	**Origin** **Peripheral** (aponeurotic) **Myotendinous Junction** **Enthesis**	5
		Graded based on extent of imaging determined muscle involvement	**Grade 1:** < 5% of muscle involved **Grade 2**(partial tear): > 5% of muscle involved; **Grade 3**: Complete tear	
Askling C, et al.(47-50)	Type of acute hamstring strain affects flexibility, strength, and time to return to pre-injury level	*Classification based on MRI determined injury location (hamstring)*	**Proximal Tendon** **Proximal muscle tendon junction** **Proximal muscle belly** **Distal muscle tendon junction** **Distal muscle belly** **Distal Tendon**	63
	Acute First-Time Hamstring Strains During High-Speed Running	*Classification (and prognostic grading) based on mechanism of injury and MRI findings*	**Stretching type** **High speed running type**	
	Acute First-Time Hamstring Strains During Slow-Speed Stretching			
	Proximal Hamstring Strains of Stretching Type in Different Sport			
Schneider-Kolsky M, et al.(51)	A Comparison Between Clinical Assessment and Magnetic Resonance Imaging of Acute Hamstring Injuries	*Classification based on imaging diagnosed site of injury*	**Biceps** **Not biceps**	58
		Grade based on clinical findings	**Grade One:** i) No Pain / < 10 degrees ROM deficit ii) Mild Pain / < 10 degrees ROM deficit **Grade Two:** i) Moderate pain / 10-25 degrees ROM deficit ii) Moderate pain / >25 degrees ROM deficit	

			Grade Three: Severe pain / >25 degrees ROM deficit +/- palpable gap	
		Grade based on MRI Lesion Size	**Length coronal view** No injury < 60mm < **Diameter axial view** No injury < 10% <	
Verrall G, et al.(52)	Assessment of Physical Examination and Magnetic Resonance Imaging Findings of Hamstring Injury as Predictors for Recurrent Injury	*Grade based on MRI Lesion Size*	**MRI transverse size** Greater or less than 55% **MRI volume** Greater or less than 21 cm^3	37
Maquirriain J, et al.(53)	Rectus Abdominus Strains in Tennis Players	*Grading (Rectus Abdominus) based on Clinical appearance*	**Slight to mild**: No pain with sit up or isometric Valsalva **Moderate:** Painful trunk ''sit-up'' motion **Severe:** Painful isometric contraction (Valsalva) and simple overhead reaching	21
Koulouris G, et al.(54)	MRI parameters for assessing risk of recurrent hamstring injuries in elite athletes	*Grading based on MRI lesion size*	**Injury length** <60 cm >60cm	31
Wood D, et al.(55)	Avulsion of the proximal hamstring origin	*Classification (Hamstring Origin Injury) based upon anatomical location and imaging*	**Type 1:** Osseous avulsions **Type 2:** Avulsion at the musculo-tendinous junction **Type 3**: Incomplete tendon avulsions from the bone **Type 4:** Complete tendon avulsions with little or no retraction **Type 5:** Complete tendon avulsions with retraction **Type 5a:** No Sciatic nerve involvement **Type 5b:** Sciatic nerve tethering	72

Gyftopoulos S, et al.(56)	Normal Anatomy and Strains of the Deep Musculotendinous Junction of the Proximal Rectus Femoris: MRI Features	*Grading based upon MRI findings*	**Grade I Tear:** Focal or diffuse high signal intensity at the musculo-tendinous junction. Feathery appearance to the muscle on all pulse sequences. Musculo-tendinous junction intact. **Grade II Tear:** Partial disruption of the musculo-tendinous junction with interstitial feathery high signal or hematoma. Low signal in chronic or old injuries **Grade III Tear:** Complete musculo-tendinous disruption with or without retraction.	20
Guerrero M, et al.(57)	Fast and slow myosins as markers of muscle injury	*Grading based upon clinical findings*	**Grade I:** Delayed onset muscle soreness and elongation, very small muscle tear. **Grade II**: Fibrillar disruption, moderate muscle tear. **Grade III:** Fibre disruption, evident muscle tear.	
		Grading based upon MRI/US findings	**Grade I:** US: Haematic suffusion and defect of some fibres 2-3 days after injury. MRI: Oedema from initial injury. **Grade II:** Oedema and fibrillar defects; **Grade III:** Greater defect associated with haematoma.	36
Balius R, et al.(58)	Central aponeurosis tears of the rectus femoris: practical sonographic prognosis	*Grading based on US findings*	**Modified Peetrons** US Grades I-III No grade 0 and grade III injuries excluded. **Proximal** **Distal**	35
Hancock C, et al.(59)	Flexor femoris muscle complex: grading systems used to describe the complete spectrum of injury	*Grading based on clinical appearance, MRI findings and theoretical pathology*	**Grade I Muscle Strain**: Microscopic tears of muscle fibres most commonly at the musculo-tendinous junction, more often proximally. Feathery appearance on fluid sensitive MR sequences. Typically heal well with RICE [rest, ice, compression, elevation]. **Grade II Partial muscle tear**: Partial macroscopic muscle fibre disruption. Focal fluid signal intensity collections within the muscle. Weeks to months to heal. **Grade III Complete muscle tear:** Disruption of the myotendinous unit, with retraction and a gap between the torn ends. Surgical intervention may be required.	Nil

Dixon J.(60)	Gastrocnemius vs. soleus strain: how to differentiate and deal with calf muscle injuries	*Grading based on clinical appearance, MRI findings and theoretical pathology*	**Grade 1 / 1st Degree/Mild:** Sharp pain at time of injury or pain with activity; Usually able to continue activity; Mild pain and localized tenderness. No or minimal loss of strength and ROM. Mild Spasm and swelling; <10% muscle fibre disruption; Bright signal on fluid-sensitive sequences. Feathery appearance, **Grade 2 / 2nd Degree / Moderate:** Unable to continue activity; clear loss of strength and ROM; >10-50% disruption of muscle fibres; Oedema and haemorrhage. **Grade 3 / 3rd Degree / Severe:** Immediate severe pain, disability; Complete loss of muscle function. Palpable defect or mass. Possible positive "thompsons" test (for calf); 5-100% disruption of muscle fibres; Complete disruption and discontinuity of muscle. Extensive edema and haemorrhage. Wavy tendon morphology and retraction.	Nil
Rodas et al.(61)	Clinical Practice Guide for muscular injuries. Epidemiology, diagnosis, treatment and prevention	*Classification based on injury mechanism and underlying pathology*	**Extrinsic:** Contusion/laceration Light/benign (grade I); Moderate (grade II); Serious (grade III)); **Intrinsic**	175
		Grading based on presumed histopathology	**Grade 0 (Contraction and / or DOMS):** Functional alteration; elevation of enzymes. Adaptive. **Grade I (Small fibrillar strain and / or muscular elongation):** Alterations of few fibres and connective tissue. **Grade II (fibrillar strain):** More affected fibres and connective tissue, with haematoma. **Grade III (Muscular strain):** Major strain or complete displacement. Loss of function.	
		Grading based on ultrasound findings	**Grade 0 (Contraction and / or DOMS):** Inconsistent. Oedema between fibres and myofascial; increased vascularity. **Grade I (Small fibrillar strain and / or muscular elongation):** Minimal discontinuity, oedema between inter-fascial fibres and fluid. **Grade II (Fibrillar strain):** Clear defect. Inter-fascial fluid and haematoma. **Grade III (Muscular strain):** Complete muscular disruption with retraction.	

		Grading based on MRI findings	**Grade 0 (Contraction and / or DOMS):** Interstitial and inter-muscular oedema. **Grade I (Small fibrillar strain and / or muscular elongation):** Increased interstitial and inter-muscular signal. **Grade II (fibrillar strain):** Strong signal, focal muscular defect, increase in the signal surrounding the tendon. **Grade III (Muscular strain):** Complete muscle and/or tendon strain with retraction.	
Malliaropoulos N, et al.(62, 63)	Posterior Thigh Muscle Injuries in Elite Track and Field Athletes	*Classified according to muscle and location*	**Proximal tendon** **Musculo-tendinous junction** **Myofascial** **Distal tendon**	165
	Re-injury After Acute Posterior Thigh Muscle Injuries in Elite Track and Field Athletes	*Grading based on US appearance (as per Peetrons 2002)*	**Grade 0:** Normal US appearance. **Grade 1:** Subtle US findings, ill-defined hyperechoic or hypoechoic intramuscular area or a swollen aponeurosis. **Grade 2:** Partial muscle tear. **Grade 3:** Complete muscle tear.	
		Grading based on Clinical Examination	**Active Range of Motion (AROM) Deficit** **Grade 1:** Deficit < 10 degrees **Grade 2:** Deficit 10-19 degrees **Grade 3:** Deficit 20-29 degrees **Grade 4:** Deficit >30 degrees	
Cohen S, et al.(64)	Hamstring Injuries in Professional Football Players: Magnetic Resonance Imaging Correlation With Return To Play	*Grading (Sum of points, 1-3 points per finding) based on MRI Appearance*	**Number of muscles involved** 0 = 0 muscles 1 = 1 muscle 2 = 2 muscles; 3 = 3 muscles **Location** 1 = Proximal 2 = middle 3 = distal **Insertion** Yes = 2 No = 0) **Cross sectional percentage of muscle or tendon involvement** 0 = 0% 1 = 25%	43

			2 = 50% 3 = ≥75% **Retraction** 0 = no retraction 1 = < 2cm retraction 2 = > 2cm retraction **Longitudinal axis involvement** 0 = 0 cm 1 = 1-5 cm 2 = 6-10 cm 3 = > 10cm)	
		Grading (traditional) based on MRI appearance	**Grade I:** T2 hyper-intense signal about a tendon or muscle without visible disruption of fibres **Grade II:** T2 hyper-intense signal around and within a tendon or muscle with fibre disruption spanning less than half the tendon or muscle width **Grade III**: Disruption of muscle or tendon fibres over more than half the muscle or tendon width	
Ekstrand J, et al.(65)	Hamstring muscle injuries in professional football: the correlation of MRI findings with return to play	*Grading based on MRI appearance*	**Grade 0:** Negative MRI without any visible pathology **Grade 1:** Oedema but no architectural distortion **Grade 2:** Architectural disruption indicating partial tear **Grade 3:** Total muscle or tendon rupture	207
Comin J, et al.(66)	Return to Competitive Play After Hamstring Injuries Involving Disruption of the Central Tendon	*Classification based on MRI determined tendon involvement (Hamstring only)*	**Central tendon disruption Central tendon intact**	62
Chan O, et al.(67)	Acute muscle strain injuries: a proposed new classification system	*Classified based on MRI determined anatomical location*	**Proximal MTJ** **Muscle** **a) proximal** **b) middle** **c) distal** **Distal MTJ**	Nil
		Sub-classified based on anatomical structures	**a.Intra-muscular** **b.Myofascial** **c. Myofascial/perifascial** **d. Myotendinous**	

			e. Combined	
		Graded (Muscle) based on MRI and US appearance	**Grade I (strain):** MRI: Less than 5% of fibre disruption; feathery oedema, intramuscular high signal on fluid-sensitive sequences. US: Normal appearance, focal or general increased echogenicity with no architectural distortion. **Grade II (Partial tear):** MRI: Oedema and haemorrhage of the muscle or musculotendinous junction, may extend along fascial planes between muscle groups. Fibres, disorganised and thin, surrounded by haematoma and perifascial fluid. US: Discontinuous muscle fibres, disruption site is hyper-vascularised and altered in echogenicity, no perimyseal striation adjacent to the MTJ. **Grade III (Complete tear):** MRI: Complete discontinuity of muscle fibres, haematoma and retraction of the muscle ends. US: Comparable with MRI.	Nil
Lee J, et al.(68)	Imaging of muscle injury in the elite athlete	*Classification based on mechanism of injury*	**Direct injury** **Indirect injury** Excessive eccentric load	Nil
		Grading based on clinical appearance	**Grade I (stretch injury):** Small tear, < 5% loss of function **Grade II (partial tear):** Larger tear, 5-50% loss of function **Grade III (complete tear):** >50% loss of function	
		Grading based on US findings	Modified "Peetrons"	
		Grading based on MRI findings	**Grade I Strain:** Increased signal on fluid sensitive fat suppressed sequences, feathery pattern. No significant disruption of muscle architecture (<5% cross sectional area). Perifascial fluid may be seen. **Grade II Strain:** Distortion of normal muscle architecture. Haematoma formation at the musculo-tendinous junction. Feathery muscle oedema. May be laxity of the central tendon within the muscle. **Grade III Strain:** Complete disruption of the musculo-tendinous unit with haematoma **Grade IIIb:** Bony avulsion. **Delayed onset muscle soreness**: Clinically distinct presentation, similar MRI to grade I injury, typically affecting more than one muscle.	

Mueller-Wohlfahrt H-W, et al.(69)	Terminology and classification of muscle injuries in sport: The Munich consensus statement	*Classification based on underlying pathology, mechanism of injury, imaging and clinical findings.*	**Indirect Muscle Disorder/Injury**: **Functional Muscle Injury** **Type 1: Overexertion related muscle disorder** **1A:** Fatigue induced muscle disorder **1B**: Delayed onset muscle soreness **Type 2: Neuromuscular muscle disorder** **2A:** Spine related neuromuscular Muscle Disorder **2B:** Muscle-related neuromuscular Muscle disorder **Indirect Muscle Disorder/Injury:** **Structural Muscle Injury** **Type 3:** Partial Muscle Tear **Type 4:** (Sub) total Muscle Tear); **Direct Muscle Injury** **Laceration** **Contusion**	*393*
Ekstrand J, et al.(70)	Return to play after thigh muscle injury in elite football players: implementation and validation of the Munich muscle injury classification	*Grading based on underlying pathology, imaging and clinical findings.*	**Type 3A:** Minor partial muscle Tear **Type 3B:** Moderate partial muscle tear **Type 4:** Subtotal; Complete muscle tear	
Peterson et al.(71)	The Diagnostic and Prognostic Value of Ultrasonography in Soccer Players With Acute Hamstring Injuries	*Description based on US finding*	**Positive** **Negative**	51
Pollock et al. (72)	British athletics muscle injury classification: A new grading system	*Grading based on Clinical and Radiological findings.*	**Grade 0a:** Focal neuromuscular injury; Normal MRI. **Grade 0b:** Generalised muscle soreness. MRI normal or consistent with DOMS. (+N = neural component). **Grade 1:** Small "tears". Pain during or after activity. Normal ROM at 24 hours, but pain with contraction. Normal strength and normal tendon on MRI. No muscle fibre disruption. **1a:** Injury extends from Fascia. < 10% cross section area. < 5cm Longitudinal length. Inter-muscular haematoma may be present. **1b:** Intra-muscular or musculotendon Junction involvement. <10% cross	0

			sectional area <5cm longitudinal length. **Grade 2:** Moderate "tears". Pain during activity requiring cessation. Limited ROM at 24 hours and reduced strength. Less than 5cm fibre disruption. **2a:** Injury extends from peripheral fascia into muscle. 10-50% cross sectional area. 5-15 cm length. **2b:** Intramuscular or musculo-tendon junction injury. 10-50% cross sectional area. 5-15 cm length. **2c:** Injury extends into tendon but < 5cm longitudinal involvement; < 50% cross sectional area of tendon involved. **Grade 3:** Extensive tear to muscle. Sudden pain; falls to ground. Significant loss of ROM and pain walking at 24 hours. **3a:** Myofascial: >50% cross sectional area. >15 cm longitudinal involvement. >5cm fibre disruption. **3b:** Muscular / Myotendinous: >50% cross sectional area. >15 cm longitudinal involvement. >5cm fibre disruption. **3c:** Intra-tendinous: tendon involvement > 5cm or > 50% of tendon cross sectional area. **Grade 4:** Complete tears. Sudden onset of pain and limitation of activity. Palpable gap. May be less pain on contraction than in Grade 3 injury. **4:** Muscle **4c:** Tendon	

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