London International Consensus and Delphi study on Hamstring Injuries Part 1: Classification

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Key words

Hamstring, classification, muscle, injury, consensus, Delphi, imaging

Data availability statement

Data are available on reasonable request. The datasets generated during and/or analysed during the current study are available from the corresponding author on reasonable request

Acknowledgements and funding

We would like to thank the large number of hamstring experts who contributed their time and effort in completing our surveys,

The consensus process and meeting were co-created and funded by the Institute of Sport Exercise and Health, London, UK and the Academic Centre for Evidence Based Sports Medicine, Amsterdam, NL

The consensus and the launch of PHAROS were partly made possible by a grant from the International Olympic Committee (IOC).

Thanks also to Naomi Shah PT (India) and Magnus Hilmarsson PT (Iceland) who assisted with meeting days

Competing interests

No member of the group reported competing interests in this study. No group member or participant received financial remuneration, and study was carried out independent of funding bodies and they did not influence the design, conduct, or results of the study

Contributorship

This manuscript is the combined effort of the attached Authors.

Bruce Paton drafted the initial manuscript. Noel Pollock and Nicol Van Dyk, and Matthew Wilson contributed significant drafting comments and edits. Other authors were responsible for minor edits. BP, FSH, JM were responsible for research and survey design and facilitating the consensus meeting days

Ethical approval information

UCL Research Ethics Committee Office for The Vice Provost Research-

Approved Project ID: 5938/002 - Title: Decision-Making in the Assessment and treatment of Hamstring Injury

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Patient involvement

This study did not involve patients but sought expert opinion regarding best practice in management of hamstring Injury

Word Count

6058 Words (Excluding title page, abstract, tables, figures, references)

References 95

Key Points

1. While classification systems exist for hamstring injuries (HSI) and encompass anatomical and imaging criteria, current classification systems are not specific to individual (hamstring) muscles.

2. Classification systems have evolved to include the specific anatomical tissue (i.e., muscle, myotendinous, tendon) as well as severity of injury gradings, and some include the mechanism of injury and athlete factors.

3. Clinicians most commonly use the British Athletics Muscle Injury Classification (BAMIC) system, with Munich and Barcelona systems also used for the classification of HSI.

4. This expert panel recommends Magnetic resonance imaging (MRI) as the imaging of choice for diagnosis with few panellists prioritising diagnostic ultrasound. Neither modality is recommended as a means of monitoring rehab progression or deciding on readiness to return to sport.

5. Experts agree classification systems for HSI should evolve to include parameters around: individual hamstring muscles, intramuscular injuries, mechanism of injury, sporting demand, functional criteria, and patient reported outcome measures (PROMS).

6. There is a need for more research into criteria that determine the need for surgical intervention

7. There is a need for more research into the effectiveness of classification systems to prognosticate and guide treatment decision-making

Abstract

Introduction: Muscle injury classification systems for hamstring injuries have evolved to use anatomy and imaging information to aid management and prognosis. However, classification systems lack reliability and validity data and are not specific to individual hamstring muscles, potentially missing parameters vital for sport and activity-specific decision-making.

Methods: A narrative evidence review was conducted followed by a modified Delphi study to build an international consensus on best-practice decision-making for the classification of hamstring injuries. This comprised a digital information gathering survey to a cohort of 46 international hamstring experts (sports medicine physicians, physiotherapists, surgeons, trainers and sports scientists) who were also invited to a face-to-face consensus group meeting in London . Fifteen of these expert clinicians attended to synthesise and refine statements around the management of hamstring injury. A 2nd digital survey was sent to a wider group of 112 international experts. Acceptance was set at 70% agreement.

Results: Round one and two survey response rates were 35/46 (76 %) and 99/112 (88.4%) of experts responding. Most commonly experts used the British Athletics Muscle Injury Classification (BAMIC) (58%), Munich (12%) and Barcelona (6%) classification systems for hamstring injury. Issues identified to advance imaging classifications systems include: detailing individual hamstring muscles, establishing optimal use of imaging in diagnosis and classification, and testing the validity and reliability of classification systems.

Conclusions: The most utilized hamstring injury classification system is the BAMIC. This consensus panel recommends hamstring injury classification systems evolve to integrate imaging and clinical parameters around: individual muscles, injury mechanism, sporting demand, functional criteria, and patient reported outcome measures (PROMS). More research

is needed on surgical referral and effectiveness criteria, and validity and reliability of classification systems to guide management.

BACKGROUND

Hamstring injuries (HSI) continue to cause significant time lost from high intensity running sports, despite an exponential growth in research on HSI prevention and management. The role of HSI classification and how this might guide management is of interest but currently unclear. The main purpose of HSI classification systems is to categorise and grade the severity of an injury[1], to aid communication and enhance clinical decision making. We present an evidence review to outline our current understanding of HSI classification systems and identify knowledge gaps, followed by an international expert Delphi study to advance the classification of HSI.

Muscle injury classification systems

There are multiple, differing muscle injury classification systems.[2-7] Anatomy is key to most systems[3 5 7 8] and most use some form of imaging (particularly magnetic resonance imaging (MRI) and ultrasound (US)).[4 5 9 10] There is a high incidence of MRI negative HSI, from 17%-31%[10-13], and many systems incorporate a grade 0 for HSI with negative imaging.[2-4 9 14] Some classifications use components of subjective and objective examination or function[12 15-17], which may associate with time to return to sport following HSI.[12 18 19] Several reviews on classification systems in muscle injury are available.[1 20-25] None of these systems are specific to individual hamstring muscles but the specific muscles have anatomical and functional differences that are relevant in management.[26] While early classification systems for muscle injuries traditionally followed a severity of injury approach (i.e. grading system)[2 15 16 27 28], they have evolved to also consider the anatomical tissue involved (i.e. fascia / muscle vs. tendon and connective tissue)[3 14], and the mechanism of injury[2 14] [table 1].

Table 1 Classification systems- abbreviated from supplementary material

Based On	Author	G0	G1	GII	GIII	GIV
Clinical Signs	**Odonoghue**		no appreciable tissue tear	Tissue Damage and reduced strength of the Muscle tendon unit	Complete tear of the muscle tendon unit and complete loss of function	
	Ryan		tear of a very small number of fibres with Fascia remaining intact	tear of a higher number of fibres, fascia still remains intact	greater number of muscle fibres involved. The muscular fascia is at least partially torn	Completed tear of the muscle belly and fascia rupture
	Wise		min pain to palpation, localised	substantial TOP, poorly localised, 6-12mm change in circumference, develops 12-24hr <50% loss of ROM, pain on contraction, loss of power, disturbed gait	Intractable TOP, diffuse, develops in 1 hr, >50% loss ROM, severe pain on contraction, almost complete loss of power, unable to WB	
	Rachun		localised pain, min swelling, bruising, minor disability	local pain +TOP, moderate bruising + disability, stretching tearing fibres without disruption	Severe pain + swelling disability, severe haematoma, loss of function, palpable defect	
Imaging	**Takebyashi**		no abnormalities or diffuse bleeding with or without local fibre rupture (less than 5% of the muscle involved)	focal fibre rupture - more than 5% of the muscle involved, with or without fascial injury	complete muscle rupture with retraction, fascial injury is present	
	Peetrons	lack of US lesion	minimal elongation with less than 5% of muscle involved - hypoechoic area	lesions involving from 5-50% of the muscle volume or cross-sectional diameter	complete muscle tears with complete retraction	
	Lee		normal or focal/general areas of increased echogenicity =/- peri fascial fluid	discontinuity of muscle fibres in echogenic perimysal strae. Hypervascularity around disrupted muscle fibres. Intramuscular fluid collection, partial detachment of adjacent fascia or aponeurosis	complete myotendinous or tendon-osseous avulsion, complete discontinuity of muscle fibres and associated haematoma. Bell clapper sign	
	Chan (ISmULT)		normal appearance. Focal or general increased echogenicity with no architectural distortion	discontinuous muscle fibres. Disruption site is hyper-vasculised and altered in echogenicity. No perimysal striation adjacent to the MTJ	complete discontinuity of muscle fibres. Haematoma and retraction of the muscle ends	proximal MTJ / muscle proximal/ middle distal/ distal MTJ+ intramuscular - myotendionous
	Schneider-Kolsky		<10 degrees ROM deficit	10-25 degrees ROM deficit	>25% ROM deficit	
	Stoller		hyperintense oedema +/- haemorrhage with preservation of the muscle morphology.	hyperintense haemorrhage with tearing of up to 50% of muscle fibres. Interstitial hyperintensity with focal hyperintensity	Complete tearing +/- muscle retraction. Hyperintense fluid filled gap + hyperintense on FSPDFSE +	

			Oedema pattern = interstitial hyperintensity and feathery distribution on FSPD or T2FSE + STIR images hyperintense subcutaneous tissue oedema + intermuscular fluid	representing haemorrhage in the muscle belly +/- intramuscular fluid. Hyperintense focal defect + partial retraction of muscle fibres. associated myotendinous + tendinous injuries. Hyperintensity + interruption +/- widening of muscle - tendon Unit	STIR. Associated adjacent hyperintense interstitial muscle changes	
Mixed	**Cohen**	point grading score - Age/ muscles/ location/ cross sectional area / retraction/ longitudinal axis T2 signal length				
	Munich	indirect	Functional muscle disorder (consider neuromeningeal) - negative imaging findings			
			structural muscle injury: Grading on US/ MRI classification System			
		direct muscle injury				
	BAMIC	negative imaging findings	<10% cross sectional area	10-50% cross sectional areas - 5-15 cm	> 50% cross sectional area >15xm (tendon >5cm)	complete rupture
		myofascial tear (4 grades) incorporating cranio-caudal length and cross-sectional area for grading - Small / moderate/ extensive / complete				
		Muscle Tendon Junction tear (4 grades) incorporating cranio-caudal length and cross-sectional area for grading				
		Intra-tendinous tear (3-4 grades) incorporating cranio-caudal length and cross-sectional area for grading				
	Barcelona - (MLG-R) mechanism of injury / Location - muscle / Grade / previous injury	negative MRI but clinical suspicion	Hyperintense muscle fibre oedema without intramuscular haemorrhage or architectural distortion (fibre architecture and pennation angle preserved). Oedema pattern: interstitial hyperintensity with feathery distribution on FSPD or T2 FSE? STIR images	Hyperintense muscle fibre and/or peritendon oedema with minor muscle fibre architectural distortion (fibre blurring and/or pennation angle distortion) ± minor intermuscular haemorrhage, but no quantifiable gap between fibres. Oedema pattern, same as for grade 1	Any quantifiable gap between fibres in craniocaudal or axial planes. Hyperintense focal defect with partial retraction of muscle fibres ± intermuscular haemorrhage. The gap between fibres at the injury's maximal area in an axial plane of the affected muscle belly should be documented. The exact % CSA should be documented as a sub-index to the grade	
		mechanism of injury	direct / indirect / stretch or sprint			
		Location	Location of lesion - proximal / middle / Distal			
		Extracellular matrix	When codifying an intra-tendon injury or an injury affecting the MTJ or intramuscular tendon showing disruption/retraction or loss of tension exist (gap), a superscript (r) should be added to the grade			
Surgical	**Wood**	Proximal Hamstring attachment rupture based on		MTJ vs Tendon injury / avulsion - bony vs tendon/avulsion- partial vs complete/ retraction distance/ sciatic nerve involvement		
	Lampainen			number of tendons involved (1-3) / level of athlete(demand)/ level of symptoms (pain + function)		

MTJ – myotendinous junction, CSA – Cross sectional area, ROM- range of motion, TOP- tender on palpation, FSPD- fat-suppressed proton density, STIR- short tau inversion recovery, FSE- Fast spin echo, US- ultrasound

Limitations of current muscle classification systems

These classification evolutions have assisted clinicians in planning management and prognostication. Different anatomical tissues have different healing time frames and load capacity, resulting in differences in optimal rehabilitation prescription, progression, readiness to return to sport[29], and risk of reinjury.[30] Current muscle injury classification systems are generic and do not differentiate between muscles, even though muscles have different anatomy and architecture. Intramuscular connective tissue and MTJ architecture, for example, differ considerably between hamstring muscles and within individuals.[31 32] The individual hamstring muscles have different roles[33], even within components of a single movement.[34] Clinicians should consider these factors when prescribing rehabilitation as the management of an injury with the same classification, within a different hamstring muscle, may require individualised management to optimise outcome. Anatomical architectural considerations, including loss of tension, anatomical displacement and sciatic nerve involvement may also be important in surgical decision-making. HSI classification systems may benefit from considering muscle-specific differences in anatomy, function or injury pattern when assessing validity, outcomes and in the further evolution of classification systems.[20 23]

Reliability and validity of classification systems

Many classification systems do not have validity or reliability evaluation, often because it is difficult to assess pathophysiology and healing outcomes at a tissue level. Surrogate measures of healing and recovery are typically used. Clinical assessment and/or imaging findings correlating with HSI severity, prognosis and outcomes are most pragmatically useful and are often used to validate systems.[18 35] Most use time to return to sport (TRTS)[36], but time to return to full training (TRFT)[11], re-injury rates[30] and performance metrics[37] have also been studied. The complete resolution of HSI signs on imaging is unlikely to be necessary for successful

RTS.[38] There is a high incidence of MRI negative injuries[10-13] but this may not impact reliability or validity of classification systems as many systems incorporate a grade 0 and these HSI generally have a better prognosis.[11 39] (Online supplement 2 describes current HSI classification systems and available validity reliability data)

The BAMIC group have investigated the prognostic validity of their system[29], and they, and others, have also demonstrated good intra and inter-rater reliability of the BAMIC system.[13 40] In a study of 44 track and field athletes with 65 HSI[30] , they observed that increased TRFT and injury recurrence was associated with injuries that involved hamstring tendon tissue ('c' classification). TRFT was also significantly associated with grading severity (less in grade 0 (10±4.7days) but higher in grade 3c (84±49.4days)). In that study there was no significant difference in TRFT between myofascial (a) and myotendinous (b) injuries or between Grade 1 and Grade 2 injuries. The study did not include direct or contusion muscle injuries, described in the Munich system, as these are rare in track and field. The BAMIC group have also outlined a rehabilitation approach, informed by the athlete's BAMIC classification [29] and completed a further 4 year follow up study after implementation of this rehabilitation approach.[11] This did note a significant difference in TRFT between Grade 1 and Grade 2 HSI classified by BAMIC and again a significant difference in TRTS for injuries that involved the tendon ('c' classification). The reinjury rates in this 4-year study were very low at 2.9% overall and 0% in the 'c' classification.

Wangensteen et al. compared the level of agreement between BAMIC, Chan, and modified Peetrons classifications using a mixed sport cohort comprising 176 HSI with MRI images[13], reporting 'substantial' to 'almost perfect' intra- and interrater reliability when scored by experienced radiologists. For BAMIC, there was an association between TRTS for grades 0 and 2 and 1 and 3. For HSI location, there was no association in TRTS between types a and b and a and c, but there was between b and c. The Chan system demonstrated no associations between anatomical site related to proximity, but differences were found on anatomical site within the muscle (2a-e). The Chan authors reported difficulties with association due to the low frequency of injury in many of the categories (3a, 4b, and 4c categorised just 1, 2, 2 injuries, respectively). Many categories had large individual TRTS, which means an individual with a HSI 3c injury would have a 95% chance of returning to sport anywhere between 3.9 to 57.5 days. In this study, for MRI positive injuries (87% of this cohort), the grading systems and the BAMIC anatomical site accounted for only 7.6-11.9% of total variance in TRTS.

These studies suggest that anatomical site and severity grading are likely to be helpful, but not fully sufficient to explain TRTS. There is likely to be a role for clinical findings and reasoning and other individual athlete and sporting factors alongside classification systems to enhance prognostication. Considering all of these contributors is the role of the expert clinician in sport.

Some authors suggest difficulty in grouping all three hamstring muscles together when classifying these injuries and suggest that each muscle should be classified separately, to consider differences in connective tissue, fascia, and tendon architecture that produce different injury types, healing rates and prognoses.[20 21 23] The BAMIC classification paper comments that the specific injured hamstring muscle should be named with the associated classification, but outcome papers are challenging with this approach due to small numbers in the subsequent classification groups. Differences in rates of healing or prognosis between hamstring muscles, or locations such as the T junction injury, are not consistent and subclassification may not be required[11], although these studies contain small numbers. Many systems make no differentiation between tendon injuries in the proximal, distal or intramuscular tendons, which may have different healing rates and reinjury risk, requiring modifications to rehabilitation and possible surgical consideration.[41-43] Most authors have found differences in rehabilitation outcomes or reinjury risk with intra-tendon injuries[44], but not all.[36] Further discrimination of class c injuries to include the distance of retraction and categorisation between the intramuscular tendon and free tendon may be helpful with respect to surgical decision-making.[45]

Classifications that use a scoring system (examination, history and imaging findings carrying different weight) produce a combined score, such as that of Cohen et al.[6], who observed that a combined score of >10 corresponded to a worse prognosis (games missed) and demonstrated that the percentage of muscle tendon involvement, the number of muscles, and the amount of retraction were significant predictors of TRTS, but age and location were not. Conversely, Hamilton et al. observed that this combined score did not provide a clinically useful prognosis for RTS, reflecting the challenges of attempting to accurately determine RTS duration.[46] This is due to rarity of severe injuries and therefore studies contain insufficient numbers of these injuries to validate classification.

Classification systems for surgical decision-making

Surgery may be required for some HSI, although these tears only probably represent 0-5% of HSI in certain athlete groups. While many bony injury classification systems assist with rehabilitation and orthopaedic surgical decision-making[47], classification systems for muscles, have historically not included surgical considerations as part of their system, due to the lack of evidence to inform surgical indications.[45] Two classification systems have attempted to describe different types of proximal hamstring tendon injuries and consideration of surgical repair. Wood et al described 5 types of injury, detailing amount of displacement, sciatic nerve involvement and location.[8] Lempainen et al have attempted to separate each tendon proximally to allow surgical consideration even in partial injuries such as semimembranosus.[48] Treating these proximal free tendon injuries non operatively can cause significant morbidity and failure to return to sport.[49]

Unfortunately, there is no reliability data for these surgical systems. Prognostic information using a cohort of 72 operations provides incidence and outcomes for the subtypes in the Wood System.[8 45] Several recently validated PROMs may help [50 51], although these scores relate to proximal hamstring ruptures, and there may other types of hamstring injury where surgery may be indicated. As knowledge advances on key indications for surgery, HSI classification systems should evolve to optimise decision-making around the role of surgery.

Classification for high grade intramuscular tendon or MTJ injuries

There are some intramuscular hamstring injuries for which surgical intervention has been considered. These include injuries at the 'T junction' of the biceps long head, proximal biceps MTJ, conjoint intramuscular tendon and semimembranosus separation injuries.[52-54] Injuries at these sites are classified within the constructs of existing classification systems rather than as defined entities. Further work is required to clarify clinical outcomes and surgical indications for injuries at these sites and to establish whether existing classification systems should be adapted to incorporate further understanding of these injuries and to assist with decision making.

Summary

There are a number of classification systems available for use by clinicians, but no single system allows optimal treatment planning or prognostication. Current classification systems are nonspecific for the individual hamstring muscle injured, despite each muscle having different anatomy, innervation, functional roles and injury patterns.[55] Apart from direct contusion injuries, the mechanism of injury has been largely overlooked in classification systems, but different mechanisms of injury may cause specific injuries such as slow stretch versus high intensity running HSI.[56-58] Pattern recognition, however, is complex as a single mechanism of injury (e.g. high speed running) may cause multiple different types of HSI.[11]

Management of HSI must consider the demands of the particular sport, such as the differences in injury patterns for sprint versus pivot type sports, or those with and without physical contact. Elite level sports require a higher performance demand and often aim to reduce TRTS. The management decisions in elite sport may be different depending on sporting demand, time of season, patient goals and many other contextual factors.[59] Different sporting levels are currently not considered in classification systems.

Clinicians managing high grade injuries may benefit from classification systems that aid rehabilitation or surgical decision-making. Furthermore, while some classifications consider proximal HSI avulsions, further evidence is required regarding the optimal management of intramuscular tendon injuries that may help inform rehabilitation guidelines and surgical indications. Finally, the testing of reliability and validity of HSI classification is a priority. No current classifications are able to predict time to return to sport or the risk of reinjury.

In view of these classification gaps and lack of robust evidence, we undertook a consensus process, including an international Delphi Study, seeking expert opinion to enhance decision-making in the classification of HSI in order to inform clinical management for athletes presenting with HSI.

Due to the limitations of small athlete numbers in studies that evaluate muscle injury classifications, and the vital importance of clinical expertise, a consensus with international Delphi process was conducted to aid progress in this area of significant interest.

Aims

1. To determine the current global practice of classifying HSI
2. To determine the key aspects of decision making in the classification of HSI
3. To provide best practice for decision making in the classification of HSI

Methods

Study design

A modified Delphi study design was used, including an international panel of experts, with the aim of reaching a consensus on best practice for classification after HSI. In the situation where clinicians must make assessment and treatment decisions based on incomplete, weak, and poor-quality evidence, clinical expertise and experience become vital. A research approach to gain insight from practitioners' expertise is useful. Single experts can be useful but a scientific approach that aims for a consensus/ agreement among a group of experts can provide more optimal recommendations[60]. The London 2020 international hamstring consensus group was established as a multidisciplinary collaboration to advance the assessment and management of HSI. The Delphi methodology was thought to present a systematic and scientific approach to capture the decision-making experience and expertise of global experts to identify and investigate areas in HSI where new decision-making approaches could be developed. There have been previous Delphi consensus studies in muscle injuries[2 61] , injury prevention[62] and aspects of management of hamstring injury, such as return to play [63 64] but other aspects of hamstring assessment and treatment may also benefit from this approach such as classification systems, decision making in rehabilitation and the justification for surgery, particularly given the disparate and conflicting approaches used currently.[23 65]

The description of our modified Delphi methods is described below, following guidance on Delphi studies[66 67] and web survey design[68], but can also be found in online supplementary material (supplementary file 1). Ethical approval for the study was sought and obtained from the institutional ethical review board (Project ID 5938/002). Participants were informed prior to commencing the surveys, with completion implying consent.

Participants – Expert Panel

Identifying appropriate experts is vital to the Delphi process[69] and an international, representative, multidisciplinary group of expert clinicians and researchers were invited to participate in this study, based on their expertise in the assessment and management of hamstring injuries. A purposive, heterogeneous representative sample of experts was chosen to ensure a mix of:- professional discipline (sport and exercise medicine physicians, physiotherapists, surgeons, sport and exercise scientists/researchers, strength and conditioning specialists and athletic trainers), international experience, sex and sporting discipline in line with Delphi methodology.[70]

The criteria for expert inclusion were: - a high level of expertise assessing, managing and/or researching hamstring injuries, based on: - the number of injuries seen; years worked managing hamstring injuries; peer reviewed publication (authorship) in hamstring research; willingness to complete the digital survey and or attend the consensus meeting and sufficient level of written and spoken English.

Possible experts were excluded if they had 1/ insufficient experience of assessment or management of hamstring injury, 2) insufficient time to fully complete the online survey. Clinicians and non-clinicians were included but asked to answer only those survey questions related to their fields of expertise. (see methodology supplement). Domains of surgery, post-surgical recovery, and rehabilitation were also identified and experts were chosen, with sufficient expertise in these combined areas as well as classification.

Coaches and trainers comprised 6% of the experts for the final survey. Athletes were not included; however, we would acknowledge their voices as vital. Many of our experts have also been athletes and 38% of the final survey expert respondents reported a personal history of hamstring injury.

There is no guideline for number of experts to be involved in a consensus,[70] but the sample size was set at 30 for the initial survey to ensure a full international and multidisciplinary sport/ profession mix. A possible drop out and non-response rate was predicted. The study aimed to follow research recommendations with opinion-based research questions.[66 71]

Modified Delphi process

The study comprised two rounds of a purposive digital survey interspersed with a face-to-face meeting round. Each round was modified, based on feedback, to achieve a consensus among the international panel of experts. Each Delphi round comprised a digital questionnaire, an analysis, and a feedback report. The study was undertaken after a review of decision-making aspects of the assessment and management of HSI. The literature was searched, the evidence discussed, and the author team led a review of the evidence presented as a narrative summary to inform the consensus rationale and knowledge gaps (see supplementary file 2).

Round one involved a digital survey, with open ended questions to a global group of clinicians and researchers with expertise in HSI. The round one survey (see appendix 1 in methods Supplement) aimed to gather information, and understand, from the experts' viewpoint, where are the gaps in the literature evidence and clinical practice in hamstring injury decision-making. The initial round 1 survey comprised open ended qualitative information gathering questions and some quantitative data questions using Likert scales to determine level of agreement. The survey used a digital institution-based software package – Opinio 7.12 (copyright 1998-2020 ObjectPlanet, Oslo Norway). The surveys in this study followed the Checklist for Reporting Results of Internet E-Surveys (CHERRIES)[68] and the reporting standard for conducting and reporting Delphi studies (CREDES)[67] to avoid bias.

The responses from the initial survey were collated and analysed with a thematic and factor analysis[72] (see table 1 in methods supplement). The expert panel identified four key domains (see * in table 1) and key questions for these domains (see tables in appendix 3): - classification and diagnosis, surgery, rehabilitation and return to running and sport. This paper deals with results of classification and diagnosis, with subsequent papers covering surgery and rehabilitation. The questions on diagnosis and classification were outlined and presented for discussion. All the panel members who completed the survey were invited to the discussion meeting. The discussion took place via a group consensus two-day meeting, alongside an international conference, to allow as many of the participants to join as possible. A nominal group consensus model was followed with a facilitated, structured approach to gather qualitative information, from this group.[73] This approach has been followed in other consensus projects.[74] [75] In discussions, facilitators maintained impartiality and ensured balanced discussion to avoid "eminence bias".[66] They aimed to work toward agreement but not force consensus. Dissenting and outlier views were considered important, representing differences in practice. This approach aimed to avoid "herding bias".[76 77]

After discussions, the key consensus statements were synthesised and refined. These sessions were chaired by each steering committee author related to their area of specialisation – classification (JM), Rehabilitation (BP), Return to running/sport (MG) and surgery (FSH). Statements were gradually refined through a process of facilitated debate until the entire panel were satisfied and on day 2 were put to the group for anonymous electronic voting. See Appendix 4 for the list of statements – rehabilitation, RTS/RTR, classification and surgery.

The consensus steering committee (established an a priori criterion threshold of 70%, with ≥70% agreed/yes responses constituting statement acceptance. 70% has been used successfully by other Delphi studies.[78-80] Eighteen statements on the diagnosis and classification of HSI reached sufficient group agreement.

The final Delphi round involved a further online survey was developed, to test these statements with this survey to a wider global international group of experts who met the previous inclusion / exclusion criteria. The participants voted on the statements with yes, no, uncertain ("forced choice") responses. This made the final survey shorter and less onerous for participants, but some further Likert or factor ranking questions determined level of agreement. (See examples within methodology supplement).

These experts voted on statements and ranked their key decision-making factors or justifications related to the domain areas found in the round 1 survey. See table – tables, for consensus statements, voting results and typical discussion points or areas of disagreement (open ended questions)

Expert panel for final round

The final survey with voting on the consensus statements, was split into domain sections – classification, surgery, rehabilitation, return to running / sport. Participants were asked to complete only the domains (sections of the survey) that were within their field and scope of expertise. The survey responses were evaluated for completeness. Survey responses in each domain were evaluated by 2 steering group members and any incomplete responses from non-experts in that particular domain were removed from the analysis. Within their expertise areas, panel members were asked to complete sections as carefully as possible and provided with response options such as "uncertain". Open ended boxes after each consensus statement also allowed them to comment, and comments and areas of disagreement were collated and analysed.

Steering committee

The surveys were designed by 2 experienced clinical academic physiotherapists, and a professor of orthopaedic surgery, who each have greater than 20 years clinical experience treating HSI and research expertise in HSI, as well as previous experience with Delphi research. A structured, iterative process was undertaken to develop the survey and it was piloted by a mixed group of 5 sports medicine physicians, 5 physiotherapists and 5 orthopaedic surgeons, and the survey was further refined based on their feedback. The expert panel were approached by email located from publicly available correspondence information on peer reviewed journal articles. Information was provided prior to participation but actively completing the survey was implied (and stated) as the consent to participate. Any participant who withdrew had data removed.

Results

Respondents

The volume of responses made reporting in one single paper difficult. For this reason, three papers are presented with decision-making domain areas of – classification, surgery and rehabilitation and RTS.

The response rates and the inclusion and exclusions for each survey round are given in the flow chart in figure 1. The compositions and characteristics of the expert panel for each round survey and the face-to-face meeting are reported below in table 2.

Table 2 Participant charactreristics of the Expert Panels

Characteristic	Categories	Survey Round	Meeting	Survey Final Round
Sex	(M: F)	33:2	14:1	81:18
Age (years)	27 - 36	11 (31.4 %)	6	32 (31.6%)
	37 - 46	13 (37.1%)	4	33(33.7%)
	47 - 56	9 (25.7%)	4	20 (20.4%)
	57 - 70	2(5.7%)	1	14 (14.3%)
Role clinician	clinician only	3 (5.7%)		26 (25%)
	researcher/scientist only	2 (8.6%)		11 (11 %)
	clinician + researcher	30 (85.7%)	15 (100%)	62 (63%)
	Neither clinician nor researcher	0		1 (1%)
Hamstring cases / year	none	0		5 (5%)
	0-5	1(2.9%)		6 (6%)
	5-10	6 (17.1%)		25 (24%)
	10-15	7 (20%)		12 (12%)
	15-20	10 (28.6%)		13 (13%)
	20or more	11 (31.4%)		38 (38%)
Health care profession	Sports medicine Physician	4 (10%)	1 (7%)	21 (18 %)
	Orthopaedic surgeon	8 (21%)	5 (35%)	18 (17 %)
	Physical Therapist	22 (55%)	10 (64%)	43 (40 %)
	Sports scientist	1 (3%)		25 (24 %)
	Athletic trainer / Strength & Conditioning coach	2 (5%)		7 (6 %)
	Other	2 (5%)		2 (2%)
Country of practice	North America	4 (11%)		10 (10%)
	Europe	26 (66%)	12 (80%) (UK,Neth,Ir)	65 (64%)
	Middle East/Africa	4 (11%)	1 (7%) SAf	12 (12%)
	Southeast Asia			1 (1%)
	South America			1 (1%)
	Australasia / pacific	5 (13%)	2(13%) (Aust)	10 (10%)

Sports	**football**	**31 (29%)**	**4 (27%)**	**79 (80%)**
	athletics	**19 (19%)**	**2 (13%)**	**59 (60%)**
	Rugby codes	**13(12%)**	**4 (27%)**	**40 (40%)**
	NFL	**5 (5%)**		**9 (9%)**
	AFL	**3 (3%)**		**9 (9%)**
	basketball	**9 (9%)**		**30 (30%)**
	volleyball	**4 (4%)**		**1 (1%)**
	Skiing and winter sports	**9(9%)**		**21 (21%)**
	hockey	**3 (3%)**	**1 (7%)**	**22 (21%)**
	judo/ martial arts/wrestling	**2 (2%)**		**24 (24%)**
	cricket			**15 (15%)**
	Ice hockey			**12 (12%)**
	Acrobatics/ gymnastics / dance			**17 (17%)**
	Gaelic football			**7 (7%)**
	Racquet sports			**17 (17%)**
	handball			**20 (20%)**
	Other	**9 (8%)**	**4 (27%)**	**6 (6%)**
Years working with HSI	**0-4**	**5 (14.3%)**		**17 (17%)**
	11-14	**8 (22.9%)**		**13 (13%)**
	5-10	**9 (25.7%)**		**22 (21%)**
	15-20	**4 (11.4%)**		**23 (23%)**
	more than 20	**9 (25.7%)**		**24 (24%)**
Highest academic	**Bachelor/Diploma**			**14 (14%)**
	Masters			**35(35%)**
	PhD			**34 (35%)**
	Clinical Doctorate			**15 (15%)**
Had hamstring injury	**hamstring problem**			**38 (38%)**
	not applicable			**61 (62%)**

UK-United Kingdom, Neth-Netherlands, IR-Ireland, Aust-Australia , SAf- South Africa

Preferred HSI classification system

Table 3 presents the participants preferred HSI classification system. For both surveys 1 and 2, BAMIC, Munich and Barcelona rank 1, 2 and 3, respectively.

Table 3: Survey results round 1- Ranking of classification systems

Classification System	Survey 1 Vote (%)	Meeting vote (%)	Survey 2 Vote (%)
British Athletics Muscle injury	17 (40)	15 (35)	56 (58)
Munich	9 (21)	10 (24)	11 (12)
Barcelona M Injury	5 (12)	6 (14)	6 (6)
Modified Peetrons US/MRI	6 (14)	3 (7)	9 (9)
Chan	2 (5)	1 (2)	1 (1)
Cohen	0 (0)	2 (5)	3 (3)
Wood	1(3)	4 (10)	5 (5)
Takebayashi	0	1 (2)	1 (1)
Nil used	2 (5)	0	2 (2)
Totals	43	42	96

In the initial survey, we asked participants what questions need answering in HSI classification. The initial survey results are presented in tables 4-6. Top 3 questions are: 1) are there different clinical presentations for fascial/Muscular/IMT/ Tendon injuries, 2) which HSI classification system most effectively guides management, and 3) does the classification of injury relate to recovery time (return to performance)?

Table 4: Questions requiring answers in hamstring injury classification systems

Category of question	Responses	% of total	Typical Responses
Classification vs anatomy	17	24%	Difference in clinical presentation between fascial/Muscular/ Tendon/ IMT?
Classification vs treatment planning	8	11%	Which classification system most effectively guides management?
Classification vs prognosis/ recovery	8	11%	Does the classification of injury relate to recovery time (RT performance)?
Subclassification	6	8%	Are we missing any important sub-categories with current classification systems?
System of choice	5	7%	Which classification system most closely predicts improvement, recovery and duration?
Classification vs clinical examination	5	7%	Can we use a simplified system that uses clinical examination outcomes?
Classification vs mechanism of Injury	5	7%	What is the association between injury type and outcome (return to play and reinjury) without too much outcome in overlap between groups?
Muscle group specific system	5	7%	Do we need to develop a classification system that is muscle (group)-specific? Do we need to consider different muscles, in grading systems?
Classification vs imaging	4	6%	Are we basing rehab outcome timeframes mainly on MRI? can we develop holistic criteria including athlete history, mechanism, presentation, clinical testing?
Classification vs surgery	3	4%	Can systems encompass surgical criteria? Is surgery indicated - early vs late surgery?
Multivariable system	2	3%	Is there a combination of radiological findings, functional characteristics (biomechanics, speed, strength, range of motion) that can be added to create a composite score?
Classification vs function	2	3%	Is there a combination of functional characteristics (biomechanics, speed, strength, range of motion) that can be added to create a composite score?
Sport specific system	1	1%	Can we develop a classification system that is sport-specific?
Validity / reliability of systems	1	1%	Are classification systems reliable and valid prior to implementation?
Total	72	100%	

When considering the key factors that influence clinician's decisions for requesting imaging, the top three answers were 1) loss of range of motion and/or strength and/or tension and/or integrity on examination, 2) symptoms, and 3) injury mechanism. Table 5 and 6 (initial survey) deal with the key factors in referral for imaging and key examination considerations for diagnosis.

Table 5: Key factors triggering referral for Imaging

Factors	number of responses	% of total
Loss ROM strength/ tension or integrity on Exam	14	16%
Symptom levels	12	14%
Injury mechanism or sound (pop)	8	9%
Failure to improve	7	8%
Severity	6	7%
Diagnosis	6	7%
Prognosis Que (need for Surgery)	4	5%
Suspected tissue type	5	6%
Particular muscle	3	3%
Athlete level	3	3%
Player or coach expectation	3	3%
Bleeding bruising	5	6%
Availability of imaging modalities	2	2%
Timing	3	3%
Local protocol	1	1%
Cost	1	1%
Red flag	1	1%
Scientific evidence	1	1%
Athlete susceptibility (including previous HSI)	1	1%
Total	**86**	**100%**

Table 6: Key factors to make HSI diagnosis

Examination aspects	Number of responses
Strength	18
Palpation findings	13
Function	8
Pain	4
Examination	4
Neural findings	3
Haematoma /swelling	2
n/a	2
History	1
Tone	0
Flexibility	0
Total	**55**

Table 7 reports the consensus statements from our meeting days and reports the results of round 2 digital survey from the 99 respondents. The levels of agreement for each of these statements is reported and those that achieved more than 70% are highlighted.

Table 7. Consensus statements and percentage agreement for round 2 survey – Global expert Panel (n=99) - **Classification**

Consensus statements related to Classification		TRUE	FALSE	Undecided	Samples of typical responses - discussion points or areas of disagreement
Anatomical (radiological) classification is essential in the diagnostic process		**62.0%**	**22.0%**	**16.0%**	It is essential in the higher-grade hamstrings to determine the tendon involvement however with smaller strains radiology is non-essential.
There is a need for One main classification system (agreed terminology and nomenclature).		**84.8%**	**2.0%**	**13.1%**	A 'one size fits all' may not be appropriate. Different sports have different mechanisms of injury, demands and therefore RTP times, and re injury rates. Seems logical that what may work for track and field doesn't necessarily hold true for football. Difficult to fit everything into one main classification anatomy, function, and prognostication.
Classification needs clear parameters such as (but not limited to):-	***Anatomical, radiological classification***	**95.9%**	**0.0%**	**4.1%**	It appears research remains undecided for the influence of anatomical location and free vs central tendon involvement in classification systems.
	Free Tendon vs Central Tendon	**86.9%**	**6.1%**	**7.1%**	Again, the evidence is limited in the classification of tendon vs MTJ injuries (as an example). No evidence suggests central tendon involved injuries are better off with surgical intervention or not. The only evidence we do have is that treating without the MRI and using clinical markers to guide progression is the only consistent approach, whether central tendon is involved or not.
	Should evolve to include surgical criteria	**52.1%**	**19.8%**	**28.1%**	Surgical criteria would be useful for practitioners deciding on prognosis and management.
Classification systems should have agreed Terminology		**91.8%**	**2.0%**	**6.1%**	Diagnostic classification system should be clear in reports and research. Only for consistency's sake from both a scientific and clinical perspective.
There is a need for a registry for hamstring injuries		**68.7%**	**10.1%**	**21.2%**	more data is useful, but I fear people will bias their interpretation of it (E.g., all central tendon injuries take longer to rehab than MTJ - but this is because you treated them based on the MRI which showed central tendon and you were conservative as a result). This bias is tough to avoid in these registry datasets and people will misconstrue the data. Would be difficult with so many sports. Maybe intra sport registry.
Mechanism of injury should be commented alongside the classification (where appropriate / known)		**82.0%**	**11.0%**	**7.0%**	This always allows for a clearer prognosis/ This is more useful than the classification system. /Affects anatomical involvement, prognosis, and rehab decisions.
We SHOULD differentiate between muscles in the classification?		**88.9%**	**4.0%**	**7.1%**	Obvious/Different muscles have different functions so a classification that guides rehab is desirable hamstrings have different structure and therefore function which needs to be clearly stated to understand if certain muscles are at greater re-injury risk or require longer / Requires a very demanding system that may be too difficult to adhere to.
Beyond anatomical classification, there is a need to have: -	***functional criteria running beside***	**90.0%**	**6.0%**	**4.0%**	Time to walk pain free/Confidence to Sprint/ patient expected time to return to sport.
	PROMS running beside	**80.4%**	**10.3%**	**9.3%**	Current PROMs for hamstring injury may not be particularly useful/ PHAT LEFS/ Marx score/ FASH.
Imaging is vital in the classification system		**70.5%**	**14.7%**	**14.7%**	To decide between conservative or surgery, not otherwise/ Would prefer that classification would guide us to ask for imaging. Not that imaging is always essential especially in low grade injury/ in professional sport, imaging is more often required than not, however does not always change management.
Immediate Physical Examination signs like bruising, loss of muscle tension, palpable defects and / *or significant* ***weakness and excessive/no response on provoking activities warrant further investigation***		**92.6%**	**2.1%**	**5.3%**	In this presentation you are suspecting a free tendon or complete rupture which may require surgery/ Pain level and mechanism (suggesting a complete tear, avulsion, or anything else that might require a surgical opinion.

MRI is the preferred imaging for diagnosis and classification		**89.5%**	**4.2%**	**6.3%**	If used, I prefer MRI/ Ultrasound imaging can be very useful if conducted by a physician/ sonographer with lots of training. Ultrasound is also very suited to examine the damaged muscle- connective tissue area under movement. Ultrasound can also be a good cheaper alternative.
MRI side to side comparison is ideal for classification		**49.5%**	**25.3%**	**25.3%**	This does not happen that often due to financial restrictions. Enough information can likely be gained from a unilateral MRI to give an accurate diagnosis. /Contralateral side is not always a 'healthy' side/Should be used together with US/I prefer a correct protocolized MRI only of the affected side.
When is Ultrasound most useful / relevant as	***primary imaging after injury PRE 48 hours***	**14.8%**	***58.0%***	**27.3%**	Ultrasound is not particularly useful when there is a lot of oedema, in the early post-injury period.
	primary imaging after injury POST 48 hours	**25.8%**	***42.7%***	**31.5%**	4-day deadline is best to see well the hematic collection.
	in the rehabilitation phase	**61.8%**	**16.9%**	**21.3%**	It depends in what aspect. Architecture - yes. Lesion tracking -no.

Discussion

This paper presents the results of a modified Delphi study and consensus in the decision making of classification of HSI. The final Delphi round comprised a digital survey determining the level of agreement from global HSI experts on the consensus statements from the London 2020 international Hamstring consensus group meeting.

Areas of agreement / disagreement

We observed that clinicians use multiple sources of information in their decision-making to inform diagnosis, classification, management, and prognosis of HSI. Both imaging and clinical examination findings were considered essential and informed each other when making decisions on treatment of HSI

Justification for imaging

- Imaging is vital in the classification system (LOA 70.5%)
- Anatomical (radiological) classification is essential in the diagnostic process (LOA 62.0%)

Imaging was deemed vital for classification; however, the survey respondents did not agree that imaging was vital for diagnosis. Survey respondents and our consensus meeting panel noted that a proportion of HSI present without positive imaging findings, and the failure of MRI to accurately predict TRTS.[18 81] Clinicians expressed that they prioritised loss of ROM / tension and symptom levels to decide on imaging, with some external factors considered important such as the type or level of sport and cost or patient expectations.[82]

While these findings are similar to the literature on the justification of imaging in HSI, there are few specific MRI or US guidelines for HSI.[83-86] These are often incorporated into general guidelines for musculoskeletal imaging.[84 87] The low range of clinical justifications may leave out some significant imaging justifications – and knowing examination features that trigger early investigation may save time and enable an athlete to receive appropriate and targeted rehabilitation.[57 88 89] Although minor and low grade HSI may not require imaging[12], intramuscular tendon injuries cannot be easily diagnosed solely with clinical examination features[90] and if this is an important potential diagnosis for that athlete, imaging should be obtained. In the second-round survey, (table 7) respondents commented that imaging and anatomy were important, but their votes showed lower levels of agreement for imaging being essential for classification (70.3 %) but not for diagnosis (56.6%) and stronger agreement on preference for clinical examination, functional markers, and history findings to be considered.

Clinical features

- Immediate Physical Examination signs including bruising, loss of muscle tension, palpable defects and/or significant weakness and excessive/no response on provoking activities warrant further investigation (LOA 92.6 %)

In the area of clinical investigation to aid diagnosis or assessment of severity, our ISEH consensus panel and survey respondents put great weight on clinical assessment findings to help diagnose and classify HSI. Immediate physical examination signs like bruising, loss of muscle tension, palpable defects and/or significant weakness and excessive/no response on provoking activities showed strong agreement as justifications for ordering imaging. Many clinicians suggested these could be diagnostic and put most emphasis on loss of tension or muscle / strength function to aid diagnosis. Second to this were symptoms and the mechanism of injury. The failure of the athlete to improve also triggered further investigation (see table 5).

Types of Imaging

- MRI is the preferred imaging for diagnosis and classification (LOA 89.5%)

MRI was the investigation of choice over US. This is consistent with literature which focuses on MRI based classification systems. Koulouris *et al.* compared the use of ultrasound to MRI for the diagnosis of acute hamstring injuries, finding MRI detected proximal hamstring avulsion injuries in 100% of cases compared to only 58.3% of cases with ultrasound scan.[91]

MRI side to side differences were felt to be less important (see table in results LOA 49.5%) due to negative MRI findings in a high proportion of HSI[12], but also financial reasons and the degree of contralateral incidental pathology often found on MRI. The consensus group and survey respondents were also discriminating in their use and timing of US, with use in the early stage (pitch side) – within the first 48 hours (LOA 14.8%) or even for primary diagnosis- after the first 48 hours (LOA 21.8%) was not practiced. There was more agreement on its use in the rehabilitation phase, possibly to monitor healing stages (LOA 61.8%), however, this did not reach our threshold LOA. This finding agrees with literature [92] and guidelines on the use of US.[84 85 87] Ultrasound has some advantages for imaging muscle including evaluation of fluid/haematoma and scar, as well as real time movement and opportunity to support intervention. It can be used in conjunction with MRI[93], but the panel were in agreement that MRI was the most helpful imaging modality.

HSI Classification Systems

- Classification systems should have agreed Terminology (LOA 91.8%)
- There is a need for one main classification system (agreed terminology and nomenclature) (LOA 84.8%)

Most of the survey respondents use the BAMIC system (57%), although they concurrently use Munich and the Barcelona systems, but less commonly used ultrasound or earlier grade 1-3 systems. While they wanted a single classification system with agreed nomenclature and terminology, they indicated that none of the classification systems were perfect, and all had areas that required improvement. Clinicians wanted a classification to help with prognosis and outcome information and provide guidance for treatment decisions, as well as allowing them to grade severity. While they acknowledged that no one classification system may be able to meet all these requirements, there was strong agreement that terminology should be consistent and agreed.

Areas where classifications must evolve

- We should differentiate between muscles in the classification (LOA 88.9%)
- Classification needs clear parameters such as (but not limited to):
    - Free Tendon vs Central Tendon (LOA 86.1%)
    - Anatomical, radiological classification (LOA 95.1%)
    - Should evolve to include surgical criteria (LOA 51.2%)
- Mechanism of injury should be commented alongside the classification (where appropriate / known) (LOA 82.0%)
- Beyond anatomical classification, there is a need to have:
    - functional criteria running alongside (LOA 90 %)
    - PROMS running alongside (LOA 80.4%)

While the survey respondents acknowledged that imaging and the involved anatomical tissue were important, many expressed the need to individualise muscles – in part, due to the differing architecture and functional roles between the hamstring muscles. This is reflected in the types of injuries, with the muscles differing in their injury patterns. Our panel agreed that it was likely to be important to consider individual muscle factors such as function and anatomy.[20 23] Muscle architecture was also a factor in the agreement on free tendon versus the intramuscular tendon.

Some comments suggested a gap in the current classification systems in classifying intramuscular tendon injuries, for example, the BF central tendon[41] or the connective tissue T junction between BF long and short head[42]. These pathologies have typical injury patterns within the BF. Some clinicians reported that the implications of these injury pattens may differ between sports. This may be one significant reason why some respondents suggested muscle specific classification was required while others suggested that sports specific classification should be considered. There are also anatomical differences within individuals, making specific classification more challenging.[55]

The panel acknowledged the importance of clinical history and examination findings in classification. They suggested a place in the classification systems for mechanism of injury and functional criteria. Surgical criteria were rated as important, but this statement did not reach consensus, reflecting differences in opinion on the role of surgery. Hamstring injuries that need surgical consideration are uncommon but ideally would be highlighted early to prevent delays in treatment and risk of reinjury, longer recovery and complications.[94] However, further evidence on the indications for surgery is required to enable subsequent clear classification and identification of these injuries so rare injuries are not mis-diagnosed by clinicians who may not deal with these types of injury regularly.[43] Finally, many suggested a multi component, multivariable classification system was important, and clinicians voted highly on the inclusion of functional criteria such as walking and running / sprinting in classification systems. They also wanted more effective patient reported outcome measures (PROMS) that have received much attention, validation and reliability work in other injury types.[95]

Are HSI registries relevant?

- There is a need for a registry for hamstring injuries (LOA 68.7%)

Clinicians came close to agreement on the need for HSI registries. Some clinicians operated in countries where registries are common for high volume injuries, such as anterior cruciate ligament injuries. These registries, however, have been set up under an orthopaedic framework. In HSI, the percentage of patients requiring surgery is small. In elite sports, such as football, registries may already exist in some form, and it may be more appropriate for the most impacted sports to use an international sporting framework (i.e., PHAROS, UEFA, FIFA).

Limitations

The panels for our 3 Delphi rounds were international, The London international hamstring consensus meeting face to face group comprised 15 out of 35 respondents (43%) to the initial digital survey. This may set up a bias, however, the panel attending were heterogenous, with a multidisciplinary mix of profession, location, sport, age and domain expertise in treatment of HSI. They comprised clinicians from Australia, Netherlands, Ireland, the Middle East but the majority of the face-to-face meeting panel were UK based. We sought and invited experts from Asia, Africa, and South America, however there were less identifiable experts (clinical or published) from these locations, and they could not attend due to pandemic travel restrictions. This may mean their HSI management practices are not represented, possibly introducing bias. However, our meeting panel all worked in elite sport with work schedules that included the management of international patient/athlete cohorts . Most did not train professionally in the UK and their work experience and current work schedules comprised USA, Africa, Middle East, Australia and Asia. They reported that many of their athletes trained internationally, and with international coaches, reflecting the current international nature of elite and Olympic sport. To further reinforce the integrity of the consensus, and provide more international perspective, authors were included with significant Middle East hamstring work experience.

Our group of experts had multiple domains of expertise and scope of practice. This consensus project involved disparate domains of:- surgery, post-surgical and non-surgical rehabilitation, classification, diagnosis, running and return to sport. It was harder to evaluate expertise in classification and diagnosis and the criteria chosen for expertise were harder to establish, academic criteria were thought to be important, but very few experts had published on classification, although they used classification systems. Many trainers and coaches had less expertise in the diagnosis and classification domain and were not included as experts, although in some countries, trainers will have this expertise. Choosing criteria for expertise is difficult for any Delphi study and this represents one weakness of this methodology.[77] Our classification section received the most responses. While we trusted the survey respondents to complete only those fields that encompassed their expertise, it may be possible that some respondents completed sections outside their domain and level of expertise or scope of practice. This was the reason for lack of full response rate for every section. Open ended questions in the first round meant that we only took information that our experts submitted, which was used and adapted for the basis of subsequent rounds. We did not include athletes/ patients in these surveys, as domain specific professional knowledge was required, but statements suggesting athletes should lead and guide decision-making in their own treatment received high (unanimous) LOA. Also 38% of respondents to our survey reported had undergone HSI, possibly contributing to the patient/ athlete voice. Further work would ideally include athletes, coaches and other sport stakeholders, whose perspective is vital.

While we attempted to be inclusive, the representation of women is low in our panels, (2/39, 1/15, and 18/99). We found less publicly available information directing to women experts, and it was found that female rates of publication are lower in HSI, with less publicly available information on expertise. Although we attempted to invite these clinicians/ researchers, the response rates lower for the women we surveyed and invited to our meeting. This has been a weakness in other consensus research. We recognise this as a significant limitation of our consensus and recommend that future work specifically prioritises endeavours to enhance representation of women within consensus and Delphi group methodology as their voice is also vital

Where possible we aimed to include equity-deserving groups while maintaining our expertise criteria for inclusion and further work should aim to include these groups. Balancing inclusion and expertise can be challenging but should be prioritised in any Delphi study.

Recommendations from Consensus on diagnosis, classification and grading of HSI

1. Imaging is important for outlining the anatomical muscle, location and tissue involved in the injury. MRI is the investigation of choice and should be performed 24-48 hours post injury. US can be used as an adjunct, as it is less useful for diagnosis but could be useful in rehabilitation to assess healing. Imaging should assist grading, using: - volume, cross sectional area, length of lesions, as well as any discontinuity in tendon or connective tissue, which may be predictive of, slower/poorer outcomes and/or recurrence.
2. A thorough history and physical examination are vital. Clinicians identified key history and examination findings that trigger imaging referral. These include loss of :- ROM, tension or contraction capability, pain, presence and pattern of bruising, swelling, the mechanism of injury and the sound (popping) or feeling (tearing/instability) at the time of injury, failure to progress in rehabilitation, and athlete factors such as previous injury, sporting type and level.
3. Classification systems need to perform multiple functions, including grading of severity and anatomical description and need to have agreed terminology to be pragmatically useful. Currently, BAMIC is the most widely used classification system for HSI, with Munich and Barcelona systems also used. Some clinicians use multiple systems, as they acknowledge strengths and weaknesses with each system. Systems are based on imaging and anatomy but have evolved to encompass mechanism of injury. Our expert clinicians preferred a single classification system to aid in decision making around treatment and prognosis.
4. Classification and grading systems may evolve to include multiple components that combine: - imaging findings – MRI / US, clinical presentation on history and examination, mechanism of injury data and athlete susceptibility data such as previous injuries and age. Hamstring function may have a place in classification, particularly running and sprinting, although this may relate more to a management outcome than a component of classification. Classification systems should also evolve or have the capacity to deal with muscles individually, due to their different architecture, functional roles, and injury patterns

5. Intramuscular tendon injuries are recognised in the BAMIC system and appear to have an increased risk of recurrence or delay returning to sport. Loss of tension and cross-sectional area of tendon injury appear to be prognostic variables.[44] Further work is required to determine optimal management pathways and further develop classification of the intramuscular tendon injury.

6. Further information in classification systems, such as inclusion of individual muscles, mechanism of injury, patient demands may aid treatment and prognostication for these injuries. High level research is needed assess if outcomes such as RTS or injury recurrence improve by utilising this information.

7. The smaller cohort of higher grade HSI that commonly recur, are harder to manage, and may benefit from detailed classification with criteria to aid decision-making around surgical management. This lacks global agreement and there are only two classification systems with surgical criteria, both focussing on proximal hamstring free tendon tears.

8. Development of key functional components and best methods of measurement for classification will be important, as are the development of adequate patient reported outcome measures (PROMS).

9. The systems should be sports specific, again acknowledging the different loads, risk situations, and injury patterns in different sports.

10. Very few classification systems have validation studies to ascertain their ability to accurately prognosticate and guide treatment decisions. Outcomes should include time to return to running, sprinting and full performance, as well as risk of recurrence. The type of numbers required for these studies may only be reached by large scale injury registries.

Conclusion

A narrative review of classification in HSI showed that systems have evolved from clinical signs only, to imaging based systems. They have evolved to include injury mechanisms, and the anatomical tissue and site, as well as the grading of injury severity. The relationship between imaging findings, grading / severity, reinjury risk and prognosis, however, is still not fully clear. While many clinicians would like to use classification systems to allow prescription of rehabilitation and an accurate prognosis, there are very few studies that have investigated this. Our Consensus group and Delphi survey rounds suggest that, in order of use, expert clinicians most frequently use BAMIC, then Munich, then Barcelona muscle injury classification systems for HSI, for the reasons of utility and simplicity. They have highlighted the need to differentiate between the three hamstring muscles and exact anatomical location to help classify these injuries. They acknowledge limitations of any classification system but suggest they could evolve to consider additional information (functional parameters, injury mechanisms, athletic sporting demands, surgical indications and PROMS) to more optimally treat HSI. Using the current systems along with this additional data may allow more tailored and effective rehabilitation for each specific injury.

References

1. Hamilton B, Valle X, Rodas G, et al. Classification and grading of muscle injuries: a narrative review. *Br J Sports Med* 2015;49(5):306. doi: 10.1136/bjsports-2014-093551 [published Online First: 2014/11/15]

2. Mueller-Wohlfahrt HW, Haensel L, Mithoefer K, et al. Terminology and classification of muscle injuries in sport: the Munich consensus statement. *Br J Sports Med* 2013;47(6):342-50. doi: 10.1136/bjsports-2012-091448 [published Online First: 2012/10/20]

3. Pollock N, James SL, Lee JC, et al. British athletics muscle injury classification: a new grading system. *Br J Sports Med* 2014;48(18):1347-51. doi: 10.1136/bjsports-2013-093302 [published Online First: 2014/07/18]

4. Peetrons P. Ultrasound of muscles. *Eur Radiol* 2002;12(1):35-43. doi: 10.1007/s00330-001-1164-6 [published Online First: 2002/02/28]

5. Chan O, Del Buono A, Best TM, et al. Acute muscle strain injuries: a proposed new classification system. *Knee surgery, sports traumatology, arthroscopy : official journal of the ESSKA* 2012;20(11):2356-62. doi: 10.1007/s00167-012-2118-z [published Online First: 2012/07/10]

6. Cohen SB, Towers JD, Zoga A, et al. Hamstring Injuries in Professional Football Players:Magnetic Resonance Imaging Correlation With Return to Play. *Sports Health* 2011;3(5):423-30. doi: 10.1177/1941738111403107

7. Valle X, Alentorn-Geli E, Tol JL, et al. Muscle Injuries in Sports: A New Evidence-Informed and Expert Consensus-Based Classification with Clinical Application. *Sports Med* 2017;47(7):1241-53. doi: 10.1007/s40279-016-0647-1 [published Online First: 2016/11/24]

8. Wood DG, Packham I, Trikha SP, et al. Avulsion of the proximal hamstring origin. *J Bone Jt Surg Ser A* 2008;90(11):2365-74. doi: 10.2106/JBJS.G.00685 [published Online First: 2008/11/04]

9. Cohen SB, Towers JD, Zoga A, et al. Hamstring injuries in professional football players: magnetic resonance imaging correlation with return to play. *Sports Health* 2011;3(5):423-30. doi: 10.1177/1941738111403107 [published Online First: 2012/09/28]

10. Wangensteen A, Guermazi A, Tol JL, et al. New MRI muscle classification systems and associations with return to sport after acute hamstring injuries: a prospective study. *Eur Radiol* 2018;28(8):3532-41. doi: 10.1007/s00330-017-5125-0 [published Online First: 2018/02/21]

11. Pollock N, Kelly S, Lee J, et al. A 4-year study of hamstring injury outcomes in elite track and field using the British Athletics rehabilitation approach. *Br J Sports Med* 2022;56(5):257-63. doi: 10.1136/bjsports-2020-103791 [published Online First: 2021/04/16]

12. Schneider-Kolsky ME, Hoving JL, Warren P, et al. A comparison between clinical assessment and magnetic resonance imaging of acute hamstring injuries. *Am J Sports Med* 2006;34(6):1008-15. doi: 10.1177/0363546505283835 [published Online First: 2006/02/16]

13. Wangensteen A, Tol JL, Roemer FW, et al. Intra- and interrater reliability of three different MRI grading and classification systems after acute hamstring injuries. *Eur J Radiol* 2017;89:182-90. doi: 10.1016/j.ejrad.2017.02.010 [published Online First: 2017/03/08]

14. Valle X, Mecho S, Pruna R, et al. The MLG-R muscle injury classification for hamstrings. Examples and guidelines for its use. *Apunts-Medicina De L Esport* 2019;54(202):73-79. doi: 10.1016/j.apunts.2018.11.002

15. O'Donoghue DH. Treatment of Injuries to Athletes. Philadelphia1962.

16. Rachun A. Standard Nomenclature of Athletic Injuries. 1st edition ed. Chicago Il1966.

17. Wise DD. Physiotherapeutic treatment of athletic injuries to the muscle--tendon complex of the leg. *Can Med Assoc J* 1977;117(6):635-9. [published Online First: 1977/09/17]

18. Wangensteen A, Almusa E, Boukarroum S, et al. MRI does not add value over and above patient history and clinical examination in predicting time to return to sport after acute hamstring injuries: A prospective cohort of 180 male athletes. *British Journal of Sports Medicine* 2015;49(24):1579-87. doi: 10.1136/bjsports-2015-094892

19. Whiteley R, van Dyk N, Wangensteen A, et al. Clinical implications from daily physiotherapy examination of 131 acute hamstring injuries and their association with running speed and rehabilitation progression. *British journal of sports medicine* 2018;52(5):303-10. doi: 10.1136/bjsports-2017-097616

20. Balius R, Pedret C, Kassarjian A. Muscle Madness and Making a Case for Muscle-Specific Classification Systems: A Leap from Tissue Injury to Organ Injury and System Dysfunction. *Sports Med* 2021;51(2):193-97. doi: 10.1007/s40279-020-01387-5 [published Online First: 2020/12/18]

21. Bisciotti GN, Balzarini L, Volpi P. The classification of muscle injuries: a critical review. *Medicina Dello Sport* 2015;68(2):165-77.

22. Hamilton B. Hamstring muscle strain injuries: what can we learn from history? *Br J Sports Med* 2012;46(13):900-3. doi: 10.1136/bjsports-2012-090931 [published Online First: 2012/03/31]

23. Hamilton B, Alonso JM, Best TM. Time for a paradigm shift in the classification of muscle injuries. *J Sport Health Sci* 2017;6(3):255-61. doi: 10.1016/j.jshs.2017.04.011 [published Online First: 2018/10/26]

24. Tol JL, Hamilton B, Best TM. Palpating muscles, massaging the evidence? An editorial relating to 'Terminology and classification of muscle injuries in sport: The Munich consensus statement'. *Br J Sports Med* 2013;47(6):340-1. doi: 10.1136/bjsports-2012-091849 [published Online First: 2012/12/12]

25. Tscholl P, Meynard T, Le Thanh N, et al. Diagnostics and classification of muscle injuries in sports. *Swiss Sports and Exercise Medicine* 2018;66(1):8-15.

26. Kellis E. Intra- and Inter-Muscular Variations in Hamstring Architecture and Mechanics and Their Implications for Injury: A Narrative Review. *Sports Medicine* 2018;48(10):2271-83. doi: 10.1007/s40279-018-0975-4

27. Smart M, Bristow WR. The treatment of muscular and joint injuries by graduated contraction. *Lancet* 1912;1(4627):1189-91. doi: 10.1016/s0140-6736(01)67707-9

28. Gilcreest EL. Rupture of muscles and tendons - Particularly subcutaneous rupture of the biceps Flexor cubiti. *Journal of the American Medical Association* 1925;84(24):1819-22. doi: DOI 10.1001/jama.1925.02660500027015

29. Macdonald B, McAleer S, Kelly S, et al. Hamstring rehabilitation in elite track and field athletes: applying the British Athletics Muscle Injury Classification in clinical practice. *British Journal of Sports Medicine* 2019:bjsports-2017-098971. doi: 10.1136/bjsports-2017-098971

30. Pollock N, Patel A, Chakraverty J, et al. Time to return to full training is delayed and recurrence rate is higher in intratendinous ('c') acute hamstring injury in elite track and field athletes: clinical application of the British Athletics Muscle Injury Classification. *Br J Sports Med* 2016;50(5):305-10. doi: 10.1136/bjsports-2015-094657 [published Online First: 2016/02/19]

31. Kellis E, Galanis N, Kapetanos G, et al. Architectural differences between the hamstring muscles. *Journal of electromyography and kinesiology : official journal of the International Society of Electrophysiological Kinesiology* 2012;22(4):520-6. doi: 10.1016/j.jelekin.2012.03.012 [published Online First: 2012/05/09]

32. Woodley SJ, Mercer SR. Hamstring muscles: Architecture and innervation. *Cells Tissues Organs* 2005;179(3):125-41. doi: 10.1159/000085004

33. Higashihara A, Ono T, Kubota J, et al. Differences in the electromyographic activity of the hamstring muscles during maximal eccentric knee flexion. *Eur J Appl Physiol* 2010;108(2):355-62. doi: 10.1007/s00421-009-1242-z [published Online First: 2009/10/10]

34. Higashihara A, Nagano Y, Ono T, et al. Differences in hamstring activation characteristics between the acceleration and maximum-speed phases of sprinting. *J Sports Sci* 2018;36(12):1313-18. doi: 10.1080/02640414.2017.1375548

35. Petersen J, Thorborg K, Nielsen MB, et al. The diagnostic and prognostic value of ultrasonography in soccer players with acute hamstring injuries. *Am J Sports Med* 2014;42(2):399-404. doi: 10.1177/0363546513512779 [published Online First: 2013/12/18]

36. Van Der Made AD, Almusa E, Reurink G, et al. Intramuscular tendon injury is not associated with an increased hamstring reinjury rate within 12 months after return to play. *British Journal of Sports Medicine* 2018;52(19):1261-66. doi: 10.1136/bjsports-2017-098725

37. Whiteley R, Massey A, Gabbett T, et al. Match High-Speed Running Distances Are Often Suppressed After Return From Hamstring Strain Injury in Professional Footballers. *Sports Health* 2021;13(3):290-95. doi: 10.1177/1941738120964456 [published Online First: 2020/11/06]

38. Vermeulen R, Almusa E, Buckens S, et al. Complete resolution of a hamstring intramuscular tendon injury on MRI is not necessary for a clinically successful return to play. *British Journal of Sports Medicine* 2021;55(7):397-402. doi: 10.1136/bjsports-2019-101808

39. Ekstrand J, Askling C, Magnusson H, et al. Return to play after thigh muscle injury in elite football players: Implementation and validation of the Munich muscle injury classification. *British Journal of Sports Medicine* 2013;47(12):769-74. doi: 10.1136/bjsports-2012-092092

40. Patel A, Chakraverty J, Pollock N, et al. British athletics muscle injury classification: a reliability study for a new grading system. *Clin Radiol* 2015;70(12):1414-20. doi: 10.1016/j.crad.2015.08.009 [published Online First: 2015/09/20]

41. Comin J, Malliaras P, Baquie P, et al. Return to competitive play after hamstring injuries involving disruption of the central tendon. *Am J Sports Med* 2013;41(1):111-5. doi: 10.1177/0363546512463679 [published Online First: 2012/11/01]

42. Entwisle T, Ling Y, Splatt A, et al. Distal Musculotendinous T Junction Injuries of the Biceps Femoris: An MRI Case Review. *Orthop J Sports Med* 2017;5(7):2325967117714998. doi: 10.1177/2325967117714998 [published Online First: 2017/08/11]

43. Van Der Made AD, Tol JL, Reurink G, et al. Potential hamstring injury blind spot: We need to raise awareness of proximal hamstring tendon avulsion injuries. *British Journal of Sports Medicine* 2019;53(7):390-92. doi: 10.1136/bjsports-2018-100063

44. Eggleston L, McMeniman M, Engstrom C. High-grade intramuscular tendon disruption in acute hamstring injury and return to play in Australian Football players. *Scandinavian Journal of Medicine and Science in Sports* 2020;30(6):1073-82. doi: 10.1111/sms.13642

45. Wood D, French SR, Munir S, et al. The surgical repair of proximal hamstring avulsions. *Bone Joint J* 2020;102-B(10):1419-27. doi: 10.1302/0301-620X.102B10.BJJ-2019-1112.R1 [published Online First: 2020/10/01]

46. Hamilton B, Wangensteen A, Whiteley R, et al. Cohen's MRI scoring system has limited value in predicting return to play. *Knee surgery, sports traumatology, arthroscopy : official journal of the ESSKA* 2018;26(4):1288-94. doi: 10.1007/s00167-016-4403-8 [published Online First: 2017/02/06]

47. Bryson WN, Fischer EJ, Jennings J, et al. Three-column classification system for tibial plateau fractures: What the orthopedic surgeon wants to know. *Radiographics* 2021;41(1):144-55. doi: 10.1148/rg.2021200106

48. Lempainen L, Banke IJ, Johansson K, et al. Clinical principles in the management of hamstring injuries. *Knee Surgery, Sports Traumatology, Arthroscopy* 2015;23(8):2449-56. doi: 10.1007/s00167-014-2912-x

49. Chang JS, Kayani B, Plastow R, et al. Management of hamstring injuries: current concepts review. *Bone Joint J* 2020;102-B(10):1281-88. doi: 10.1302/0301-620X.102B10.BJJ-2020-1210.R1 [published Online First: 2020/10/01]

50. Blakeney WG, Zilko SR, Edmonston SJ, et al. Proximal hamstring tendon avulsion surgery: evaluation of the Perth Hamstring Assessment Tool. *Knee Surgery, Sports Traumatology, Arthroscopy* 2017;25(6):1936-42. doi: 10.1007/s00167-016-4214-y

51. French SR, Kaila R, Munir S, et al. Validation of the Sydney Hamstring Origin Rupture Evaluation (SHORE). *Bone Joint J* 2020;102-B(3):388-93. doi: 10.1302/0301-620X.102B3.BJJ-2019-0840.R1 [published Online First: 2020/03/03]

52. Ayuob A, Kayani B, Haddad FS. Acute Surgical Repair of Complete, Nonavulsion Proximal Semimembranosus Injuries in Professional Athletes. *Am J Sports Med* 2020;48(9):2170-77. doi: 10.1177/0363546520934467 [published Online First: 2020/07/16]

53. Ayuob A, Kayani B, Haddad FS. Musculotendinous Junction Injuries of the Proximal Biceps Femoris: A Prospective Study of 64 Patients Treated Surgically. *Am J Sports Med* 2020;48(8):1974-82. doi: 10.1177/0363546520926999 [published Online First: 2020/07/01]

54. Kayani B, Ayuob A, Begum F, et al. Surgical Repair of Distal Musculotendinous T Junction Injuries of the Biceps Femoris. *American Journal of Sports Medicine* 2020;48(10):2456-64. doi: 10.1177/0363546520938679

55. Afonso J, Rocha-Rodrigues S, Clemente FM, et al. The Hamstrings: Anatomic and Physiologic Variations and Their Potential Relationships With Injury Risk. *Front Physiol* 2021;12:694604. doi: 10.3389/fphys.2021.694604 [published Online First: 2021/07/27]

56. Askling CM, Heiderscheit BC. Acute hamstring muscle injury: Types, rehabilitation, and return to sports. Sports Injuries: Prevention, Diagnosis, Treatment and Rehabilitation, Second Edition2015:2137-47.

57. Askling CM, Tengvar M, Saartok T, et al. Acute first-time hamstring strains during slow-speed stretching: clinical, magnetic resonance imaging, and recovery characteristics. *Am J Sports Med* 2007;35(10):1716-24. doi: 10.1177/0363546507303563 [published Online First: 2007/06/15]

58. Askling CM, Tengvar M, Saartok T, et al. Acute first-time hamstring strains during high-speed running: a longitudinal study including clinical and magnetic resonance imaging findings. *Am J Sports Med* 2007;35(2):197-206. doi: 10.1177/0363546506294679 [published Online First: 2006/12/16]

59. Dijkstra HP, Pollock N, Chakraverty R, et al. Return to play in elite sport: A shared decision-making process. *British Journal of Sports Medicine* 2017;51(5):419-20. doi: 10.1136/bjsports-2016-096209

60. Minas H, Jorm AF. Where there is no evidence: Use of expert consensus methods to fill the evidence gap in low-income countries and cultural minorities. *International Journal of Mental Health Systems* 2010;4 doi: 10.1186/1752-4458-4-33

61. McCall A, Pruna R, Van der Horst N, et al. Exercise-Based Strategies to Prevent Muscle Injury in Male Elite Footballers: An Expert-Led Delphi Survey of 21 Practitioners Belonging to 18 Teams from the Big-5 European Leagues. *Sports Medicine* 2020;50(9):1667-81. doi: 10.1007/s40279-020-01315-7

62. Donaldson A, Cook J, Gabbe B, et al. Bridging the gap between content and context: Establishing expert consensus on the content of an exercise training program to prevent lower-limb injuries. *Clinical Journal of Sport Medicine* 2015;25(3):221-29. doi: 10.1097/JSM.0000000000000124

63. van der Horst N, Backx F, Goedhart EA, et al. Return to play after hamstring injuries in football (soccer): a worldwide Delphi procedure regarding definition, medical criteria and decision-making. *British Journal of Sports Medicine* 2017;51(22):1583-91. doi: 10.1136/bjsports-2016-097206

64. Zambaldi M, Beasley I, Rushton A. Return to play criteria after hamstring muscle injury in professional football: A Delphi consensus study. *British Journal of Sports Medicine* 2017;51(16):1221-26. doi: 10.1136/bjsports-2016-097131

65. Lightsey HM, Kantrowitz DE, Swindell HW, et al. Variability of United States Online Rehabilitation Protocols for Proximal Hamstring Tendon Repair. *Orthopaedic Journal of Sports Medicine* 2018;6(2) doi: 10.1177/2325967118755116

66. Hasson F, Keeney S, McKenna H. Research guidelines for the Delphi survey technique. *Journal of Advanced Nursing* 2000;32(4):1008-15.

67. Jünger S, Payne SA, Brine J, et al. Guidance on Conducting and REporting DElphi Studies (CREDES) in palliative care: Recommendations based on a methodological systematic review. *Palliat Med* 2017;31(8):684-706. doi: 10.1177/0269216317690685 [published Online First: 2017/02/14]

68. Eysenbach G. Improving the quality of Web surveys: the Checklist for Reporting Results of Internet E-Surveys (CHERRIES). *Journal of medical Internet research* 2004;6(3):e34-e34. doi: 10.2196/jmir.6.3.e34

69. Powell C. The Delphi technique: Myths and realities. *Journal of Advanced Nursing* 2003;41(4):376-82. doi: 10.1046/j.1365-2648.2003.02537.x

70. Hsu CC, Sandford BA. The Delphi technique: Making sense of consensus. *Practical Assessment, Research and Evaluation* 2007;12(10):1-8.

71. de Villiers MR, de Villiers PJT, Kent AP. The Delphi technique in health sciences education research. *Medical Teacher* 2005;27(7):639-43. doi: 10.1080/13611260500069947

72. Harper D, Thompson AR. Qualitative Research Methods in Mental Health and Psychotherapy: A Guide for Students and Practitioners2011.

73. Fink A, Kosecoff J, Chassin M, et al. Consensus methods: characteristics and guidelines for use. *American journal of public health* 1984;74(9):979-83. doi: 10.2105/ajph.74.9.979

74. Fuller CW, Ekstrand J, Junge A, et al. Consensus statement on injury definitions and data collection procedures in studies of football (soccer) injuries. *Clinical Journal of Sport Medicine* 2006;16(2):97-106. doi: 10.1097/00042752-200603000-00003

75. Griffin DR, Dickenson EJ, O'Donnell J, et al. The Warwick Agreement on femoroacetabular impingement syndrome (FAI syndrome): An international consensus statement. *British Journal of Sports Medicine* 2016;50(19):1169-76. doi: 10.1136/bjsports-2016-096743

76. Shrier I. Consensus statements that fail to recognise dissent are flawed by design: a narrative review with 10 suggested improvements. *British Journal of Sports Medicine* 2020:bjsports-2020-102545. doi: 10.1136/bjsports-2020-102545

77. Blazey P, Crossley KM, Ardern CL, et al. It is time for consensus on 'consensus statements'. *British Journal of Sports Medicine* 2022;56(6):306. doi: 10.1136/bjsports-2021-104578

78. Verhagen AP, De Vet HCW, De Bie RA, et al. The Delphi list: A criteria list for quality assessment of randomized clinical trials for conducting systematic reviews developed by Delphi consensus. *Journal of Clinical Epidemiology* 1998;51(12):1235-41. doi: 10.1016/S0895-4356(98)00131-0

79. Huisstede BMA, Hoogvliet P, Henk Coert J, et al. Multidisciplinary consensus guideline for managing trigger finger: Results from the European HANDGUIDE study. *Physical Therapy* 2014;94(10):1421-33. doi: 10.2522/ptj.20130135

80. Kleynen M, Braun SM, Bleijlevens MH, et al. Using a Delphi technique to seek consensus regarding definitions, descriptions and classification of terms related to implicit and explicit forms of motor learning. *PLoS ONE* 2014;9(6) doi: 10.1371/journal.pone.0100227

81. De Vos RJ, Reurink G, Goudswaard GJ, et al. Clinical findings just after return to play predict hamstring re-injury, but baseline MRI findings do not. *Br J Sports Med* 2014;48(18):1377-84. doi: 10.1136/bjsports-2014-093737 [published Online First: 2014/07/20]

82. Orchard J. What role for MRI in hamstring strains? An argument for a difference between recreational and professional athletes. *British journal of sports medicine* 2014;48(18):1337-38. doi: 10.1136/bjsports-2014-093900

83. Hamstrings - Guidelines for MR Imaging of Sports Injuries: European Society of Skeletal Radiology Sports Sub-Committee, 2016.

84. Klauser AS, Tagliafico A, Allen GM, et al. Clinical indications for musculoskeletal ultrasound: A Delphi-based consensus paper of the European society of musculoskeletal radiology. *Eur Radiol* 2012;22(5):1140-48. doi: 10.1007/s00330-011-2356-3

85. Sconfienza LM, Albano D, Allen G, et al. Clinical indications for musculoskeletal ultrasound updated in 2017 by European Society of Musculoskeletal Radiology (ESSR) consensus. *Eur Radiol* 2018;28(12):5338-51. doi: 10.1007/s00330-018-5474-3

86. Barcelona F. Muscle Injuries Clinical Guide 3.0. 2015. https://muscletechnetwork.org/wp-content/uploads/2015/04/MUSCLE-INJURIES-CLINICAL-GUIDE-3.0-LAST-VERSION.pdf.

87. Messina C, Bignotti B, Tagliafico A, et al. A critical appraisal of the quality of adult musculoskeletal ultrasound guidelines using the AGREE II tool: an EuroAIM initiative. *Insights Imaging* 2017;8(5):491-97. doi: 10.1007/s13244-017-0563-4

88. De Smet AA, Best TM. MR imaging of the distribution and location of acute hamstring injuries in athletes. *AJR Am J Roentgenol* 2000;174(2):393-9. doi: 10.2214/ajr.174.2.1740393 [published Online First: 2000/02/05]

89. Slavotinek JP, Verrall GM, Fon GT. Hamstring injury in athletes: using MR imaging measurements to compare extent of muscle injury with amount of time lost from competition. *AJR Am J Roentgenol* 2002;179(6):1621-8. doi: 10.2214/ajr.179.6.1791621 [published Online First: 2002/11/20]

90. Crema MD, Guermazi A, Reurink G, et al. Can a clinical examination demonstrate intramuscular tendon involvement in acute hamstring injuries? *Orthopaedic Journal of Sports Medicine* 2017;5(10) doi: 10.1177/2325967117733434

91. Koulouris G, Connell D. Evaluation of the hamstring muscle complex following acute injury. *Skeletal Radiology* 2003;32(10):582-89. doi: 10.1007/s00256-003-0674-5

92. Allen GM. The use of ultrasound in athletes. *Eur J Radiol* 2018;109:136-41. doi: 10.1016/j.ejrad.2018.10.028 [published Online First: 2018/12/12]

93. Nazarian LN. The top 10 reasons musculoskeletal sonography is an important complementary or alternative technique to MRI. *American Journal of Roentgenology* 2008;190(6):1621-26. doi: 10.2214/AJR.07.3385

94. Bodendorfer BM, Curley AJ, Kotler JA, et al. Outcomes After Operative and Nonoperative Treatment of Proximal Hamstring Avulsions: A Systematic Review and Meta-analysis. *American Journal of Sports Medicine* 2018;46(11):2798-808. doi: 10.1177/0363546517732526

95. Martin RL, Cibulka MT, Bolgla LA, et al. Hamstring Strain Injury in Athletes. *Journal of Orthopaedic and Sports Physical Therapy* 2022;52(3):CPG1-CPG44. doi: 10.2519/jospt.2022.0301