London International Consensus and Delphi study on Hamstring Injuries.

Part 2: Operative Management

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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

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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.

Ricci Plastow drafted the initial manuscript for Surgery. Babar Kayani, Bruce Paton, Noel Pollock and Fares Haddad contributed significant drafting comments and edits. Other authors were all responsible for minor edits. BP, FSH, JM were responsible for research and survey design and facilitated the consensus meeting days. With GK, DW, FSH leading discussion.

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

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Key Points

1. Indications for operative intervention of hamstring injuries include: gapping and loss of tension at the zone of tendinous injury; symptomatic displaced bony avulsions; and proximal free tendon injuries with functional compromise not responsive to non-operative treatment.
2. Surgical intervention has the capacity to restore anatomy and function and may reduce the risk of injury recurrence.
3. Elite level athletes with severe grade musculotendinous junction and distal hamstring injuries demanding return to previous sporting level and a low risk of reinjury, merit surgical consideration as well as the non-surgical rehabilitation to achieve their specific demands.
4. Further research is warranted to refine criteria for surgical intervention and the decision-making process.

Abstract:

Introduction: The key indications for surgical repair of hamstring injuries (HSI) remain unclear in the literature due to a lack of high-level evidence and expert knowledge. The 2020 London International Hamstring Consensus meeting aimed to highlight clear surgical indications and to create a foundation for future research.

Methods: A literature review was conducted followed by a modified Delphi process, with an international expert panel. Purposive sampling was used with 2 rounds of online questionnaires and an intermediate round involving a consensus meeting. The initial information gathering (round 1) questionnaire was sent to 46 international experts, which comprised open ended questions covering decision-making domains in HSI. Thematic analysis of responses outlined key domains, which were evaluated by a smaller international subgroup (n=15) comprising clinical academic sports medicine physicians, physiotherapists, and orthopaedic surgeons in a consensus meeting. After group discussion of each domain, a series of consensus statements were prepared, debated and refined. A round 2 questionnaire was sent to 112 international hamstring experts to vote on these statements and determine level of agreement. The consensus threshold was set a priori at 70% agreement.

Results: Round 1 and 2 survey respondents were 35/46 (76%) and 99/112 (88.4%), respectively. The consensus group agreed that the indications for operative intervention included: gapping at the zone of tendinous injury (87.2% agreement) and loss of tension (70.7%); symptomatic displaced bony avulsions (72.8%); and proximal free tendon injuries with functional compromise refractory to non-operative treatment (72.2%). Other important considerations for operative intervention included: the demands of the athlete/patient and the expected functional outcome (87.1%) based on the anatomy of the injury; the risk of

functional loss/performance deficit with non-operative management (72.2%); and the capacity to restore anatomy and function (87.1%).
Further research is needed to determine whether surgery can reduce the risk of reinjury as consensus was not reached within the whole group (48.2%) but was agreed by surgeons (70%) in the cohort. The consensus group did not support the use of corticosteroids or endoscopic surgery without further evidence.

Conclusions These guidelines will help standardise treatment of hamstring injuries, specifically the indications and decision-making for surgical intervention.

Background

Hamstring injuries (HSI) are the most common injuries sustained in competitive sports and high-speed running, with rates as high as 26% of all injuries.[1-3] These injuries are also increasingly being diagnosed in the ageing population who want to remain physically active. HSI may lead to significant functional compromise, scarring to adjacent neurological structures causing 'hamstring syndrome' and premature retirement from sporting activity.[4-6] The majority of these injuries can be treated non-operatively, however, more severe, high-grade injuries may merit surgical intervention. These injuries are potentially career-threatening at the elite level with significant hamstring isokinetic strength deficits up to 38% reported after proximal hamstring avulsion [7-9] when compared to the uninjured leg with patients treated non surgically. Reinjury rates vary greatly in the literature from 0-63% in severe graded tears when treated non-surgically.[10-14] We present a review of the literature to outline our current understanding of HSI surgical indications and identify knowledge gaps, followed by an international expert Delphi study to advance the treatment of HSI.

Surgical Repair of Proximal Hamstring Avulsions

There is considerable literature supporting surgical repair of displaced complete proximal hamstring avulsions. The Wood classification was introduced in 2008[15] and recommended this treatment after review of 71 patients showing improved patient satisfaction, functional outcome scores and return to sport. Since then, many case series have followed and a recent meta-analysis by Bodendorfer et al reviewed 795 high-grade proximal HSI and found that operative treatment had significantly higher patient satisfaction (90.8% vs 52.9%) and hamstring strength (85.0% vs 64.0%) compared to non-operative treatment.[7] A further systematic review showed similar improved outcomes with the addition of higher return to sport in surgical repair (94.5%) versus non operative cases (54.2%)[16]. The two largest non-operative case series[9 17] included in the review had only 24 patients together with an average age of 58.9 (32.5-76.5) and 50.8 years. Pihl et al[18] have shown less sporting activity per week in a non-operative group of 2.7 hours versus 5.2 hours in the surgical group. However, a recent prospective study noted comparable clinical outcomes at 1 year between operative and non-operative treatment when using a shared decision making model in patients with complete (≥1 proximal tendon (90% both conjoint and semimembranosus)) hamstring avulsions.[19] Patient specific demands and requirements therefore should be considered in the decision making process when looking at surgical indications. Lower demand patients may want to consider non operative treatment if daily function is not significantly affected. High demand athletes, however, cannot accept decrements in strength or performance.

Partial Proximal Hamstring Avulsions

Partial avulsions have traditionally been managed non operatively and only surgically repaired if refractory to a period of pain free strength-based rehabilitation.[20-22] This can cause significant loss in function for some athletes and older individuals where 'proximal hamstring syndrome' has been reported[6 21 23]. Lempainen et al[21] studied 48 cases of proximal partial avulsion with 18 athletes unable to return to pre injury sporting level. Following surgical repair 87% of athletes were able to return to previous sporting level by 5 months (range 1-12 months).

Musculotendinous Junction and Intramuscular tendon injuries

MTJ injuries have been traditionally treated non operatively with varying success in return to sport timing and recurrence of injury rates. There is evidence that surgical repair in proximal and distal high grade MTJ injuries can return athletes to their previous level of sport with a low risk of recurrence.[20 24 25]Ayoub et al[20] have shown in 41 high level athletes with severe grade proximal biceps femoris MTJ injuries that 100% return to preinjury level at 13.4 ± 5.1 weeks. Only 4.8% of patients had reinjury confirmed in the hamstring complex[26]. Kayani et al[24] have shown similar results in distal biceps femoris injuries traditionally treated non operatively with 34 professional athletes all returning to full sporting activity at 11.7 ± 3.6 weeks. There were no cases of reinjury at 1 year follow up.

Pollock et al[26] demonstrated a longer return to sport time of 84 days with intramuscular tendon injuries versus 10 days in minor grade injuries. They also showed a higher risk of reinjury up to 57% in athletes with severe proximal and distal grade 3c injuries. A follow up study, after a change in rehabilitation philosophy, demonstrated lower rates of reinjury in these types of tear, with zero reinjuries in elite level track athletes with intramuscular tendon tears[10]. However, both these elite athlete studies only had 7 athletes in the 3c categorisation highlighting the low-level evidence available to help with decision making. A larger study in

64 footballers with intramuscular tendon injury demonstrated no change in 1-year reinjury rate when compared with hamstring injuries that did not involve the tendon.[13] There was also no change in those tendon injuries that were associated with loss of tension/waviness. This variation reinforces the need for the Delphi consensus process until higher levels of evidence are obtained.

Timing of Surgical Repair

The timing of surgical repair can significantly influence patient outcomes, with acute intervention reducing return to sport timing and complication rates.[7 16 27] A meta-analysis undertaken by Bodendorfer et al found that surgical intervention for proximal hamstring tears within 8 weeks of injury was associated with reduced sciatic nerve complication rates compared to surgery after 8 weeks of injury (3.09 Vs 6.61%).[7] Subbu et al reported on outcomes in 108 patients undergoing surgical treatment of HSI, and found average time for return to play was 16 weeks with acute repairs compared to an average time of 29 weeks in delayed repairs over 6 months.[27] Therefore, if deciding on operative intervention it seems prudent to perform surgery early to prevent more technically difficult procedures with higher risk and longer recovery times.

Distal Hamstring Injuries

Distal HSI have been under reported in the literature with the largest surgical review including only 18 patients by Lempainen et al. This broadly included complete avulsions through to musculotendinous injuries refractory to rehabilitation. Mean (±SD) overall time to return to sport was 4.9 ± 3.3 months suggesting these injuries may also be considered for surgical repair[28]. Sonnery-Cottet et al have shown distal injuries refractory to non-surgical rehabilitation RTS on average 3.4 months (range, 2-5 months) following surgical repair

highlighting the need for surgical consideration. Several case series have reinforced the option of surgical repair for distal hamstring avulsions and MTJ injuries.[24 25 29]

Summary

With limited comparative studies and existing guidelines on the treatment of hamstring injuries, the 2020 London International Hamstring Consensus meeting was convened with the aim of standardising treatment and decision-making of hamstring injuries. This utilised the existing clinical evidence and expert opinion through a Delphi process to better establish guidelines for the diagnosis and classification (Part 1); operative management (Part 2); and rehabilitation of patients with hamstring injuries (Part 3). This paper reports the results for operative management (Part 2).

Methods

We carried out a literature review using the below search strategy to include all areas relevant to the four consensus domains described.

Search Strategy

A systematic literature search was performed up to January 2020 in PubMed, CINAHL, Cochrane library, EMBASE. The following keywords were used: ‘‘hamstring,’’ ‘‘avulsion,’’ ‘‘rupture,’’ ‘‘semitendinosus,’’ ‘‘semimembranosus,’’ ‘‘biceps femoris,’’ Boolean operators ‘‘OR’’ and ‘‘AND’’ were used to combine synonyms and categories. No methodical quality tool was used to assess the articles as we did not want to exclude research that may be valuable in discussion. 1626 articles were identified and reduced to 115 after abstract review. 31 articles were added following article reviews and expert knowledge from panel members. The 146 articles were used to publish a current concepts review[30] in preparation for a

modified Delphi design, including a global panel of experts, with the aim of reaching a consensus on surgical indications for HSI.

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 operative Management 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[31]. 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[32 33] , injury prevention[34] and aspects of management of hamstring injury, such as return to play [35 36] but operative management of hamstring injuries may also benefit from this approach, particularly the optimum use and indication for surgical management.[37]

The description of our modified Delphi methods is described below, following guidance on Delphi studies[38 39] and web survey design(the Checklist for Reporting Results of Internet E-Surveys(CHERRIES)),[40] 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[41] 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 (including decision-making around surgical management). 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.[42]

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

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, surgeons and non-surgeons were included but asked to answer only those survey questions related to their scope of professional practice and fields of expertise. (see methodology supplement). Domains of classification and rehabilitation were also identified and experts were chosen, with sufficient expertise in these combined areas as well as. surgery, post-surgical recovery.

Coaches and trainers comprised 6% of the experts for the final survey but answered rehabilitation rather than surgical sections of the 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,[42] 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 of 20-40% was predicted. The study aimed to follow research recommendations with opinion-based research questions.[38 43]

Modified Delphi process

The study comprised two rounds of a purposive digital survey interspersed with a face-to-face meeting round. 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 members of the surgical author team completed and published a review of the evidence.[5] 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)[40] and the reporting standard for conducting and reporting Delphi studies (CREDES)[39] to avoid bias. The responses from the initial survey were collated and analysed with a thematic and factor analysis[44] (see table 1 in methods supplement). The expert panel identified four key domains and key questions for these domains - classification and diagnosis, surgery, rehabilitation and

return to running and sport. This paper deals with results of the surgery domain, with subsequent papers covering classification and rehabilitation. The questions 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.[45] This approach has been followed in other consensus projects.[46] [47] In discussions, facilitators maintained impartiality and ensured balanced discussion to avoid "eminence bias".[38] 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".[48] [49]

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. 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 table 3 for the list of statements relating to surgery.

An a priori criterion threshold was established of 70%, with ≥70% agreed/yes responses constituting statement acceptance. 70% has been used successfully by other Delphi studies.[50-52] Fifteen statements around surgical management of HSI reached sufficient group agreement. The final Delphi round involved a further online survey, to test these statements with 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).

The experts in the final round voted on statements and ranked their key decision-making factors or justifications related to the domain areas (including surgery) found in the round 1 survey. See table 3 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 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/ dissenting views were collated and analysed. Non surgeons were permitted to answer the surgical sections, as many non-surgical clinicians must diagnose, consider indications, make referral for surgical opinion or rehabilitate after hamstring surgery.

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 or from 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

The methodology and sample reporting information from the consensus are available online in the online supplementary file and paper 1 of this three-part series. A flow chart of the rounds of the survey is included below in figure 1 (Figure 2 supplementary file) and contains participant numbers and response rates. The composition and characteristics of the participants at each round (is also included below in table 1 (table 2 supplementary file).

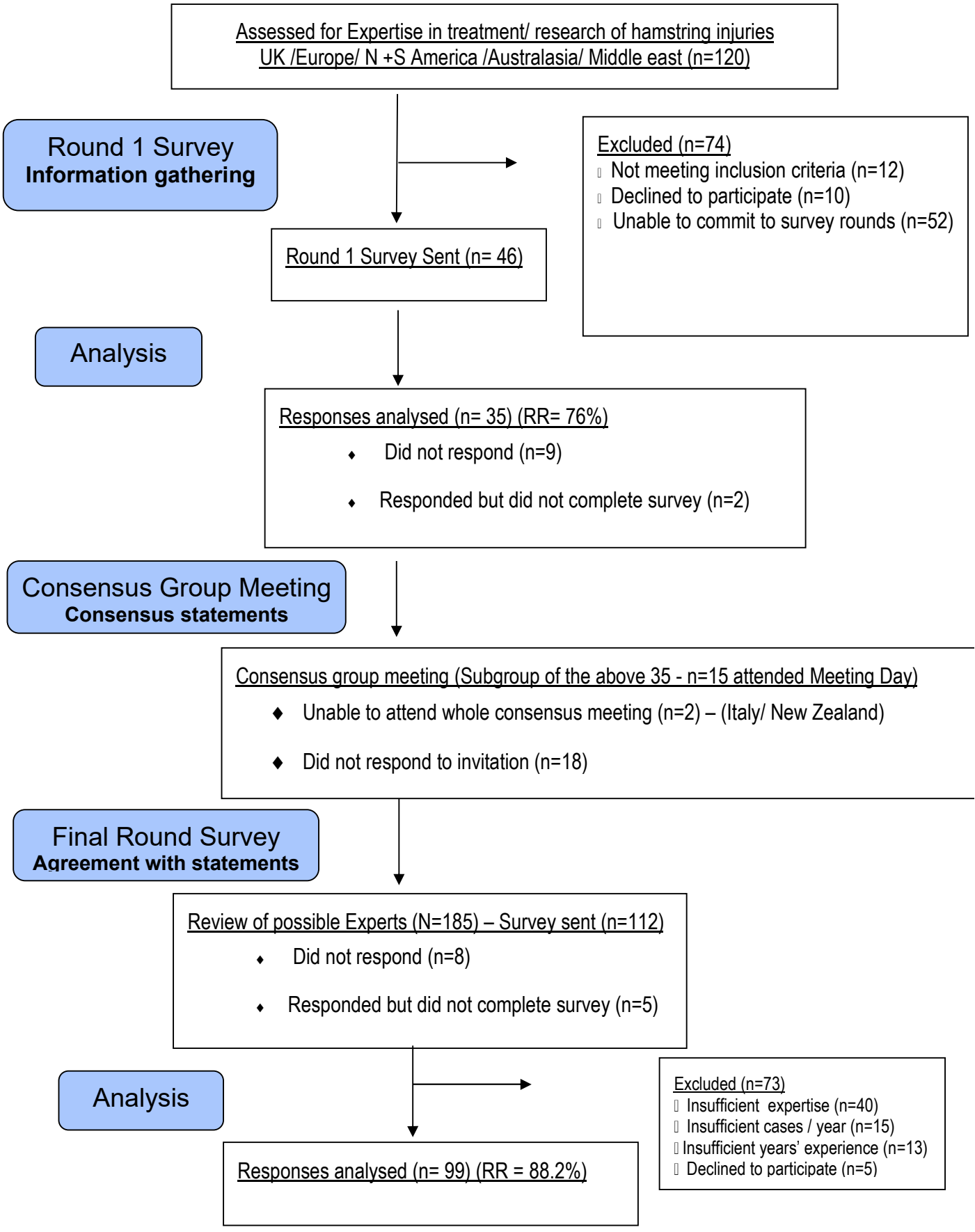

Figure 1: Flow diagram of participants and response rates (RR)

Table 1 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%)**
	0-4	**1(2.9%)**		**6 (6%)**
	5-9	**6 (17.1%)**		**25 (24%)**
	10-14	**7 (20%)**		**12 (12%)**
	15-19	**10 (28.6%)**		**13 (13%)**
	20 or 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**			**17 (17%)**
	5-9	**5 (14.3%)**		**13 (13%)**
	10-14	**8 (22.9%)**		**22 (21%)**
	15-20	**9 (25.7%)**		**23 (23%)**
	more than 20	**4 (11.4%)**		**24 (24%)**
Highest academic	**Bachelor/Diploma**	**9 (25.7%)**		**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

The questions the experts gave us in the surgery section of the round 1 information gathering survey are presented in table 2. The consensus statements below related to surgery (see table 3 below) highlight agreement of over 70% between panel members, which is an established value used for this process in the literature.[53 54]

Consensus Statements:	Agreement
Factors that drive surgical intervention include:	
- Gapping at the zone of tendinous injury	87.2%
- Loss of muscle tension	70.7%
Criteria for surgical intervention in the proximal free tendon injuries include:	
- Loss of muscle and tendon tension which results in a gap	83.5%
- Risk of functional loss / performance deficit with non-operative management	72.2%
The indications for surgery in hamstring injuries are dependent on the anatomy of the injury, the demands of the athlete/patient and the expected functional outcome	87.1%
Surgical management has the capacity to restore anatomy and function	87.1%
Displaced bony avulsions of the ischium should be managed operatively if symptomatic	72.8%
Corticosteroid injections have no role in the treatment of undisplaced hamstring avulsion injuries	80.0%

Table 4 shows a breakdown of the responses by profession and the larger group which includes all clinicians and /or researchers . This highlights the difference in opinion on some statements reaching consensus agreement over 70%. We also highlight areas where agreement was not achieved due to significant disagreement between disciplines, highlighting the need for further research. We have included a brief sample of typical responses and areas of disagreement and dissent.

Table 2 ***What are the questions you would most want answered on Surgery for HSI?***

Domain Area (Theme)	***responses***	***Typical responses***
Outcomes	***8***	Does it affect functional outcomes?
Indications	***9***	What level of tendon disruption requires surgery?
Surgery vs Conservative	***7***	Is it more effective than conservative management?
Long term effects	***4***	What are the long-term outcomes for elite athletes having had surgery?
Surgery & RTS	***3***	Does it affect time to return preinjury level of sporting activity?
Recurrence rate	***3***	Does surgery reduce reinjury?
Techniques	***3***	Can surgical drainage of large intramuscular haemorrhage improve recovery without repair of muscle?
Timing post injury	***3***	How soon after certain pathologies should surgery be undertaken?
Rehabilitation post-Surgery	***1***	Development of an evidence-based rehabilitation protocol.
Terminology	***1***	Consistent terminology much-needed
Injury factors	***1***	Can we grade injuries needing surgery
Surgery never required	***1***	
Relationship w classification	***1***	When is surgery indicated for particular hamstring classifications?
Total	***45***	

Table 3. Consensus statements and percentage agreement for round 2 survey – Global expert Panel - **Surgery**

Statements related to domain of Surgery		responses	not answered	TRUE	FALSE	Undecided	Samples of typical responses - discussion points or areas of disagreement/dissent
Factors that drive surgical intervention include: -	***Previous hamstring harvest or HSI***	**83**	**32**	**26.5%**	**38.6%**	**34.9%**	I think all of these are relevant but none of them determine/ drive/ necessarily require surgical intervention. Undecided if any of these factor into surgical intervention unless coupled with poor functional outcomes (e.g., lack of rehab progress etc). The level of athlete and stage of competition are also factors to consider.
	Recurrent Injury	**83**	**32**	**33.7%**	**38.6%**	**27.7%**	All factors should be considered, and the importance of each factor differs depending on type of injury and type of patient. Recurrence: not been proven that surgery will reduce recurrence rate. I am not aware of any convincing, high quality scientific data on the success of surgery following hamstring injuries.
	Injuries with a high recurrence rate	**84**	**31**	**40.5%**	**28.6%**	**31.0%**	
	Gapping at the zone of injury	**86**	**29**	**87.2%**	**2.3%**	**10.5%**	This was felt to be the main driver. Degree of tendon retraction important the main indication for surgery if complete free tendon (BA grade 4) for grade intra tendon injury > 50% of the CSA. High (3b) grade injuries can make a complete return to sport.
	Loss of tension	**82**	**33**	**70.7%**	**13.4%**	**15.9%**	Loss of tension is evident in most injuries, as an acute sign, but improves with healing, it is less important than size of gap and loss of tendon tension more important than myofascial tension
The indications for surgery in hamstring injuries are dependent on: - the anatomy of the injury the demands on the athlete/patient and the expected functional outcome.		**85**	**30**	**87.1%**	**9.4%**	**3.5%**	I don't know that we have enough information now to be able to say with any confidence who is truly in need of surgery (if anyone), Until we simply have decent outcome studies looking at usual care, and something comes out of the data, we're guessing. Dependent on the anatomy but not the demands of the athlete/ patient or the expected functional outcome. Function, recurrence, and lack of progress are the main ones for me. Failure of conservative care would seem to be the only indication at the moment as near as I can tell. This is true but just in some type of injuries (e.g., those affecting the free tendon). Anatomy yes If conjoint tendon full rupture in elite athlete, I would advocate surgery. Semimembranosus full rupture would advocate conservative. Degree of tendon retraction important in ST or BF rupture. If small and healing possible then would trial conservative first.
Surgical management has the capacity to: -	***Speed up recovery timescales***	**86**	**29**	**36.0%**	**36.0%**	**27.9%**	Speed up: not supported by literature/surveys. Current protocols are very slow. For Speed up recovery timescales = I would say speeds up and gives more consistent/ predictable recovery which gives us good outcomes. Only for high grade avulsions.
	Restore Anatomy and function	**85**	**30**	**87.1%**	**1.2%**	**11.8%**	We need more research into this, but potentially true as surgery is often undertaken with failed conservative management.
	Reduce risk of recurrence	**85**	**30**	**48.2%**	**17.6%**	**34.1%**	Need more research into this but potentially true as surgery often undertaken with failed conservative management. Reduced recurrence has been the experience in our cohort. Recurrence: not been proven that surgery will reduce recurrence rate. I have seen reinjury at different location following grade 4 injuries and free tendon repair. Reoccurrence will be hugely influenced by post operative rehabilitation and a progressive RTP. Surgery will restore anatomy, but an injury may reoccur due to ineffective rehabilitation. Recurrent injury only relevant if recurrent tendon or previous surgery, or sciatic nerve issue requiring neurolysis. Reduces recurrence we believe but less predictability with conservative treatment in high grade tendon injury.
Hamstring fixation should be performed endoscopically		**84**	**31**	**9.5%**	**25.0%**	***65.5%***	Need better field of view - attachment footprint is too large and sciatic nerve involvement should be checked
The reporting of hamstring recurrence should be based on the IOC criteria and cover a two-year time frame		**84**	**31**	**53.6%**	**11.9%**	**34.5%**	Long term outcomes certainly would make for a fairer appraisal of benefits. Assume this in reference to the Methodological consensus statement on reporting of injuries? I think as we standardize our approach, this is certainly the most relevant and up to date reference for reporting. Yes, for research purposes but 2 years is a long time. I would prefer 1 season
Undisplaced bony hamstring avulsions DO NOT require immediate operative intervention		**81**	**34**	**50.6%**	**18.5%**	**30.9%**	There are several factors that contribute to this decision-making process, having a binary approach is too difficult. In addition, there needs clarity of what type of bony avulsion is being referenced. It depends on athlete characteristics. Function during rehab should dictate this.

							Need to be re-imaged and monitored closely.
Displaced bony avulsions of the ischium should be managed operatively if symptomatic		**81**	**34**	**72.8%**	**4.9%**	**22.2%**	Depends on function, how much displacement, and athlete level and characteristics.
Surgical intervention for bony avulsions of the ischium should be: -	***Internal fixation***	**78**	**37**	**46.2%**	**5.1%**	**48.7%**	It depends on the time frame and the fragment size, bone to bone healing is preferable. If the fragment is too small, non-union may develop with internal fixation and in this scenario resection and soft tissue repair is favoured.
	Resection of Avulsed bone and Soft Tissue Repair	**77**	**38**	**31.2%**	**14.3%**	**54.5%**	
Undisplaced soft tissue hamstring avulsions can be initially managed non operatively		**80**	**35**	**61.3%**	**7.5%**	**31.3%**	Depends on time frames and upcoming competitions. Maybe able to be managed non-operatively if time frames allow. However, surgery will help give an accurate RTP prediction. This is dependent on several factors such as extent of injury, which hamstring, playing position etc
Undisplaced proximal hamstring origin tears should be managed operatively in athletes		**79**	**36**	**32.9%**	**27.8%**	**39.2%**	We don't have RCTs,
Criteria for surgical intervention in the proximal free tendon injuries include	***loss of muscle and tendon tension which results in a gap***	**79**	**36**	**83.5%**	**1.3%**	**15.2%**	Dependent on size of gap, and the level of athlete?
	risk of functional loss / performance deficit with non-operative management	**79**	**36**	**72.2%**	**7.6%**	**20.3%**	Proven loss of function in a patient who has a thorough understanding of the outcomes of surgical and conservative care and the patient still wishes to undergo surgery. We don't have RCTs, tough one. Dependant on whether elite or recreational athlete.
The management of free tendon injuries with displacement differs from that of intramuscular tendon injuries where the overall fascial envelope is still intact		**79**	**36**	**69.6% ****	**6.3%**	**24.1%**	Intramuscular tendon injuries benefit from the 'scaffold' of surrounding muscular tissue I think free tendon injuries are a different type of injury than a hamstring injury with damage to the intramuscular tendon and require therefore specific treatment. The jury is still out on this. It would be a good topic for a well-coordinated multi-centre RCT.
Undisplaced soft tissue hamstring avulsions is there a role for	***corticosteroid injections***	**80**	**35**	**2.5%**	**80.0%**	**17.5%**	Evidence conflicting, but panel consensus disagreement on this statement.
	injecting Blood / Platelet Rich Plasma (PRP)?	**80**	**33**	**16.3%**	***50.0%***	**33.8%**	? PRP although evidence is weak at best. We have not used PRP but can see why it is worth consideration if you were going to trial conservative management.
	Other injections	**69**	**46**	**1.4%**	***53.6%***	**44.9%**	Dry needling. No conclusive evidence that these approaches improve outcomes.
Does haematoma aspiration have a role in	***avulsions***	**79**	**36**	**19.0%**	**40.5%**	**40.5%**	Perhaps large haematoma around the sciatic nerve - risk of fibrosis and adhesions.
	Tendon Injuries	**79**	**36**	**19.0%**	**41.8%**	**39.2%**	Injections/aspirations increase infection risk and haematomas often recur after aspiration. However, there may be. Has a role but precaution as the blood product may actually assist healing and fibrosis/ tear bridging. exceptions in case of very large or painful haematomas where the patient is fully informed and decides to take the risk. Only when it gives symptoms (content of haematoma is comparable to PRP).
	Other types of HSI	**78**	**37**	**28.2%**	**33.3%**	**38.5%**	Morel-lavallae lesion Contusions for symptomatic relief
There is a role for drainage of haematomas without surgery for hamstring muscle injuries and avulsions		**77**	**38**	**29.9%**	**32.5%**	**37.7%**	The haematoma being a space occupying lesion and preventing complete healing makes theoretical sense, but the few times we've tried it, the gap promptly refilled with blood despite firm compression bandaging. Maybe there's a technically better way to do this, but we've not figured it out yet. Hematoma potentially contributes to regeneration.

Table 4 – Round 2 Survey Consensus statement 4 – Responses split by profession

Surgery has the capacity to:		speed up recovery time frames				restore anatomy and function				prevent recurrence			
	N	agree	disagree	undecided	not answered	agree	disagree	undecided	not answered	agree	disagree	undecided	not answered
Orthopaedic surgeon	**20**	60.0%	15.0%	5.0%	20.0%	80.0%	0.0%	0.0%	20.0%	70.0%	0.0%	10.0%	20.0%
Sports Doctor	**22**	31.8%	31.8%	22.7%	13.6%	72.7%	4.5%	9.1%	13.6%	36.4%	22.7%	27.3%	13.6%
Physiotherapist	**44**	27.3%	38.6%	25.0%	9.1%	81.8%	0.0%	6.8%	11.4%	38.6%	15.9%	34.1%	11.4%
Researcher only	**8**	0.0%	25.0%	50.0%	25.0%	37.5%	0.0%	37.5%	25.0%	0.0%	25.0%	50.0%	25.0%
Athletic Trainer	**2**	0.0%	0.0%	0.0%	100.0%	0.0%	0.0%	0.0%	100.0%	0.0%	0.0%	0.0%	100.0%
General surgeon	**1**	0.0%	100.0%	0.0%	0.0%	100.0%	0.0%	0.0%	0.0%	0.0%	100.0%	0.0%	0.0%
Radiologist	**1**	0.0%	100.0%	0.0%	0.0%	100.0%	0.0%	0.0%	0.0%	100.0%	0.0%	0.0%	0.0%
General Practitioner	**1**	0.0%	0.0%	100.0%	0.0%	100.0%	0.0%	0.0%	0.0%	100.0%	0.0%	0.0%	0.0%
Scientific Director	**2**	0.0%	0.0%	100.0%	0.0%	0.0%	0.0%	100.0%	0.0%	0.0%	0.0%	100.0%	0.0%
Total	**101**	**30.7%**	**30.7%**	**23.8%**	**14.9%**	**73.3%**	**1.0%**	**9.9%**	**15.8%**	**40.6%**	**14.9%**	**28.7%**	**15.8%**
Unanswered Removed		**36.0%**	**36.0%**	**27.9%**		**87.1%**	**1.2%**	**11.8%**		**48.2%**	**17.6%**	**34.1%**	

Discussion

The 2020 London International Hamstring Consensus meeting was convened with the aim of standardising treatment and surgical decision making of hamstring injuries. The consensus group achieved agreement on six statements highlighted in the results section. We now discuss the agreed indications for surgery and the literature that supported these statements, the treatments that should be avoided and further research that is needed.

Agreed Indications for Surgery

The majority of hamstring injuries will be treated non-operatively, however high-grade injuries such as complete proximal avulsions may need surgical intervention. The consensus article on the diagnosis and classification systems highlights that anatomy of the injury is crucial in deciding when to operate on hamstring injuries. Wood et al classified proximal injuries into 6 types highlighting the significant differences in anatomy of injury and aid surgeons in treating each type differently.[15] Complete proximal avulsion injuries with displacement (type 5 and 6 injuries within Wood's classification)[15], generally warrant consideration for surgical repair.[7] The two largest series on non-operative management of proximal free tendon injuries within the systematic review highlight hamstring strength deficit and patient reported functional loss in patients affecting their return to sport.[9 17]

Hofmann et al[9] and Shambaugh et al[17] confirmed deficits in isometric hamstring strength in non-operatively managed complete avulsion injuries. RTS rates were 72% and 100% in the non-operative and operative groups respectively. The patients' functional demands are important in the decision making process. and elite sports people and high demand individuals with proximal free tendon injuries may be considered for surgery to prevent functional loss and performance deficits.

The consensus statements recommend that gapping at the injury site and loss of tension should result in consideration of surgical repair even if only one tendon is affected. Confusion has arisen in classification of proximal tendon avulsions when one or two tendons are involved, with varying terms such as partial or incomplete avulsion used to describe isolated semimembranosus or conjoined tendon injuries. The existing literature demonstrates that operative repair of proximal hamstring avulsion injuries with gapping present on MRI is associated with high levels of patient satisfaction, excellent functional outcomes and return to sport with low risk of recurrence. [7 15 16 30 55 56]

Lempainen et al have suggested an alternative MR classification, separating each tendon to allow surgical treatment of one tendon avulsions with gapping at the zone of injury in athletes.[57] The literature on isolated semimembranosus complete avulsions confirms improved patient outcomes and RTS when surgically repaired.[58] Askling et al when first describing the semimembranosus stretching injury highlighted poor return to sport with 47% retiring due to the injury[59], whilst Ayoub et al have proven with surgical repair the RTS rate was 95%.[58]

Type 2 musculotendinous junction (MTJ) and type 3 incomplete avulsions have traditionally been treated non-operatively when following the Wood classification system. The consensus group highlighted the importance of anatomical and functional outcome considerations when deciding on operative repair. While the aforementioned surgical outcomes with operative treatment for avulsion injuries are well-reported, recent studies have expanded these surgical indications to include central tendon injuries, musculotendinous injuries and distal hamstring injuries refractory to non-operative treatment.[20-22 24 25 59 60]

Small case series in elite athletes have suggested surgically repairing severe MTJ injuries (Type 2) may improve functional outcomes and facilitate early return to sporting activity[20 24 25 60]. Ayoub et al[20] presented the largest series of 64 proximal biceps femoris MTJ injuries surgically repaired in high level athletes with 100% returning to preinjury level of sport. Mean ± SD time from surgical intervention to return to sporting activity was 13.4 ± 5.1 weeks. This may suggest severe graded MTJ injuries in high-level athletes benefit from surgical repair. Sonnery-Cottet *et al.*[60] reviewed outcomes in ten athletes undergoing surgical repair of the musculotendinous junction that had failed a minimum of three months non-operative treatment. The study included six patients with proximal musculotendinous junction injuries and four patients with distal musculotendinous hamstring injuries. The authors reported that all ten patients returned to their preinjury level of activity at a mean 3.4 months (range, 2-5 months) after surgery, and no recurrence at mean follow-up time of 28.7 months. Without comparative groups treated non operatively however it is difficult for the consensus group to specify indications for surgery in each classification type. Shared decision making involving the patient and their demands will help direct surgery.

Lempainen et al[21] analysed 48 cases of partial proximal avulsions in athletes only, with 89% non operatively treated patients having unsatisfactory results and needing surgery. These type 3 injuries on the Wood classification have the recommendation of rehabilitation and surgery if symptoms persist. The consensus group recommends early surgery to restore function in patients such as Lempainen's group where 18 athletes could not participate in sport before surgical repair. Kayani et al[24] have shown in athletes that surgical repair of the distal biceps femoris MTJ injuries helps restore previous hamstring strength (93.1% Vs 63.1% pre op at 0º) with improved LEFS (64.5 Vs 27.2 pre op score).

The consensus group agreed that displaced bony avulsion of the ischium should be managed

operatively if symptomatic. Wood et al classified the bony apophysis avulsion type 1 injury within their system, with repair recommended if there was 1-2cm displacement. Other case series reinforce this idea with Kujala et al[61] describing displaced bony avulsion injuries developing fibrous scar tissue resulting in posterior thigh pain when sitting, also known as 'hamstring syndrome'.[6]

A recent systematic review of limited case series reported on 90 patients (mean age 16 years) with 100% RTS in patients treated non operatively with less than 1.5cm retraction and 100% RTS in patients treated surgically if over 1.5cm.[62] The main complication was non-union at 18% in the non-operative group. It is therefore recommended that symptomatic displaced avulsions who develop symptoms from non-union or excessive scar tissue from displacement should be treated operatively.

Distal hamstring injuries are under reported in the literature, but several studies have shown significant improvement in return to sport for athletes with distal hamstring injuries surgically repaired. [24 25 28 60] Knapik et al reported a systematic review of 22 distal biceps femoris injuries, including avulsion and musculotendinous junction injuries. After surgical repair, the mean time to return to sport was 4.2 ± 2.6 months for MTJ injuries and 6.4 ± 3.2 months for complete avulsion injuries.[29] Fourteen of the patients had ongoing symptoms preventing return to sport which was the indication for surgical repair. These high rates of failure to return to sport confirm the consensus statement that surgical repair may need consideration if there is risk of performance deficit with non-operative management.

<u>Treatment Not Recommended by the Consensus Group</u>

The group agreed that corticosteroid injections have no role in the treatment of undisplaced hamstring avulsion injuries (Level of agreement 80%). This is due to a lack of high-level research proving injections of any kind improve the outcome of avulsion injuries. Levine et

al[63] published data from the NFL suggesting steroid injections improved recovery time in players but without a control group this evidence is low level. We know that steroids have a detrimental effect on the initial healing phase of tendons and therefore we cannot recommend this treatment.[64]

Areas for Further Research

The consensus statements below did not reach agreement but highlight areas where further research is needed to improve our understanding of best practice. We feel it is important to include them to generate further debate and research.

Consensus Statement 8: Surgical management has the capacity to reduce the risk of recurrence.
Level of Agreement entire consensus group: Agree 48.2% Undecided 34.1% Disagree 17.6%
Level of Agreement Surgeons Only: Agree 70%

The majority of surgeons agreed surgical management can reduce risk of recurrence (70%), but other clinicians and researchers did not agree on this point. There is a debate within the sports medicine and orthopaedic community regarding the role of surgery in reducing risk of recurrence with low quality studies demonstrating variable recurrence rates for injuries managed with non-operative rehabilitation and with surgery. It is interesting to note that surgeons felt more strongly that surgery had the capacity to reduce recurrence whereas non-surgical clinicians and researchers did not. This may reflect a degree of confirmation bias regarding personal practice due to limited literature evidence.

A previous hamstring injury, increasing the risk of further hamstring injury by two-to-six times in many studies.[2 5 65] Arnason et al[2] highlighted previous injury in 306 male football

players across two seasons produced an odds ratio of 11.6 (3.5-39.0 95% CI) for developing recurrent injury. Pollock et al[26] using the BAMIC classification have shown that reinjury risk increases with the severity of injury up to 63% in athletes. Subsequently following a change in rehabilitation, they have shown 0% reinjury rate in 2021 in all intramuscular hamstring tendon injuries[66]. However, both of these studies had small numbers of tendon injuries. A potential limitation of the BAMIC classification is seen when grouping high grade 3c injuries together, ranging from greater than 50% cross sectional area (CSA) up to 99% of tendon CSA involvement (relative to maximum tendon CSA). MTJ injuries with 99% involvement may be more likely to require surgical repair. As discussed in part 1 of this consensus, we highlighted the need for classification of these high-grade injuries to evolve and other factors may be required to enable further classification and subsequent research to enhance decision making.

Musculotendinous injuries develop scar tissue to heal, and this creates loss of muscle tension and function.[67] With severe grade 3b/c injuries the volume of scar tissue developing can be significant. Previous biomechanical studies by Slider et al [68 69] have shown that scar tissue has inferior biomechanical strength when compared to native tendon tissue and less compliance during contraction when compared to muscle which can lead to reinjury and loss of tension in the hamstrings.[70] However, in a study of 108 athletes with hamstring injury no association between the presence of scar (fibrosis) on MRI and reinjury was found. [71]
The risk of recurrent injury is rarely mentioned in the literature following surgery with the largest series from Askling et al highlighting only one re rupture in 200 patients undergoing proximal avulsion repair.[72] Ayoub et al presented 64 cases of severe proximal MTJ injuries in athletes surgically repaired. They recorded 3 cases of re rupture (4.7%) at 29.2 months follow up (range, 24.0-37.1 months).[20] This is the largest series on MTJ injuries and demonstrates a good outcome and low reinjury rate.

Non-operative management of distal musculotendinous T junction injuries of the biceps femoris has been reported to be associated with high risk of recurrence.[73] Entwistle *et al.*[73] reviewed 106 MRI scans from 55 patients undergoing non-operative treatment of these injuries and reported injury recurrence in 57 cases (54%) within two years follow-up. Kayani et al however have shown with surgical repair in 34 professional athletes that 100% RTS with Mean time from surgical repair to full sporting activity being 11.76 +/- 3.6 weeks. This group had no reinjuries during the follow up period , in clear contrast to the high reinjury rate stated in the Entwistle et al paper.

Current evidence suggests wide variation in recurrence rates for non-surgical rehabilitation, whilst surgical repair offers significantly low rates for high grade injuries. The international panel of surgeons involved have now set up a registry database called PHAROS which will allow prospective data collection of hamstring repair outcomes. This will progress our knowledge and develop awareness of surgical outcomes, complications and the potential indications for surgery to assist in certain athletes or specific injuries.

Consensus Statement 9: Hamstring fixation should be performed endoscopically. Level of Agreement: Agree 9.8% Undecided 65.9%

The endoscopic technique is a new surgical technique[74 75] described for proximal avulsion repair, but we need further research comparing this to the current open technique with further understanding of the risks and benefits.

Consensus Statement 10: Surgical intervention for bony avulsions of the ischium should be: - Resection of avulsed bone and soft tissue repair. Level of Agreement: Agree 29.3% Undecided 56%

This surgical technique has been described in past literature[61 62] along with internal fixation of the bony fragment but only small case series and reports are available and therefore the best surgical technique is poorly understood. Further research is needed to compare techniques, outcomes and complication rates.

Limitations

The London international hamstring consensus meeting 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, sport, age and domain expertise in treatment of HSI comprising sufficient expertise to synthesise our consensus statements.

They comprised clinicians from Australia, Netherlands, Ireland and 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, and a digital alternative for attendance was not added. This may mean that many global 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 operative management, as this may encompass surgeons but also those referring for surgical opinion or rehabilitation after surgery. The criteria chosen for expertise were harder to establish, academic criteria were thought to be important, but very few experts had published on operative management, although they performed or referred for surgery. Many trainers and coaches had less expertise in the operative management domain and were not included as experts, although in some countries and sports, trainers and coaches will have this expertise. Choosing criteria for expertise is difficult for any Delphi study and this represents one weakness of this methodology.[49] While we trusted the survey respondents to complete only those fields that encompassed their expertise, it may be possible that some respondents completed sections that were outside their areas 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 gave, and adapted subsequent rounds based on their responses. We did not include athletes/ patients in these surveys, as it was thought that domain specific professional knowledge and expertise was required, but ultimately, athletes / patients are the experts on their own injuries. The experience gained from sustaining multiple hamstring injuries and having to decide how to manage and rehabilitate them , make the athletes arguably the most experienced experts. Statements suggesting athletes should lead and guide decision-making in their own treatment received high (unanimous) LOA. Further work (and future delphi studies) must include athletes, coaches, patients 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). This was due to less publicly available information directing to women experts and lower rates of female publication in HSI (especially operative management- with less female orthopaedic surgeons). Although we attempted to invite these clinicians/ researchers, the response rates were 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.

With new standardised scoring systems such as the SHORE and PHAT tools being created, we hope to see higher level research on the best treatment for hamstring injuries. One multicentre randomised controlled trial is currently recruiting patients to operative and non-operative treatment arms for proximal avulsion injuries.[76] This will potentially improve our understanding on when to offer surgical repair along with the Proximal Hamstring Avulsion Registry (PHAROS) which is gathering prospective data on hamstring repair outcomes internationally.

Conclusion

The London International Hamstring Consensus meeting agreed that the indications for operative intervention included the following: gapping and loss of tension at the zone of injury; symptomatic displaced bony avulsions; and proximal free tendon injuries with functional compromise refractory to non-operative treatment. It will depend on the anatomy

of the injury and the demands of the patient/athlete whether surgery is indicated but it has the capacity to restore anatomy and function. Further research is needed to help decide if surgical repair reduces the risk of reinjury and to understand risks and complications of surgery. The consensus group did not support the use of corticosteroids or endoscopic surgery currently. Emerging evidence reinforces the consensus statements with improved hamstring strength and return to sport. Not all hamstring injuries will need surgical repair, but certain factors highlighted in this consensus will aid in decision making for clinicians treating hamstring injuries.

References

1. Askling CM, Tengvar M, Thorstensson A. Acute hamstring injuries in Swedish elite football: A prospective randomised controlled clinical trial comparing two rehabilitation protocols. *British Journal of Sports Medicine* 2013;47(15):953-59. doi: 10.1136/bjsports-2013-092165
2. Arnason A, Andersen TE, Holme I, et al. Prevention of hamstring strains in elite soccer: an intervention study. *Scand J Med Sci Sports* 2008;18(1):40-8. doi: 10.1111/j.1600-0838.2006.00634.x [published Online First: 2007/03/16]
3. Askling CM, Koulouris, G., Saartok, T., Werner, S., & Best, T. M. Total proximal hamstring ruptures: Clinical and MRI aspects including guidelines for postoperative rehabilitation. *Knee Surgery, Sports Traumatology and Arthroscopy* 2013;21:515-33. doi: Doi.org/10.1007/s00167-012-2311-0.
4. Askling CM, Tengvar M, Saartok T, et al. Proximal hamstring strains of stretching type in different sports: Injury situations, clinical and magnetic resonance imaging characteristics, and return to sport. *American Journal of Sports Medicine* 2008;36(9):1799-804. doi: 10.1177/0363546508315892
5. 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]
6. Puranen J, Orava S. The hamstring syndrome. A new diagnosis of gluteal sciatic pain. *Am J Sports Med* 1988;16(5):517-21. doi: 10.1177/036354658801600515
7. Bodendorfer BM, Curley AJ, Kotler JA, et al. Outcomes After Operative and Nonoperative Treatment of Proximal Hamstring Avulsions: A Systematic Review and Meta-analysis. *Am J Sports Med* 2018;46(11):2798-808. doi: 10.1177/0363546517732526 [published Online First: 2017/10/11]
8. Harris JD, Griesser MJ, Best TM, et al. Treatment of proximal hamstring ruptures - a systematic review. *INT J SPORTS MED* 2011;32(7):490-5. doi: 10.1055/s-0031-1273753 [published Online First: 2011/05/13]
9. Hofmann KJ, Paggi A, Connors D, et al. Complete Avulsion of the Proximal Hamstring Insertion: Functional Outcomes After Nonsurgical Treatment. *J Bone Joint Surg Am* 2014;96(12):1022-25. doi: 10.2106/jbjs.M.01074

10. 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]
11. 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. *British Journal of Sports Medicine* 2016;50(5):305-10. doi: 10.1136/bjsports-2015-094657
12. Green B, Bourne MN, van Dyk N, et al. Recalibrating the risk of hamstring strain injury (HSI) - A 2020 systematic review and meta-analysis of risk factors for index and recurrent HSI in sport. *British Journal of Sports Medicine* 2020:bjsports-2019-100983. doi: 10.1136/bjsports-2019-100983
13. 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
14. Van Der Made AD, Almusa E, Whiteley R, et al. Intramuscular tendon involvement on MRI has limited value for predicting time to return to play following acute hamstring injury. *British Journal of Sports Medicine* 2018;52(2):83-88. doi: 10.1136/bjsports-2017-097659
15. 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]
16. Buckwalter J, Westermann R, Amendola A. Complete proximal hamstring avulsions: is there a role for conservative management? A systematic review of acute repairs and non-operative management. *Journal of ISAKOS: Joint Disorders & Orthopaedic Sports Medicine* 2017;2(1):31-35. doi: 10.1136/jisakos-2016-000105
17. Shambaugh BC, Olsen JR, Lacerte E, et al. A Comparison of Nonoperative and Operative Treatment of Complete Proximal Hamstring Ruptures. *Orthop J Sports Med* 2017;5(11):2325967117738551. doi: 10.1177/2325967117738551 [published Online First: 2017/12/05]
18. Pihl E, Skoldenberg O, Nasell H, et al. Patient-reported outcomes after surgical and non-surgical treatment of proximal hamstring avulsions in middle-aged patients. *BMJ Open Sport Exerc Med* 2019;5(1):e000511. doi: 10.1136/bmjsem-2019-000511 [published Online First: 2019/06/14]
19. van der Made AD, Peters RW, Verheul C, et al. Proximal hamstring tendon avulsions: comparable clinical outcomes of operative and non-operative treatment at 1-year follow-up using a shared decision-making model. *Br J Sports Med* 2022;56(6):340-48. doi: 10.1136/bjsports-2021-104588 [published Online First: 2022/01/09]
20. 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]
21. Lempainen L, Sarimo J, Heikkila J, et al. Surgical treatment of partial tears of the proximal origin of the hamstring muscles. *Br J Sports Med* 2006;40(8):688-91. doi: 10.1136/bjsm.2006.028191 [published Online First: 2006/06/23]
22. Kayani B, Ayuob A, Begum F, et al. Surgical Management of Chronic Incomplete Proximal Hamstring Avulsion Injuries. *Am J Sports Med* 2020;48(5):1160-67. doi: 10.1177/0363546520908819 [published Online First: 2020/03/18]

23. Pietrzak JR, Kayani B, Tahmassebi J, et al. Proximal hamstring tendinopathy: pathophysiology, diagnosis and treatment. *Br J Hosp Med (Lond)* 2018;79(7):389-94. doi: 10.12968/hmed.2018.79.7.389
24. 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
25. Thompson JW, Plastow R, Kayani B, et al. Surgical Repair of Distal Biceps Femoris Avulsion Injuries in Professional Athletes. *Orthop J Sports Med* 2021;9(3):2325967121999643. doi: 10.1177/2325967121999643 [published Online First: 20210326]
26. 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]
27. Subbu R, Benjamin-Laing H, Haddad F. Timing of surgery for complete proximal hamstring avulsion injuries: successful clinical outcomes at 6 weeks, 6 months, and after 6 months of injury. *Am J Sports Med* 2015;43(2):385-91. doi: 10.1177/0363546514557938 [published Online First: 2014/11/19]
28. Lempainen L, Sarimo J, Mattila K, et al. Distal tears of the hamstring muscles: review of the literature and our results of surgical treatment. *Br J Sports Med* 2007;41(2):80-3; discussion 83. doi: 10.1136/bjsm.2006.031211 [published Online First: 20061130]
29. Knapik DM, Metcalf KB, Voos JE. Isolated Tearing and Avulsion of the Distal Biceps Femoris Tendon During Sporting Activities: A Systematic Review. *Orthop J Sports Med* 2018;6(7):2325967118781828. doi: 10.1177/2325967118781828 [published Online First: 20180703]
30. Chang JS, Kayani B, Plastow R, et al. Management of hamstring injuries: Current concepts review. *Bone and Joint Journal* 2020;102(10):1281-88. doi: 10.1302/0301-620X.102B10.BJJ-2020-1210.R1
31. 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
32. 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
33. 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]
34. 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
35. 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. *Br J Sports Med* 2017;51(22):1583-91. doi: 10.1136/bjsports-2016-097206 [published Online First: 20170330]

36. 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
37. Lightsey HM, Kantrowitz DE, Swindell HW, et al. Variability of United States Online Rehabilitation Protocols for Proximal Hamstring Tendon Repair. *Orthop J Sports Med* 2018;6(2):2325967118755116. doi: 10.1177/2325967118755116 [published Online First: 2018/03/08]
38. Hasson F, Keeney S, McKenna H. Research guidelines for the Delphi survey technique. *Journal of Advanced Nursing* 2000;32(4):1008-15.
39. 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]
40. 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
41. 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
42. Hsu CC, Sandford BA. The Delphi technique: Making sense of consensus. *Practical Assessment, Research and Evaluation* 2007;12(10):1-8.
43. 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
44. Harper D, Thompson AR. Qualitative Research Methods in Mental Health and Psychotherapy: A Guide for Students and Practitioners2011.
45. 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
46. 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
47. 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
48. 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
49. 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
50. Verhagen AP, de Vet HC, 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. *J Clin Epidemiol* 1998;51(12):1235-41. doi: 10.1016/s0895-4356(98)00131-0
51. 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
52. 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
53. Hsu C-C, Sandford BA. The Delphi Technique: Making Sense of Consensus. *Practical Assessment, Research and Evaluation* 2007;12:10.
54. Hohmann E, Cote MP, Brand JC. Research Pearls: Expert Consensus Based Evidence Using the Delphi Method. *Arthroscopy* 2018;34(12):3278-82. doi: 10.1016/j.arthro.2018.10.004
55. Barnett AJ, Negus JJ, Barton T, et al. Reattachment of the proximal hamstring origin: outcome in patients with partial and complete tears. *Knee surgery, sports traumatology, arthroscopy : official journal of the ESSKA* 2015;23(7):2130-5. doi: 10.1007/s00167-013-2817-0 [published Online First: 2014/01/15]
56. Cohen S, Bradley J. Acute proximal hamstring rupture. *The Journal of the American Academy of Orthopaedic Surgeons* 2007;15(6):350-5. doi: 10.5435/00124635-200706000-00004 [published Online First: 2007/06/06]
57. 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
58. 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]
59. 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]
60. Sonnery-Cottet B, Daggett M, Gardon R, et al. Surgical Management of Recurrent Musculotendinous Hamstring Injury in Professional Athletes. *Orthop J Sports Med* 2015;3(10):2325967115606393. doi: 10.1177/2325967115606393 [published Online First: 20151001]
61. Kujala UM, Orava S, Järvinen M. Hamstring injuries. Current trends in treatment and prevention. *Sports Medicine* 1997;23(6):397-404. doi: 10.2165/00007256-199723060-00005
62. Nauta HJA, van der Made AD, Tol JL, et al. Satisfactory clinical outcome of operative and non-operative treatment of avulsion fracture of the hamstring origin with treatment selection based on extent of displacement: a systematic review. *Knee Surg Sports Traumatol Arthrosc* 2021;29(6):1813-21. doi: 10.1007/s00167-020-06222-y [published Online First: 20200818]
63. Levine WN, Bergfeld JA, Tessendorf W, et al. Intramuscular corticosteroid injection for hamstring injuries. A 13-year experience in the National Football League. *Am J Sports Med* 2000;28(3):297-300. doi: 10.1177/03635465000280030301
64. Beiner JM, Jokl P, Cholewicki J, et al. The effect of anabolic steroids and corticosteroids on healing of muscle contusion injury. *Am J Sports Med* 1999;27(1):2-9. doi: 10.1177/03635465990270011101
65. De Visser HM, Reijman M, Heijboer MP, et al. Risk factors of recurrent hamstring injuries: A systematic review. *British Journal of Sports Medicine* 2012;46(2):124-30. doi: 10.1136/bjsports-2011-090317
66. 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. *British Journal of Sports Medicine* 2021 doi: 10.1136/bjsports-2020-103791

67. Järvinen TA, Järvinen TL, Kääriäinen M, et al. Muscle injuries: biology and treatment. *Am J Sports Med* 2005;33(5):745-64. doi: 10.1177/0363546505274714
68. Silder A, Heiderscheit BC, Thelen DG, et al. MR observations of long-term musculotendon remodeling following a hamstring strain injury. *Skeletal Radiology* 2008;37(12):1101-09. doi: 10.1007/s00256-008-0546-0
69. Silder A, Reeder SB, Thelen DG. The influence of prior hamstring injury on lengthening muscle tissue mechanics. *J Biomech* 2010;43(12):2254-60. doi: 10.1016/j.jbiomech.2010.02.038 [published Online First: 2010/05/18]
70. Jönhagen S, Nemeth G, Eriksson E. Hamstring Injuries in Sprinters: The Role of Concentric and Eccentric Hamstring Muscle Strength and Flexibility. *The American Journal of Sports Medicine* 1994;22(2):262-66. doi: 10.1177/036354659402200218
71. Reurink G, Almusa E, Goudswaard GJ, et al. No association between fibrosis on magnetic resonance imaging at return to play and hamstring reinjury risk. *Am J Sports Med* 2015;43(5):1228-34. doi: 10.1177/0363546515572603 [published Online First: 20150306]
72. Askling CM, Koulouris G, Saartok T, et al. Total proximal hamstring ruptures: clinical and MRI aspects including guidelines for postoperative rehabilitation. *Knee surgery, sports traumatology, arthroscopy : official journal of the ESSKA* 2013;21(3):515-33. doi: 10.1007/s00167-012-2311-0 [published Online First: 2012/12/12]
73. 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]
74. Dierckman BD, Guanche CA. Endoscopic proximal hamstring repair and ischial bursectomy. *Arthrosc Tech* 2012;1(2):e201-7. doi: 10.1016/j.eats.2012.07.005 [published Online First: 20121012]
75. Laskovski JR, Kahn AJ, Urchek RJ, et al. Endoscopic Proximal Hamstring Repair and Ischial Bursectomy Using Modified Portal Placement and Patient Positioning. *Arthrosc Tech* 2018;7(11):e1071-e78. doi: 10.1016/j.eats.2018.07.001 [published Online First: 20181001]
76. Pihl E, Kristoffersen MH, Rosenlund AM, et al. The proximal hamstring avulsion clinical trial (PHACT)-a randomised controlled non-inferiority trial of operative versus non-operative treatment of proximal hamstrings avulsions: study protocol. *BMJ Open* 2019;9(9):e031607. doi: 10.1136/bmjopen-2019-031607 [published Online First: 2019/09/15]