Calf muscle strain injuries in sport: a systematic review of risk factors for injury

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ABSTRACT

Objective To systematically review the literature to identify risk factors for calf strain injury, and to direct future research into calf muscle injuries.

Design Systematic review

Data sources Database searches conducted for Medline, CINAHL, EMBASE, AMED, AUSPORT, SportDiscus, PEDro and Cochrane Library. Manual reference checks, ahead of press searches, citation tracking. From inception to June 2016.

Eligibility criteria for selecting studies Studies evaluating and presenting data related to intrinsic or extrinsic risk factors for sustaining future calf injury.

Results Ten studies were obtained for review. Subjects across football, Australian football, rugby union, basketball and triathlon were reported on, representing 5397 athletes and 518 calf/ lower leg muscle injuries. Best evidence synthesis highlights chronological age and previous history of calf strain are the strongest risk factors for future calf muscle injury. Previous lower limb injuries (hamstring, quadriceps, adductor, knee) show some limited evidence for an association. Numerous factors lack evidence of an association, including height, weight, gender and side dominance.

Summary/conclusion Increasing age and previous calf strain injury are the most predictive of future calf injury. The overall paucity of evidence and the trend for studies of a high risk of bias show that further research needs to be undertaken.

INTRODUCTION

The lower leg is an essential biomechanical component during movements requiring both explosive power and prolonged endurance.[1 2] The calf complex is critical during any weight-bearing or locomotive activity and therefore injury impacts on a number of athletic populations.[3–5] Calf muscle strain injuries (CMSI) are common across sports involving high-speed running or high volumes of running load, acceleration and deceleration, and upon fatiguing conditions of play or performance.[6–8]

Football codes are significantly impacted by CMSI, with football showing match-play incidences of 0.84 per 1000 hours,[9] rugby union risk ratios (RR) ranging from 0.98 to 5.85 across positions[10] and CSMI representing one of the highest soft tissue injury incidences (3.0 per club per season) and recurrences (16%) in Australian Rules football.[11] Calf injuries have a high mean time to return to sport in the event of any recurrence[9] and are more likely to occur during critical competitive periods, such as the end of the competition season in football.[12] Injuries to the lower leg/calf are one of the most prevalent muscle injuries in athletes involved in pole vault,[3] in preprofessional dancers[4] and in triathletes.[13] The prevalence of gradual onset calf injury is an issue in sports such as tennis, with a prevalence of 5.2% in collegiate standard players.[5]

In the literature to date, there is an absence of definitive data relating to risk factors for CMSI. Some suggested factors based on existing studies and anecdotal opinions relate to player intrinsic characteristics such as age,[6] fatigue or training volumes[7 14] and previous soft tissue injuries.[6 8] The identification of risk factors for injury may assist in the assessment and management of athletes and injury prevention. This systematic review aims to synthesise variables influencing risk of future calf strain injuries in sport, with a secondary aim to direct future research into this important area.

METHODS

Search strategy and selection of studies

A systematic literature search was conducted across databases Medline, CINAHL, EMBASE, AMED, AUSPORT, SportDiscus, PEDro and the Cochrane Library, from inception to June 2016.

Keywords from the research question were mapped to medical subject headings where possible. Citation tracking and reference list scanning of included articles and manual ahead-of-press searches were carried out subsequently. References acquired were imported into EndNote X3 software (Thomson Reuters, USA) and duplicates were removed. Two examiners (BG and TP) independently applied selection criteria to abstract and titles of the search yield, subsequently reaching agreement on full-text versions to be obtained for potential inclusion. Selection criteria were reapplied against full-text versions by both examiners in consultation. See Supplementary Material for an example search strategy.

Study selection criteria

Participants/Injury

Articles were included if examining either a primary or recurrence of a CMSI in humans in sport or sports-related activity. These injuries were distinguished from Achilles tendon-type pathologies, traumatic bony or contusion-type soft tissue injuries, or overuse conditions where possible. Included studies had to present discrete data for calf or lower leg muscle injury.

Risk factors

Included studies were required to examine one or more variables in association with risk of CMSI. Only risk factors measured prospectively were

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acceptable, unless retrospective analysis evaluated non-modifiable risk factors. This was to avoid the limitations of retrospective analysis for identifying whether measured relationships were the result of, or predisposed to, the recorded injury. Data relating only to match-play versus training injury incidences were also considered irrelevant to the aims of the review.

Study type

Epidemiological or descriptive studies reporting incidences only, intervention studies, non-systematic reviews, case studies and opinion articles were not included. Studies were required to be available in full text, from peer-reviewed sources and written in the English language. Unpublished data and conference abstracts were not included because of the lack of rigorous methodological appraisal.

DATA COLLECTION AND ANALYSIS

Data extraction

Data extraction was undertaken with a focus on sports activity, participant characteristics, specific extrinsic or intrinsic risk factors examined and CMSI injury outcomes. Methods of analysis were also examined in terms of injury diagnosis, study durations, overall results (including statistical techniques used and their specific findings) and general heterogeneity between variables measured in different studies. Non-blinded reviewers (BG and TP) extracted data independently, including means, SD, HR, RR and OR. Other variables extracted from included studies related to match or activity characteristics.

Data analysis, risk of bias assessment and best evidence synthesis

Because of the small number of studies available, and heterogeneity of data sets and variables measured, meta-analyses were not performed. Instead, a qualitative synthesis of results was primarily undertaken, with any probability and risk data (HR, OR and RR) presented in the results of this review taken directly from included studies. Paucity of data did not permit meta-analysis or further computation of other statistical relationships.

A risk of bias assessment was carried out by two independent reviewers (BG and TP) using a modified version of the Quality in Prognosis Studies (QUIPS) tool, as previously outlined[15 16] and also conducted in a recent muscle-related systematic review of the literature.[17] Six subheadings were used to appraise different study design elements and potential sources of bias, with a number of criteria within each category, each scoring a 'yes' or 'no.' A subheading was considered to have high risk of bias if less than 75% of the items within it achieved a score of 'yes.' The subheading was otherwise considered to have a low risk of bias if more than 75% of the criteria received a score of 'yes.' The overall risk of bias for a study was then calculated according to how many of the six subheadings were deemed to be high risk, which has been advocated for in the literature previously.[18] A study was considered to be of low overall risk of bias if at least five of the six categories were satisfied, along with requiring a low risk for the subheading relating to outcome measurement (item 4). All discrepancies in results of risk of bias assessment between independent reviewers (BG and TP) were compared and discussed until full agreement was reached. A copy of the modified QUIPS can be found in online supplementary appendix 1.

A best evidence synthesis was then undertaken since many of the studies presented heterogeneous study design, statistical methods or overall quality. This combined approach enables clarification of the strength of evidence around a particular measured variable.[19] A best evidence synthesis has been described in the literature previously,[19 20] and employed in muscle-related systematic reviews to qualitatively analyse according to five hierarchical criteria aligned to study quality and clinical results presented[17 21]:

1. Strong evidence: consistent findings in more than one high-quality study.

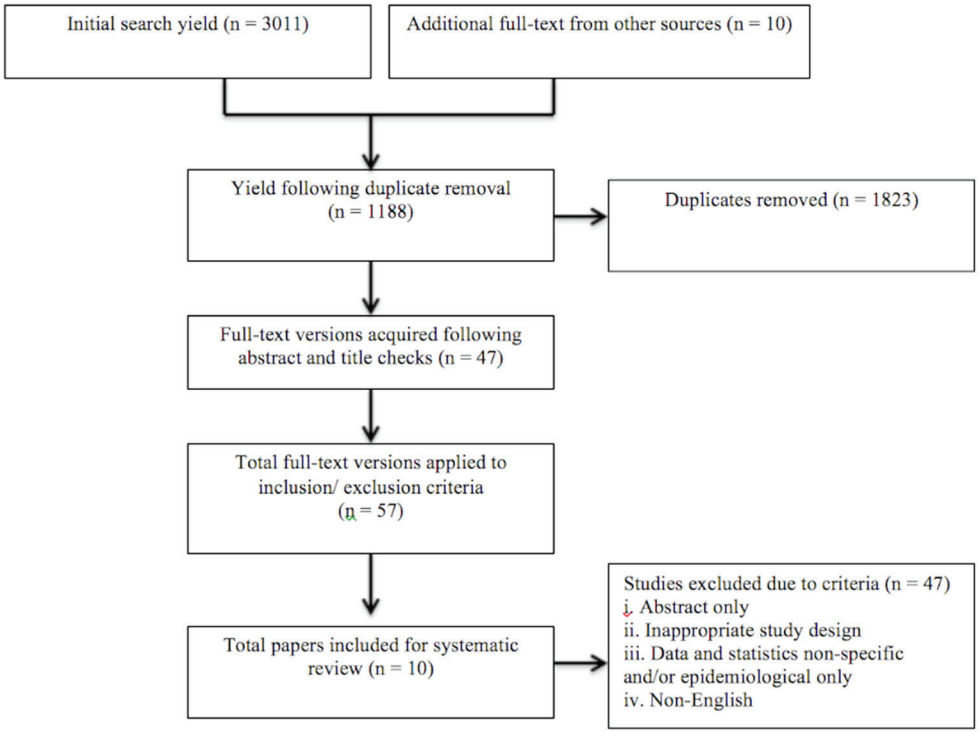

Figure 1 Search flow diagram.

Table 1 Characteristics of included studies

Study	Study design	Sample and/or sport	Number/rate of CMSI or 'lower leg'	Risk factors	Specific outcome	Length of tracking
Bengtsson *et al* (2013)[7]	Prospective cohort	27 European professional football (soccer) teams from 10 countries—621 individual players	CMSI RR=1.13/1000 hours match exposure	Match load, between match recovery, match characteristics	Acute calf muscle injury diagnosed and recorded on electronic injury registry by club medical staff	11 seasons
Brooks and Kemp (2011)[10]	Prospective cohort	899 players from 14 English Premiership rugby union clubs	NA	Playing position, match-related injury	Acute calf muscle strain injury diagnosed and reported by club medical staff	4 seasons
Hägglund *et al* (2013)[8]	Prospective cohort	1401 players from 26 soccer clubs across 10 countries	CMSI (n=306)	Previous calf muscle injury, previous other muscle injuries, age, stature, body mass, playing position	Acute calf muscle injury as diagnosed by club medical staff	2001–2010 seasons
Orchard *et al* (2014)[11]	Prospective cohort	1607 elite Australian Rules football players	CMSI (n=140)	Age, height, weight, BMI, month, environmental conditions, calf injury within 8 weeks, previous calf injury beyond 8 weeks, older players (age>23), past quadriceps injury beyond 8 weeks	Calf strain injury assessment and diagnosis by club medical staff, with or without imaging investigations	1992–1999 competition seasons
Carling *et al* (2015)[14]	Prospective observational	25 professional soccer players from one club	Calf IRR=4.1/1000 hours match exposure	Fixture congestion and match characteristics	Calf muscle injury as diagnosed and recorded by club	6 seasons (2009–2015)
Nilstad *et al* (2014)[23]	Prospective cohort	173 elite female Norwegian soccer players from 12 teams	'Leg/foot' injuries (n=28)	Previous knee injury, age, BMI, lower extremity strength, dynamic balance, knee biomechanics and laxity, foot posture (pronation)	Calf injuries (as captured leg/foot injury data)	1 season
McKay *et al* (2001)[25]	Prospective cohort	Elite and recreational Australian basketball players—190 players	'Calf/anterior leg' injuries (n=12)	Gender, level of competition	Calf muscle injury (as captured in 'Calf/Anterior Leg' injuries data)	2 seasons
Faude *et al* (2006)[22]	Prospective cohort	143 German national league soccer players over 12 teams	'Lower leg' injuries (n=19)	Anthropometric measurements, playing position, injury history, training and match exposure time	Calf muscle injury (as captured in 'lower leg' data pool)	1 season
Korkia *et al* (1994)[13]	Prospective study	155 British triathletes	'Lower leg' injuries (n=13)	Training history, injury history	Calf muscle injuries (as reported in 'lower leg' injury) as self-reported questionnaire	1 season
Gabbett and Domrow (2007)[24]	Prospective cohort	183 subelite rugby league players	'Thigh and calf' injuries 41.3/1000 hours	Training load and injury data according to competition phases	Calf muscle injury (as described in combined 'Thigh and Calf' data)	2 seasons

BMI, body mass index; CMSI, calf muscle strain injury; IRR, injury rate ratio; NA, not applicable; RR, rate ratio.

2. Moderate evidence: consistent findings in one high-quality study and one or multiple low-quality studies, or by consistent findings in multiple low-quality studies.
3. Limited evidence: findings presented from a single study only (high-quality or low-quality study).
4. Conflicting evidence: findings across more than one study that does not have consistent results.
5. No evidence: no randomised controlled trials or non-randomised controlled trials available for assessment.

RESULTS

Search results

The initial search yielded a total of 1188 studies after removal of duplicates. Application of selection criteria to titles and abstracts of the initial yield resulted in full-text versions of 47 studies being acquired for further analysis. Application of criteria to full-text articles left eight studies remaining to be included. Citation tracking, ahead-of-press searches and reference scanning resulted in another potential 10 articles, of which two met the inclusion and exclusion criteria (figure 1). Reasons for exclusion are included in online supplementary appendix 2.

Description of the included studies

A total of 10 studies were included for the purposes of this systematic review, accounting for a total participant pool of more than 5000 participants across football,[7 8 14 22 23] Australian Rules football,[6] rugby union,[10 24] basketball[25] and triathlon.[13] Data extraction was performed on all of the 10 included studies. A detailed description of the study characteristics is presented in table 1.

Risk of bias assessment and best evidence synthesis

Seven studies[7 10 13 14 22 24 25] were scored with a high risk of bias, while the other remaining three studies[6 8 23] were determined to have a low risk of bias (table 2). Authors retained agreement on all scoring and bias assessment results.

Key areas of bias across the 10 included studies were related to study attrition, study confounding variables and measurement of prognostic factors. All studies presented simple univariate statistical methods, while four offered some relevant information from multivariate models.[6 8 23 25] For full details of the best evidence synthesis, see table 3 below.

Evaluation of risk factors

Chronological age

Strong evidence exists for an association between increased age and future calf strain, measured in Australian football and football athletes[6 8] (table 3). Two large prospective studies with low risk of bias found significant associations across both univariate and multivariate analyses.[6 8]

Table 2 Risk of bias assessment

Study	Potential risk of bias item						Risk of bias
	1	2	3	4	5	6	
Bengtsson *et al* (2013)[7]	+	–	+	+	–	+	High
Brooks and Kemp (2011)[10]	+	–	+	+	–	+	High
Hägglund *et al* (2013)[8]	+	+	+	+	–	+	Low
Orchard (2001)[6]	+	–	+	+	+	+	Low
Carling *et al* (2015)[14]	–	+	–	+	+	+	High
Nilstad *et al* (2014)[23]	+	+	–	+	+	+	Low
McKay *et al* (2001)[25]	–	+	–	–	–	+	High
Faude *et al* (2006)[22]	+	–	+	+	–	+	High
Korkia *et al* (1994)[13]	–	–	–	–	–	–	High
Gabbett and Domrow (2007)[24]	+	–	+	+	+	–	High

Individual player characteristics

Moderate evidence was found for no association between limb dominance and calf muscle or lower leg muscle injury, across one high risk and one low risk of bias study.[8 22] Limited evidence for no association between player stature and future CMSI was highlighted in a single study with low risk of bias, while strong evidence of no relationship was presented across a pair of low risk of bias studies reporting on player mass.[6 8] There may however be a limited association in terms of the specific measure of body mass index (BMI) and calf strain risk.[6] Player height and gender showed limited evidence for no association in low-risk and high-risk studies, respectively[6 25] (table 3).

Match characteristics, fatigue and playing schedule

The precompetition or preseason period showed limited evidence for higher risk of calf injury compared with other phases of the season, examined in a single high risk of bias study.[24] During the competitive season, a pair of high risk of bias studies together provides moderate evidence for no association between periods of greater playing schedule congestion or less between-match recovery and sustaining a CMSI.[7 14] Examining playing standard or competition level offered only limited findings of no association in a single high-risk study.[25] The actual position played by the athletes in rugby and football codes provides conflicting evidence of no relationship[8 10] (table 3).

History of previous CMSI

Two low risks of bias studies provide strong evidence for history of previous calf muscle injury and future risk[6 8] (table 3). Data

Table 3 Results of the best evidence synthesis

	N	Univariate		Multivariate		Association with risk (↑↓\=)	Best evidence synthesis	
		Low risk of bias	High risk of bias	Low risk of bias	High risk of bias		Presence of association	Level of evidence
Risk factors								
Chronological age	3008	6 8		6		↑6 8	Yes	Strong
Sex	190		25			=25	No	Limited
Limb dominance	1544	8	22			=8 22	No	Moderate
Player stature	1401	8				=8	No	Limited
Player body mass/weight	3008	6 8				=6 8	No	Strong
BMI	1607	6				↑6	Yes	Limited
Player height	1607	6				=6	No	Limited
Preseason period	183		24			↑24	Yes	Limited
Shorter between-match recovery/congested playing schedule	621		7 14			=7 14	No	Moderate
Level of competition	190		25			=25	No	Limited
Playing position	2300	8	10			=8 10	No	Conflicting
Previous calf muscle strain injury	3008	6 8				↑6 8	Yes	Strong
Previous adductor	1401	8				↑8	Yes	Limited
Previous quadriceps	1607	6				↑6	Yes	Limited
Previous knee	173	23				↑23	Yes	Limited
Previous hamstring	1401	8				↑8	Yes	Limited
Previous 'lower leg, knee, thigh, ankle/foot and back'	155		13			↑13	Yes	Limited
Temperature	1607	6				=6	No	Limited
Evaporation in previous 7 days	1607	6				=6	No	Limited
Rainfall in previous 7 days	1607	6				=6	No	Limited
Rainfall on game day	1607	6				=6	No	Limited
Month of year	1607	6				=6	No	Limited

↑↑, association with future calf muscle strain; ↓, association with lower risk for future calf muscle strain; =, no association with future calf muscle strain; BMI, body mass index.

were presented using univariate and multivariate approaches, with one study further dichotomising data to highlight an elevated risk for future calf strain if a calf muscle injury had been experienced in the preceding 8-week period (RR=8.94, 95% CI 5.1 to 15.66).[6]

History of other previous lower limb injury

Four studies presented data relating to other previous injury and future calf or lower leg injury in triathletes, football and Australian Rules athletes[6 8 13 23] (table 3).

Across a number of low risk of bias studies, some limited evidence exists for an association between previous adductor, previous hamstring, previous quadriceps, and previous knee injury and future CMSI.[6 8 23] Previous 'lower leg, knee, thigh, ankle/foot and back' injury in the preceding 12-month period was identified by a single high risk of bias study and classified as having a limited association.[13]

Other extrinsic variables

There was limited evidence for no association between temperature, evaporation in the previous week, game-day rainfall, rainfall in the previous week and month of the year with sustaining a calf or lower leg muscle injury.[6]

DISCUSSION

This review established that the strongest risk factors for CMSI are increased player age and any history of previous CMSI. There may also be limited evidence that other lower limb soft tissue or joint injuries (hamstring, quadriceps, adductor, knee) predispose athletes to calf or lower leg muscle injuries, along with being in the preseason period or the player having an increased BMI.

This review also identified a number of factors showing no association with future calf strain. Strong evidence for no association was found for absolute player mass, along with moderate evidence for no relationship with reduced between-match recovery or schedule congestion. A number of individual player characteristics (height, stature, side dominance, gender) and playing standard further failed to highlight an association, as did any environmental factor examined. There seems to be some conflicting evidence regarding positional demands in football and rugby codes, across multiple studies of both low and high risks of bias. Overall, the small number of studies and variables available for synthesis together with the lack of homogeneity in data presented and methodological approaches to outcome measurement limits the conclusions that can be drawn. In addition, the quality of the included studies was variable. Risk of bias assessment showed that there were clear discrepancies in terms of overall study quality, which influenced the strength and number of definitive findings when synthesising the evidence.

Confirmation of chronological age and previous muscle injury as strong risk factors for future muscle strain is not surprising given these non-modifiable risk factors have been implicated in risk for hamstring,[26] groin[8 27] and quadriceps[6] strain injuries. Increasing age as a risk factor also bears relevance to previous literature detailing age-related neuromuscular maladaptations and loss in skeletal muscle tissue quality and function.[28 29] Age-related structural tissue changes are linked with progressive loss of important neuromuscular attributes such as power outputs or rate of force development,[29] and disruptions to motor unit discharge rates.[30] In the event of previous injury, maladaptive responses have been tracked following hamstring[31–33] and ACL[34 35] injuries, affecting factors relating to strength,[31–35] neurology[31 32 34] and tissue architecture.[32 33 35]

Local structural tissue alterations are an important maladaptation to consider, particularly given their association with tendon continuum presentations in the Achilles.[36 37] Literature has previously established the importance of gastrocnemius fascicle length in sprinting athletes, and therefore maximal power outputs over fast velocities,[1] with both a strong and statistically significant correlation with maximal sprinting speed.[1 2] This may also highlight the importance of tissue extensibility or flexibility, of which long fascicular lengths are a purported requisite, despite no direct evidence exploring its role in calf strain injury risk. More recent studies into the hamstring strain injuries have underlined this structural necessity in the hamstring complex.[38] The presence of shorter fascicle lengths in the biceps femoris below a certain threshold resulted in significantly elevated risk for future hamstring muscle strains.[38] Local factors relating to calf muscle fascicle length, pennation angle, cross-sectional area and tissue quality may therefore be worthwhile when evaluating risk of injury compared with more global and less specific variables such as stature, height and weight.

These areas provide some direction for future calf research, along with recent studies that have presented significant associations between measures of different strength qualities and soft tissue injury—namely eccentric strength[39] and strength endurance[40] for sustaining future hamstring muscle strains. Related works have also identified an important association between greater levels of eccentric strength and increasing fascicle lengths as able to ameliorate risk of non-modifiable risk factors of age and previous injury history,[38] which is particularly relevant given that these were the only two risk factors with strong evidence in this review. Rehabilitation and conditioning practices could hope to mirror these findings, along with recent literature detailing the importance of long-term training chronicity in building athlete preparedness and injury resilience.[41] Implementing interventions for eliciting adaptation to fascicle lengths and eccentric capacity in the calf complex however require scientific validation and further research.

What is already known on this topic?

- The calf complex is essential to lower limb mechanics during locomotive and weight-bearing tasks.
- Calf muscle strain injuries (CMSI) are a common soft tissue injury across numerous team and individual sporting codes.
- Literature in this area is limited, and a systematic analysis establishing a group of possible risk factors, and any inter-relationships between these factors, has not been performed to date.

What this study adds?

- Despite a limited number of studies available, data analysis provides evidence for age and previous CMSI as the strongest risk factors for calf strain injury.
- Previous adductor, hamstring, quadriceps or knee injury may also influence likelihood of injury.
- Variables relating to individual player characteristics and environmental descriptors do not seem to be related to future calf or lower leg strain.
- This review highlights the factors that need further study in the scientific literature, with future direction of research similar to that undertaken recently in the field of hamstrings.

The small number of studies and variables explored in this review provides some direction in the topic of CMSI. However, the overall paucity of homogenous data and overall study quality influence the quality of conclusions that can be made. There is also the potential for a publication bias given that only published literature was included for the purposes of review, and a language bias associated with inclusion of English-language only publications. Findings from this systematic review should be considered with understanding that there are limitations in both the quality of evidence and the amount of evidence available. Clinical interpretation of findings should consider that there are potentially other influences on risk for future CMSI than are mentioned or examined in detail in this systematic review.

CONCLUSION

History of a previous calf muscle strain and increasing player age provide the strongest evidence for future calf strain risk. Factors such as player weight, height, gender and side dominance can be considered to lack evidence of an association with sustaining a calf muscle injury. A number of other measures and variables may also have an influence on risk; however, additional research is required to build the evidence base in this area, and to offer some further understanding of risk.

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