ISSN 0008-3194 (p)/ISSN 1715-6181 (e)/2025/107–119/$2.00/©JCCA 2025

Secondary prevention of musculoskeletal sports injuries: a scoping review of early detection and early intervention strategies

Aske Holm-Jensen, M.Sc PhD(c)[1]
Evgenios Vlachos, MSc, MA, PhD[2,3]
Louise Kamuk Storm, PhD[1]
Corrie Myburgh, MApplSc, MMed, PhD[1,4,5]

Background: *Early detection and early intervention of musculoskeletal sports injuries is a promising, but underexplored area. Poor conceptual clarity of secondary prevention strategies currently hampers research and clinical application.*

Methods: *We conducted a scoping review, aimed at summarizing secondary prevention strategies of musculoskeletal sports injuries into recommendations for researchers, athletes, and clinicians. We searched seven databases for the terms: sport, injury, and early detection/intervention.*

Prévention secondaire des blessures musculo-squelettiques liées au sport : une revue exploratoire des stratégies de détection et d'intervention précoces

Contexte: *La détection et l'intervention précoces des blessures musculo-squelettiques liées au sport est un domaine prometteur, mais peu exploré. La faible clarté conceptuelle des stratégies de prévention secondaire entrave actuellement la recherche et l'application clinique.*

Méthodes: *Nous avons réalisé une revue exploratoire, qui vise à résumer les stratégies de prévention secondaire des blessures musculo-squelettiques liées au sport en formulant des recommandations pour les chercheurs, les athlètes et les cliniciens. Nous avons effectué des recherches sur les termes suivants dans sept bases de données : sport, blessure et détection/intervention précoce.*

[1] University of Southern Denmark, Department of Sports Science and Clinical Biomechanics, Odense, Denmark
[2] University of Southern Denmark, University Library of Southern Denmark, Odense, Denmark
[3] University of Southern Denmark, The Maersk Mc-Kinney Moller Institute, Odense, Denmark
[4] The Chiropractic Knowledge Hub, University of Southern Denmark, Odense, Denmark
[5] Department of Chiropractic, University of Johannesburg, South-Africa

Corresponding author:
Aske Holm-Jensen, University of Southern Denmark, Campusvej 55, Odense M, Denmark.
E-mail: aholm-jensen@health.sdu.dk
Tel: +45 50 45 72 97.

Conflicts of Interest:
The authors have no disclaimers or competing interests to report in the preparation of this manuscript. The project, as part of an ongoing PhD-project, is funded by the Danish Chiropractors' Foundation (Grant numbers R155-A3521-B2270 and R185-A4249-B2270) and the PhD-student is employed at the Institute of Sports and Clinical Biomechanics, University of Southern Denmark, Denmark.

Results: *Nine studies reported early detection/intervention strategies. Strength testing is a promising approach to early injury detection. We recommend caution in interpretating early imaged abnormalities due to heterogeneous findings. Observing early symptoms appears the most adopted pragmatic approach. Early rehabilitation and passive therapies seem effective as early interventions. Early load reduction is likely difficult to implement, due to performance expectations.* Conclusions: *The evidence for early detection/intervention is limited. Further research into assessing early detection/intervention strategies and their use in practice, is necessary to formulate concrete recommendations.*

(JCCA. 2025;69(2):107-119)

KEY WORDS: athletic injury; musculoskeletal sport injury; overuse injury; tendinopathy; strain injury; sprain injury; secondary prevention; secondary prophylaxis; preventing worsening; preventing exacerbation; early diagnosis; early identification; early treatment; early therapy; early rest; early rehabilitation; early phase; early stage; prehabilitation

Résultats: *Neuf études ont débouché sur des rapports sur des stratégies de détection/intervention précoce. Les tests de force sont une approche prometteuse pour la détection précoce des blessures. Nous recommandons la prudence dans l'interprétation des anomalies d'imagerie précoces en raison de résultats hétérogènes. Observer les premiers symptômes semble être l'approche pragmatique la plus adoptée. La réhabilitation précoce et les thérapies passives semblent efficaces en tant qu'interventions précoces. Il est probable que la réduction précoce de la charge soit difficile à mettre en œuvre en raison des attentes en matière de performance.*

Conclusions: *Les données probantes en matière de détection/intervention précoce sont limitées. Des recherches supplémentaires sur l'évaluation des stratégies de détection précoce/intervention et leur application pratique sont nécessaires pour formuler des recommandations concrètes.*

(JCCA. 2025;69(2):107-119)

MOTS CLÉS : blessure athlétique; blessure musculo-squelettique liée au sport; blessure par surutilisation; tendinopathie; blessure de tension; blessure d'entorse; prévention secondaire; prophylaxie secondaire; prévention de l'aggravation; prévention de l'exacerbation; diagnostic précoce; identification précoce; traitement précoce; thérapie précoce; repos précoce; réhabilitation précoce; phase précoce; stade précoce; préhabilitation

Introduction

Risk of musculoskeletal (MSK) injury is an inherent part of an athletic career.[1] Playing with MSK injuries is not only a risk for the individual athlete,[2,3] it is also a major problem for their affiliated clubs and organizations.[4,5] Despite considerable research into prevention strategies, it is still difficult to minimize MSK injuries in elite sports contexts.[6] The numerous efforts to prevent MSK injuries have primarily been evaluated at the group level before the onset of MSK injury (traditionally referred to as primary prevention[7]), in an attempt to reduce the risk of MSK injury.[8] However, primary prevention does not consider that athletes accept the risk of MSK injury in their pursuit of improved performance, and risk avoidance is therefore not a realistic strategy.[9,10] In fact, one might argue in the extreme that risk avoidance merely postpones the inevitable onset of MSK injury.[11,12] Consequently, several international consensus statements in the last decade have argued for a shift on focus towards early detection and early intervention.[13-15]

Early detection and subsequent early intervention fall within the domain of secondary prevention.[16] Yet, secondary prevention, which aims to prevent the complications, recurrence or worsening of a MSK injury, appears relatively under-explored.[16] Available evidence in this area focuses mainly on the prevention of MSK injury com-

plications, particularly knee osteoarthritis after anterior cruciate ligament injury,[17] and prevention of recurrences, particularly of ankle sprains or hamstring strains.[18,19] Moreover, there seem to be much fewer studies on the prevention of index MSK injury worsening. In fact, when examining the citations of a recent comprehensive review on MSK injury prevention strategies, reviews on early detection or early intervention strategies for MSK sports injuries appear absent.[20]

Research into early detection has mainly aimed at predicting future symptoms,[21,22] assessing early MSK injury stages,[23,24] or predicting symptom duration,[25,26] generally providing optimistic strategies for detecting MSK sports injuries early. Concurrently, intervening early appears favorable.[27-29] However, to our knowledge, there is a research gap in the combination of these two clinical practices. Clinicians and newly injured athletes are likely to be impeded by this apparent research disconnect. The high incidence of MSK injuries and athletes' acceptance of the risk of MSK injury underlines the importance of supporting clinicians and athletes in better decision making at the time of MSK injury.

The research gap on early detection and early intervention makes it difficult to compare and contrast such strategies. When secondary preventative strategies used by athletes in practice are unexplored, researchers assessing specific secondary preventative strategies may unintentionally assess strategies irrelevant to athletes in practice. Vice versa, without secondary preventative strategies assessed in experimental research, researchers will struggle formulating inquiries into evidence-based strategies in use among athletes in practice.

With the above in mind, to move the state-of-the art of early MSK injury detection and prevention forward, a summary description and synthesis of the evidence would be helpful to clinicians, athletes, and researchers in decision-making.

Objectives

Our objective was to scope available literature relating to secondary prevention of MSK sports injuries. We operationalized this objective by posing two research questions:

1) How may the purpose, results and strategies of the research literature on early detection and early intervention of musculoskeletal sports injuries be characterized and consolidated?
2) How may the research literature on early detection and early intervention of musculoskeletal sports injuries be articulated into practical recommendations for clinicians, athletes, and researchers?

Methods

We followed a scoping review approach,[30] in order to extract data from multiple study types dispersed across various disciplines,[31] and followed the extended PRISMA guidelines for reporting findings.[30,32]

Protocol and registration

The iterative nature of a scoping review allows for refinement of exclusion and inclusion criteria to ensure an adequate yet feasible scope of relevant evidence.[30] As such, no protocol was published beforehand, to provide the flexibility for this iterative process.[30]

Search strategy development

We performed two preliminary searches. We initially searched Scopus for *athlete*, *injury*, and *secondary prevention*, to identify additional search terms. A larger second search was then performed, inspired by the definitions of Holm-Jensen et al.,[16] on three secondary prevention domains: *Preventing recurrence*, *preventing sequelae/complications,* and *preventing worsening* (the latter mainly identified by the search terms *early detection/intervention*). The preliminary search identified many studies on preventing MSK injury sequelae and recurrence, but only few investigating early detection and early intervention. The studies in these preliminary searches informed our search string that was composed of three blocks: *athlete*, *injury* and *early detection/intervention*. Synonyms, truncation and proximity operators were applied where relevant.

Information sources

The final search string was applied in the Scopus, SportDiscus, Sports Medicine and Education Index, PubMed/Medline, Web of Science, Cochrane library (the Reviews- and Trials-databases), and Cinahl databases. The date of the search was the 10th of January 2024. The search strings for each database are included in the Supplementary Material. We used the software tool Covidence to streamline

the process and auto-remove duplicates before the manual screening.[33] Two independent reviewers screened the titles and abstracts, reaching consensus on disagreements. Finally, two independent reviewers assessed the full text for final study selection, again reaching consensus on disagreements. After the final study selection, a single author screened the reference lists of the included studies for relevant studies.

Study selection/Eligibility criteria

Studies were included if they described or assessed early detection followed by early intervention of MSK sports injuries.

Populations

We included only MSK sports injuries in athletic populations, without limiting the breadth of the search on specific sports. We included studies on ballet dancers and military personnel, due to their traditional performance-optimizing culture, resembling sport environments.[34,35] Concussion (traumatic brain injury) was notably excluded, although on par with MSK sports injuries in sports research in general. However, the preventative strategies for concussion are very different than for MSK sports injuries, such as policy/rule changes, equipment use, and technique alteration, and strategies for early detection and early intervention are not yet adopted in the concussion research literature.[36]

Interventions

The search strategy was structured to identify studies with a secondary preventative aim, i.e. preventing worsening, or early detection followed by early intervention.

Outcomes

We included outcomes of indicators of a MSK injury worsening, such as clinical symptoms, return-to-play time, and more. We excluded outcomes related to risk of MSK injury (traditionally coined primary prevention,[16] or MSK injury recurrences or complications (other secondary prevention domains[16]), to focus our review on preventing MSK injury worsening.

Study designs

We included English peer-reviewed scientific journal articles and book chapters, published between 1.1.2004 and 31.12.2023. We excluded non-original research, such as literature reviews and study protocols, and anecdotal evidence, such as case reports and small (<10) case series. Other noteworthy exclusions are cross-sectional studies, attempting to identify index or recurrent MSK injury risks (primary prevention[16]), and case series, in which the recruitment to the study was made *after* the diagnosis has been made, as such without a preventative aim.

Data extraction

We extracted the following data from the included studies: sport, number of participants, age, competitive level, sex, country, injury (e.g. hamstring strain), study design, purpose, publication year, early detection strategy, early intervention strategy, and outcome. The extraction was performed individually by the lead author using a customized form, designed and created by the author team.

Results

An overview of the identification, screening, and inclusion process is provided in the PRISMA flowchart (Figure 1). Of 5851 manuscripts, 2932 articles underwent title/abstract screening, 86 articles were reviewed in full, and nine studies were included. We identified eight protocols for potentially relevant studies. We sought the published studies, and included seven of these for full text review, excluding the last as it was a duplicate. We identified eight extra studies through colleagues that performed an adjacent review with a similar search strategy.[16]

Excluded studies

We excluded 77 studies after full-text review. Twelve studies had designs unfit for our review, namely non-original research or study protocols. Full text could not be obtained for seven studies. Four of these studies were evaluation of early surgery, and it was unclear how the researchers employed early detection strategies, if any. We excluded three studies employing both early detection and early intervention strategies. One assessed early surgery for hamstring injury, but for a non-athletic population.[37] Another assessed early surgery among athletes, but for skin friction injuries.[38] The last assessed early medication for prevention of bone stress injury, but in mice.[39]

We excluded six studies on other domains of prevention, such as prevention of the index injury, injury recurrences, or injury complications. These distinct domains

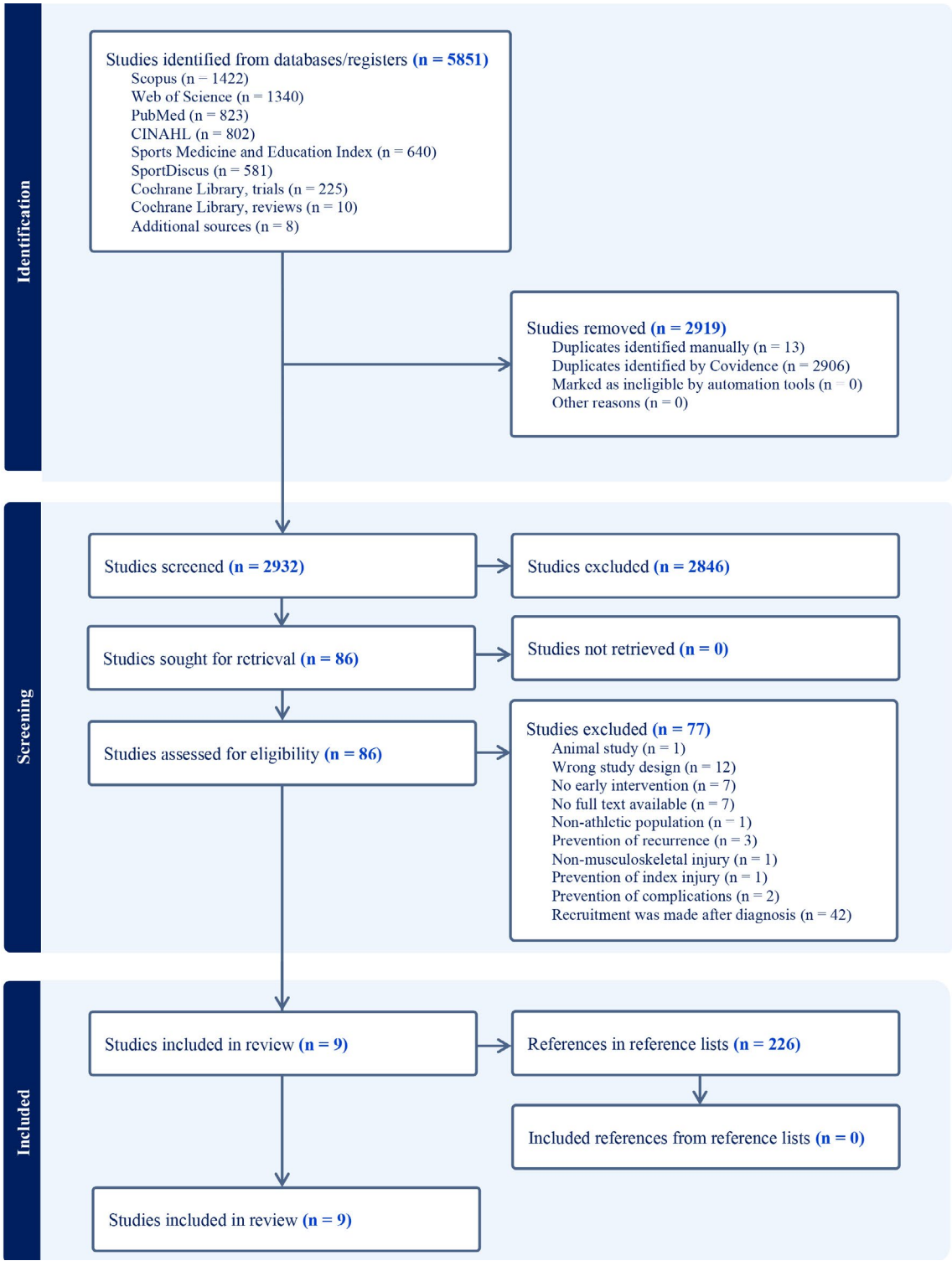

Figure 1.
PRISMA Flowchart demonstrating the identification, screening, and inclusion process.

were identified by Holm-Jensen et al,[16] and while it may be argued that injury recurrences and complications are a subsequent worsening of the index injury, the sport injury researchers define it inconsistently.[16] As argued in the introduction, there are numerous studies investigating the prevention of MSK injury recurrences and complications, but there is a gap in the prevention of index MSK injury worsening, such as detection injuries early and intervening early. These excluded articles assessed strength training regardless of preventative goal, and all without employing any early detection.

Also, we excluded all case series, in which recruitment to the respective study was made after the diagnosis was made, notwithstanding that the researchers employed early intervention. Our rationale was that such studies have no secondary preventative aim. We excluded 42 of such case series, most of them on acute ankle or knee injuries.[40,41] If we had included these studies in our review, our review would be less focused on prevention, but likely describing pain medication, functional rehabilitation, and surgery as early intervention strategies. Also, the dominant early detection strategy would simply be short symptom duration.

Furthermore, we also excluded seven studies on early detection strategies in isolation. These studies, mainly aiming to predict future symptoms,[21,22] assess early injury stages,[23,24] or predict symptom duration,[25,26] are all without an interventional element, and in turn lacks a secondary preventative aim. If we had included these studies, our review would likely have focused on imaging studies of tendinopathy or bone stress injuries, to predict future symptoms or symptom duration.[21,25]

Study characteristics

Of the nine included studies, three cohort studies and two trial studies assessed preventative strategies on 369 athletes in various sports. Four interview studies, although not directly inquiring into early detection/early intervention in their study purpose, nonetheless gave answers to our research questions in their data. These studies were performed on 53 medical personnel and 21 athletes. Full details of study characteristics are summarized in Table 1.

Early detection strategies

Three different early detection strategy domains were identified, these being: strength loss testing, imaging for abnormalities, and observing early symptoms.

Strength loss testing

Wollin *et al*. (2018) and Wollin *et al*. (2020) performed post-match screening of asymptomatic footballers' isometric hip adduction strength and knee flexion strength, respectively.[42,43] Their theory was that strength is reduced immediately preceding injury symptoms. When they identified such strength reduction, indicating early injuries, the athletes immediately reduced high-risk training load and performed strength rehabilitation.[42,43] This strategy was employed in practice in the study by Pizzari *et al*.[44] Their context was preventing osteitis pubis, also a groin injury, in Australian football.[44]

Imaging for abnormalities

Harada *et al*. screened the medial elbow for abnormalities in the throwing-arm of asymptomatic baseball throwers with ultrasound.[45] Their theory was that abnormalities precede injury symptoms. If any abnormalities, such as osteochondritis dissecans, were present and confirmed on plain radiograph, the athletes were advised to stop throwing.[45]

Vincenzo *et al*. screened the knee for bone abnormalities of asymptomatic runners with magnetic resonance imaging.[46] Their theory was that abnormalities precede injury symptoms. If any abnormalities, such as patellar enthesopathy, were present, they were treated with electromagnetic field therapy.[46] Like strength screening, this strategy appeared employed in practice as well, in the context of preventing osteitis pubis in Australian football.[44]

Observing early symptoms

Dimitrova *et al*. monitored asymptomatic wrestlers for onset of low back pain.[47] If presented with an athlete with low back pain, they performed a test battery of strength and range-of-motion of the lower back, and performed strength and mobilization exercises accordingly.[47]

In practice, it appears that the prevailing early detection strategy for MSK injury is observing for early symptoms. Three studies state that observing for persisting pain is such a detection strategy,[48-50] while three studies suggest clinical findings as well, such as joint swelling, crepitus, etc.[49,50] or reduced range-of-motion.[44] Studies are conflicted on altered training load and technique; Two studies employ it is as early detection strategy,[48,50] and one refrains from it.[49] Two studies advocate for athlete educa-

Table 1.
Descriptive summary of the included studies.

REFERENCE	PARTICIPANTS	INJURY	STUDY DESIGN	PURPOSE	EARLY DETECTION STRATEGIES	EARLY INTERVENTION STRATEGIES	OUTCOME
WOLLIN, 2018	27 football players.	Groin strain.	Cohort study.	Observe effect of preventative intervention.	Strength loss testing.	High-risk load reduction. Strength rehabilitation.	Health and function improved quickly in high-risk footballers.
WOLLIN, 2020	74 football players.	Hamstring strain.	Controlled trial.	Compare effects of prevention to no intervention.	Strength loss testing.	High-risk load reduction. Strength rehabilitation.	Lower incidence and burden of injury in the intervention group.
HARADA, 2006	153 baseball players.	Medial elbow injury.	Cohort study.	Observe effect of preventative intervention.	Ultrasound and radiographic imaging for abnormalities.	Sports participation restriction.	Early rate of return to high level function.
DMITROVA, 2011	95 wrestlers.	Low back pain.	Cohort study.	Observe effect of preventative intervention.	Observation of early pain.	Sports participation restriction, strength training, and stretching.	Early rate of return to high level function.
VINCENZO, 2016	20 runners.	Knee bone stress injury.	Controlled trial.	Compare effects of prevention to no intervention.	Magnetic resonance imaging for abnormalities.	Pulsed electro-magnetic field.	Early rate of reduction in bone marrow edema compared to control group.
PIZZARI, 2008	36 medical personnel in Australian football.	Osteitis pubis.	Interview study.	Explore experiences with injury management.	Athlete education on early symptoms. Strength loss testing. Biomedical imaging for abnormalities.	Rest, training load modification, exercise alteration, manual therapy, and gradual return-to-play.	Management of osteitis pubis requires early identification of warning signs.
FAWCETT, 2020	10 medical personnel in gymnastics.	Low back pain.	Interview study.	Explore experiences with injury management.	Observation of early training technique alteration. Athlete education on early symptoms. Observation of pain persistence.	Training load modification and technique modification.	The coach and medical team can improve early detection and outcome.
KOX, 2018	7 medical personnel in different sports.	Overuse wrist injury.	Interview study.	Explore early detection strategies of wrist overuse injury.	Observation of pain severity. Observation of pain persistence.	Pain medication and taping/bracing.	Pain, clicking, crepitation, swelling and limited range of motion were useful for early detection.
KOX, 2019	21 medical personnel in different sports.	Overuse wrist injury.	Interview study.	Explore early detection strategies of wrist overuse injury.	Observation of pain severity. Observation of pain persistence. Monitoring performance reduction.	Rest, pain medication, taping/bracing, and medical help.	Athletes consider pain and limitation during daily activities as early indicators of injury, while sport-related pain and limitations may not be.

tion on early symptoms to promote earlier injury management.[44,48]

Early intervention strategies

The included studies essentially employed three different strategies, these being load reduction, rehabilitation and passive therapies.

Load reduction

Seven of nine included studies employed reduction or modification of training load, four of them being experimental studies,[42,43,45,47] and three of them observational studies.[44,48,50]

Rehabilitation

Strength rehabilitation was employed in four studies, three of them being experimental studies,[42,43,47] and one of them being an observational study.[44] Range-of-motion rehabilitation was employed in one experimental study,[47] and technique rehabilitation was employed in two observational studies.[44,48]

Passive therapies

Several passive therapies were employed. Electro-magnetic field therapy was assessed in one experimental study.[46] Manual therapy,[44] taping/bracing,[49,50] and pain medication[49,50] were reported in observational studies.

Discussion

We identified only nine studies, which stands in stark contrast to the 155 empirical injury prevention studies in other prevention domains.[8] Thus, based on our inclusion criteria we therefore contend that current evidence for early detection and early intervention strategies is limited. Furthermore, the samples, methods, and outcomes of the included studies in our review are heterogenous, leading to further difficulties in formulating recommendations for future clinical practice. No observational studies directly assessed early detection and early detection strategies used by athletes in practice, merely being reported in studies observing either MSK injury management in general, or early MSK injury detection strategies. This is likely to impede researchers from formulating clinically relevant secondary preventative strategies, as the evidence for existing practices is limited. Despite the limited evidence, our study nevertheless offers several novel insights.

Early detection

Firstly, early detection can be grouped into three strategies: *Strength loss testing*, *imaging for abnormalities*, and *observing early symptoms* (Figure 2).

Using strength loss testing as an early MSK injury detection strategy is a rather novel concept, with the studies published in 2018 and 2020.[42,43] The concept is supported by other studies demonstrating that strength testing may be employed to detect early MSK injury,[51,52] and we found no studies contradicting this. While the approach seems promising, and as such we recommend that athletes and clinicians consider this strategy in their early MSK injury management, the number of included participants is low, and therefore it should be explored further in research.

Imaging for abnormalities as an early detection strategy may have merit, but also concerns. Several cross-sectional studies have demonstrated a high prevalence of imaging abnormalities in asymptomatic athletes.[53-55] While these abnormalities may predict future symptoms in athletes,[22] these abnormalities may not be convincingly modifiable with interventions.[56] To formulate clinical recommendations, further research into which imaging abnormalities predict MSK injury, and which may be modifiable with interventions, is required.

Our review identified five studies observing for early symptoms as the early detection strategy.[44,47-50] However,

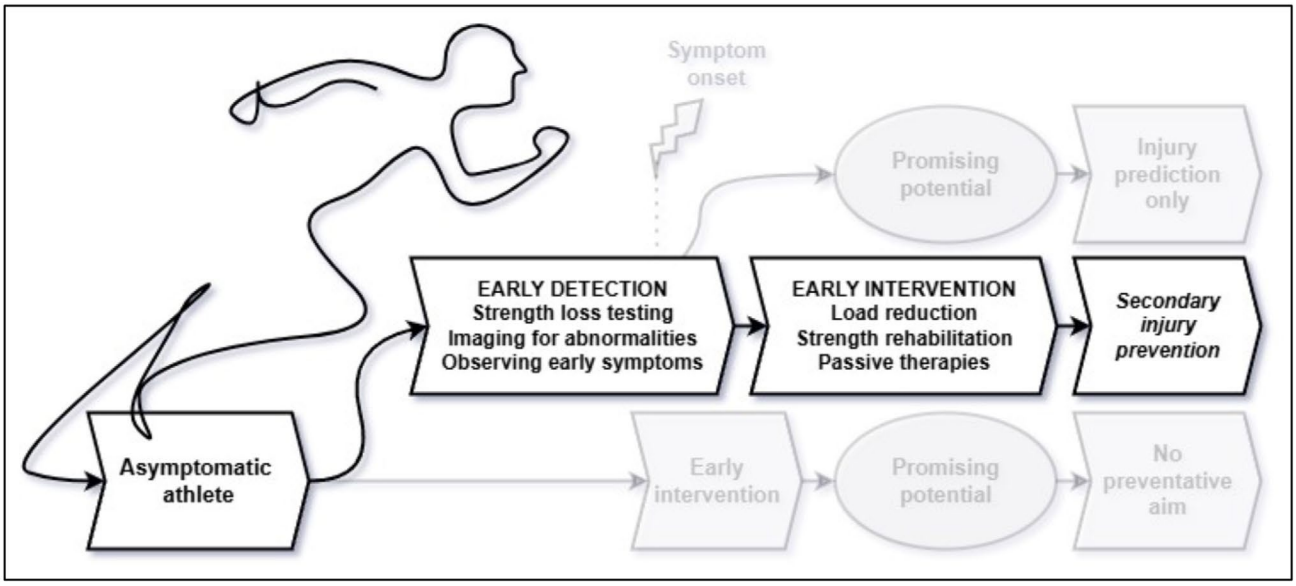

Figure 2.
Visualization of key findings relating to early detection strategies and early intervention strategies.

athletes often self-manage their MSK injuries,[57,58] and await seeking medical support until their symptoms impact on their performance.[59] From a clinical perspective, waiting for the symptom onset may be later than what is ideal. However, we identified no studies comparing these different early detection strategies, and further studies into this are required before we can formulate concrete recommendations.

Preventing worsening of musculoskeletal pain (i.e. chronification) in the general population appears to support mainly patient education.[60,61] In our review, athlete education appears to be a comparatively less employed strategy, only mentioned in observational studies to promote openness to reporting injury symptoms early to the medical teams.[44,48] We recommend that athlete education is considered in both clinical practice and future research. However, as the evidence base is thin, future research may likely either support or disprove this.

Lastly, we did not select studies based on a certain definition of "early". Scholars in this field typically define "early" as asymptomatic findings,[62] some as low disease grade,[63] and some as short symptom duration.[64] In our review, the authors' definition of "early" is linked to their early detection strategy, and thus we did not identify any studies employing low disease grade as an early detection strategy. Researchers in this field are sure to encounter this definition, and the lack of this definition in the included studies in our review highlights the limits of the evidence. We recommend researchers consider assessing and comparing low disease grades with the other identified early detection strategies (strength loss testing, imaging for abnormalities, and observing early symptoms) as well.

Early interventions

Our review also identified three different early intervention domains: *Load reduction*, *rehabilitation*, and *passive therapies* (Figure 2). Load management in general has been explored in other contexts than early intervention strategies. The acute/chronic training load ratio has been explored extensively and reviewed, primarily to assess if it predicts MSK injury or not.[65] Some studies have attempted to modify training load to reduce MSK injury risk, but all in the context of primary prevention.[66,67] Generally, results are promising. Different load reduction strategies exist, from absence-from-play at one end of the spectrum, to lowered intensity in specific training techniques at the other end. In our review, the two trials investigating load reduction did so by reducing specific exposure to sprinting, high-speed running, and explosive acceleration/deceleration activities, based on hamstring strain related injury mechanisms in football.[43,46] While the number of participants in the two included trials is low (74 and 20 participants), this load reduction strategy appears promising.[43,46] In the two cohort studies, the load reduction strategy entailed restricting sports (wrestling or baseball pitching) participation in general, also with promising results.[45,47]

On the contrary, it seems that athletes consistently maintain their training and competing load while injured,[68-71] even though their performance appears to suffer.[72] A proposed reason for this is that athletes consistently strive for better performance and accept the risk of MSK injury.[9,10] Kox *et al*., included in our review, also identified this dilemma,[49] who saw medical personnel refraining from using load reduction as an early detection strategy, arguing that athletes continue training despite MSK injuries.[49] Kox *et al*. also saw that medical personnel observed for performance reduction as an early detection strategy instead.[50] While it was outside of our scope to assess the effect of load reduction (in the case of our results, reduction of sports participation or only high-risk activities), it nonetheless appears promising in research context, but likely troublesome to implement in practice. As such, we recommend both that clinicians and athletes consider this approach for early MSK injury management, but also that researchers adjust studies to reflect real-life behavior of athletes.

Rehabilitation and passive therapies have been examined extensively in other contexts. Low back pain in the general population appears to be the most extensively researched musculoskeletal problem, generally recommending strength rehabilitation and manual therapies.[73] In the context of prevention of MSK sports injuries in general, strength training dominates the research landscape.[8] Although this preventative strategy has mainly been applied before MSK injury onset (i.e. primary prevention), the results have been promising.[74] Passive therapies appear underrepresented in the context of preventing MSK sports injuries,[8] but it may have merit in preventing MSK pain in the general population.[75] While it was outside of our scope to assess the effect of either rehabilitation or passive therapies, it seems safe to recommend these early strategies after early MSK injury detection.

Recommendations for researchers, athletes and clinicians

To summarize our (preliminary) practical recommendations, we encourage researchers to focus on exploring secondary preventative strategies used in practice among athletes. We also suggest that researchers contrast and compare the different early detection strategies in combination with interventions.

Regarding early detection, we suggest that athletes and clinicians consider strength testing as an early MSK injury detection method, but be mindful that the evidence base is thin, and these results are preliminary and may change in the future. We encourage caution in interpreting imaging abnormalities and observing for early symptoms, until these early MSK injury detection strategies have been assessed and compared.

Regarding early intervention, the evidence supports clinicians and athletes employing early use of passive therapies and rehabilitation. In contrast, while we recommend clinicians and athletes use load reduction as an early intervention, it will likely be difficult to implement in athletic practice, due to performance expectations and performance-seeking behavior of athletes.

Limitations

This scoping review was rigorously conducted, following recognized guidelines.[30,32] We nonetheless state a few limitations. This scoping review only includes articles from the last 20 years, and only in English language, nor did we search for grey literature. Additionally, only a single author screened the reference lists of the nine included studies and extracted the data from the included studies. It is possible that without such limitations, our conclusion that the evidence is limited may have been different. We urge future researchers, aiming to reproduce our result, to employ multiple reviewers for this step to lessen bias. Research on non-musculoskeletal injuries was excluded, and even though they are relevant in sport injury context, it is likely that different secondary preventative strategies exist for these conditions.

Conclusions

This scoping review summarizes and consolidates the secondary prevention strategies in the context of musculoskeletal sports injuries. The review identified four experimental studies and five observational studies on early detection and early intervention.

Early detection strategies are strength loss testing, imaging for abnormalities, and observing early symptoms. Strength loss testing is a novel approach and may be considered by clinicians and athletes in their early injury management. The evidence necessitates caution in interpreting imaging abnormalities and observing for early symptoms, until these early musculoskeletal injury detection strategies have been assessed and compared.

Early rehabilitation and passive therapies are likely to be effective as stand-alone or components of early preventative strategies. Early load reduction, although effective as an early intervention, will likely be difficult to implement, due to performance expectations and performance-seeking behavior.

Based on this scoping of the literature, we have found that the evidence for secondary preventative strategies regarding early detection *and* early intervention for musculoskeletal sports injuries is limited. Considering the potential for clinical practice and athlete care optimization, there is a need for both exploratory and experimental research in this area. In particular, no observational studies directly assessed early detection and early intervention strategies in practice, and to formulate clinically relevant future research questions, such assessment is needed.

Acknowledgements: The authors wish to acknowledge Frederik Hjørnholm Kreuzfeldt for his assistance in full-text reviewing the articles for inclusion.

Highlights

- The evidence for secondary preventative strategies regarding early detection and early intervention is limited, compared to the sports injury research field in general.
- The explored early detection strategies are strength loss testing, imaging for abnormalities, and observing early symptoms. We recommend heedfulness until these early detection strategies have been assessed and compared.
- The explored early intervention strategies are training load reduction, rehabilitation, and passive therapies. We recommend considering athletic performance-seeking behavior when implementing training load reduction.

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