

HAVE WE CHANGED OUR APPROACH TO HAMSTRING INJURIES?

A RISK FACTOR REVIEW

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INTRODUCTION

Hamstring injuries represent a substantial injury burden in football¹, and is the most common non-contact muscle injury overall². It has been demonstrated that player availability impacts negatively on team success³⁻⁵, and therefore the management of hamstring injuries continue to receive much attention in the literature⁶⁻⁸, as well as the mainstream media. However, injury prevention efforts have not reduced the number of injuries at the elite level. Incidence patterns in the UEFA Champions League have demonstrated a steady increase of 2.3% in the hamstring injury rate per year, at least

until 2014⁹. These results are worrying, considering that investigations identifying risk factors associated with these injuries have been plentiful¹⁰⁻¹². Unfortunately, these studies continue to provide contrasting conclusions, often directly contradicting each other's findings. This is evident in systematic reviews that do not provide substantial evidence for any specific, modifiable risk factor¹⁰⁻¹².

In this report, we highlight some of the recent risk factor findings in the larger context of injury prevention. We consider what clinical implications these findings might hold and make recommendations for clinical practice.

RISK FACTORS AND PREVENTION

A number of intervention studies have shown to be effective at reducing hamstring injuries; the greatest effect found in studies focused on eccentric strengthening^{6,7,13}. Although not specifically aimed at hamstring injuries, similar success was observed where the intervention was aimed at neuromuscular function and improving flexibility^{3,14,15}. There are perceptions and beliefs around these prevention strategies, from the players regarding soreness or the coaching staff regarding usefulness, that pose serious barriers to implementation^{16,17}. These issues are important to address if we are to have success in implementing

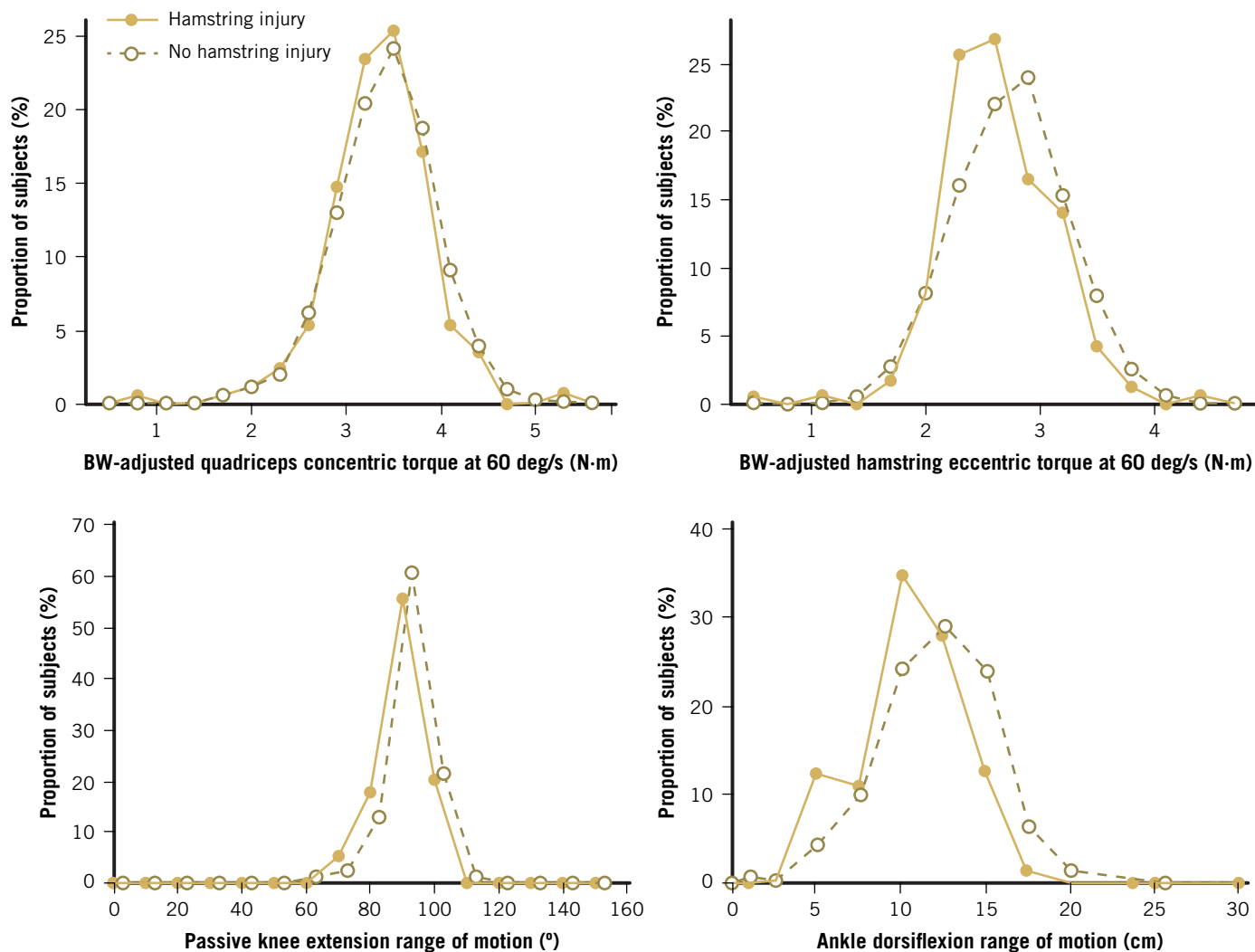


Figure 1: Distribution of injured (closed symbols) and uninjured players (open symbols) for significant variables a) strength and b) flexibility.

prevention programmes in the real world. However, there seems to be a “disconnect” between the identification of risk factors associated with hamstring injury, and the results of injury prevention studies.

NON-MODIFIABLE RISK FACTORS

Age, ethnicity, and playing position

Age is consistently identified as a risk factor for hamstring injury. It is not clear why older players are at greater risk of injury^{12,18,19}. Some theories have been suggested, such as loss of muscle mass leading to decreased strength, and changes in muscle structure. Amason et al did not find a mediating effect of previous injury on age, confirming an independent relationship between age and risk of hamstring injury²⁰. However, in a separate investigation, the risk associated with increased age was mitigated by improvements in eccentric strength²¹, suggesting that the interaction between

these two risk factors, one modifiable and the other non-modifiable, may be important.

Recent studies from large investigations on risk factors from the Arabic peninsula did not find ethnicity to be associated with an increased risk of hamstring injury^{18,22,23}. The role of ethnicity and how it may impact injury risk is still poorly understood²⁴.

Predictably, goalkeepers are much less likely to sustain a hamstring injury when compared to outfielders. High speed running is considered the predominant hamstring injury mechanism involved in football, and outfielders are naturally required to do much more running compared to goalkeepers^{25,26}.

Previous injury is not associated with risk of injury... wait, what?

A history of previous injury has been identified as a risk factor for hamstring injury^{11,12,20,27}. Hamilton et al explores

two potential theories to explain the relationship between previous injury and subsequent injury²⁸. Firstly, a causal relationship exists between previous injury and future risk of injury, most likely due to inadequate rehabilitation. This might lead to incomplete healing, weakness of the previously injured tissue, and other possible functional movement or even psychological factors that persist after return to sport²⁸. Alternatively, a “no causal marker” theory is proposed, where previous injury is simply a marker for other factors that would cause an individual to be at greater risk of injury. This would suggest that confounding bias is present when a history of previous injury is examined as a potential risk factor.

Recent investigations from Qatar provide some interesting results. Previous injury was found to be a risk factor in the first study over a four-year period. However, during the subsequent two seasons, previous injury

was not found to be associated with an increased risk of hamstring injury.

To interpret these contrasting results, let us consider the context of this investigation. Two large randomised control trials (RCT) were being conducted at the Aspetar Orthopaedic and Sports Medicine Hospital during this period. Both studies incorporated a structured criteria-based rehabilitation programme and included a large number of football players. While the second RCT is currently being concluded, the first RCT reported a 12-month re-injury rate of 6%^{29,30}, which is low compared to reports from other football populations³¹. If we consider previous injury a “no causal marker” for other predisposing factors, present in certain individuals, our finding suggest that the introduction of a systematic, criteria based rehabilitation programme may have reduced the risk associated with previous injury by addressing some of these factors. Alternatively, if we assume that a causal relationship exists between previous injury and subsequent hamstring injury, the player may have received adequate rehabilitation, including optimal loading and criteria-based progression to address predisposing risk factors^{32,33}. Either way, this study did not aim to measure the effect of a rehabilitation programme for hamstring injuries on the risk of subsequent injury. However, in this cohort, with the study centre being the focal point of care for the entire football league, it seems a plausible explanation. Such an effect has also been observed in volleyball, where the association between previous injury and ankle sprains was no longer identified after the implementation of a structured rehabilitation programme³⁴.

MODIFIABLE RISK FACTORS

Strength – an oldie but a goodie?

Isokinetic dynamometer strength testing is still considered a reliable measure of determining the strength profile of individual players³⁵. At the elite level, coaches and medical staff rely heavily on isokinetic testing, often making recommendations for training or rehabilitation based on the results of these tests^{17,36,37}. Previous prospective studies have investigated a host of measures derived from these tests, including peak torque, both as an absolute value and normalised to bodyweight, leading to contradicting results¹².

In a comprehensive isokinetic strength assessment in the largest cohort of football players to date, a significant association was found between lower concentric quadriceps and eccentric hamstring strength, normalised to bodyweight, at slow speed¹⁸. Confirming the results from previous meta-analysis¹², another large prospective cohort study indicated that greater quadriceps strength was associated with an increased risk of hamstring injury²².

The findings in both our studies indicate that there is a relationship, albeit weak, between strength and risk of hamstring injury.

Ratios – an imperfect solution

In addition to peak strength measures, different strength ratios have received much

attention in the literature, in particular the hamstrings to quadriceps (H:Q) ratio^{12,38-40}. Interestingly, there is inconsistency in identifying the H:Q ratio as a risk factor for hamstring injury, as observed in the meta-analysis by Freckleton and Pizzari¹². Several candidate H:Q ratios, both conventional and dynamic entities of mixed isokinetic strength, had no association with subsequent injury.

There has been some debate over how these ratios are interpreted statistically⁴¹. A ratio assumes that the slope of the relationship between the logarithmically-transformed numerator and denominator is one. If this assumption is violated, then the ratio will scale inaccurately at the lower and higher ends of the range measured, leading to errors in interpretation. Also, when





Clinically, it is likely that the strength of players will change in response to team training and individual strengthening regimens. Risk factors are time-based, and we observe substantial temporal variability.



normally distributed variables are divided by each other, it is unlikely that the resulting ratio is normally distributed itself⁴¹.

Nordic hamstring exercise – does it deserve the attention it's getting?

Nordic hamstring exercise, performed as a screening test, was previously dichotomised into a pass/fail result based on range of motion, it was not identified as a risk factor for injury⁴². With the subsequent development of a novel testing device, the eccentric force produced during the test was made measureable⁴³. The novel test device has been used in preseason Nordic hamstring exercise strength assessments in football and Australian football, with these studies reporting players with lower eccentric strength during the Nordic hamstring exercise being more likely to suffer a hamstring injury^{21,44}. In these studies, other potential effect modifiers, such as previous injury, age and biceps femoris fascicle length, were included in a multifactorial model, but did not markedly improve the association between limb strength imbalances with risk of hamstring injury⁴⁵. However, considering that these studies identified increased risk of injury with eccentric strength measured during the Nordic hamstring exercise, it highlights the importance of validating these risk factors in different cohorts⁴⁵.

The use of the Nordic hamstring exercise in intervention programmes has been successful, and we do not contest that the

Nordic hamstring strength test may be a useful tool to the clinician. In fact, it has arguably been shown as the most effective intervention tool to reduce the incidence of hamstring injuries in football^{6,7,20}. In the clinical context, it might still be useful to perform the Nordic hamstring strength test to determine a baseline before implementing a specific eccentric strength training programme. However, in a large middle east cohort, eccentric hamstring strength measured during the Nordic hamstring exercise was not identified as risk factor for hamstring injury.

Flexibility of the posterior thigh and ankle

Two studies have reported a significant association between hamstring flexibility and injury, measured with the supine straight leg raise test^{15,46}. In contrast, studies that measured flexibility using the active and passive knee extension test did report an association^{20,42,47}. The sit-and-reach test has also been used to determine hamstring flexibility, with no association between hamstring flexibility and risk of hamstring injury⁴⁸. Measures other than the tests that measure posterior thigh flexibility have also been suggested as potential risk factors^{49,50}. The dorsiflexion lunge test, measuring ankle range of motion, has been investigated previously⁴⁹. A recent meta-analysis reported conflicting evidence for the ankle dorsiflexion lunge test¹². However, both passive knee extension and ankle dorsiflexion range of motion have

demonstrated a significant association with increased risk of hamstring injury¹⁹. Interestingly, both these tests represent range of motion changes in the posterior kinetic chain.

The relationship between intrinsic neuromuscular function and risk of hamstring injury

It is difficult to encapsulate all the components necessary for optimal neuromuscular function in one single test, or even a combination of variables. Recent investigations into the lumbo-pelvic-hip complex suggest that the neuromuscular coordination in the posterior kinetic chain influences the risk of hamstring injury in male football players⁶¹. This suggests a protective effect if the global musculature is addressed in terms of neuromuscular function^{51,52}. In the first investigation of intrinsic neuromuscular function pre-injury, neither rate of torque development nor the onset of muscle activity for any of the concentric or eccentric quadriceps and hamstring isokinetic modes of testing were associated with risk of hamstring injury. Considering previous findings, differences in rate of torque development and muscle activity³² are most likely the consequence of the injury, and both these variables may be altered post-injury. Previous findings suggest that insufficient capacity to generate force (altered rate of torque development) and delayed muscle activity during the early phase of the movement may represent a

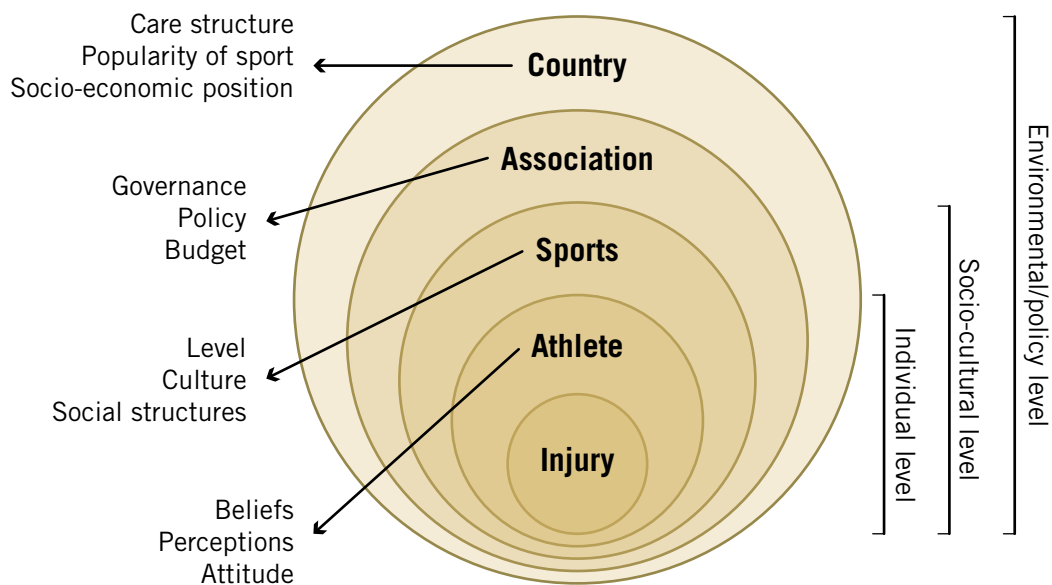


Figure 2: A socioecological view of sports injuries that includes context at multiple levels, i.e. individual, sociocultural and environmental. Bolling et al Sports Medicine (2018):1-8.

reduction in ‘early neural drive’, indicating altered neuromuscular function^{53,54}. These differences post-injury might be expected to influence the stimulus needed to induce muscle hypertrophy and sarcomerogenesis, predominantly during eccentric contraction, needed for adequate rehabilitation⁵³. It is important to acknowledge that these measures only represent one aspect of intrinsic neuromuscular function.

Fyfe et al has suggested a conceptual framework where neuromuscular inhibition persists after hamstring injury, therefore sabotaging the rehabilitation process, leading to several maladaptations, poor outcomes, and elevated risk of re-injury⁵⁵. General consensus regarding return to play criteria after hamstring injury do not include an assessment of neuromuscular function^{75,6}. In fact, due to the difficulty in defining and assessing neuromuscular function, it was specifically excluded from one of the consensus statements⁵⁷. It raises two questions - are we addressing neuromuscular function appropriately in our rehabilitation? And secondly, should the player that has suffered a hamstring injury continue to receive training focused on resolving neuromuscular inhibition even after return to play?

Workload – the new kid on the block?

Emerging evidence supports the clinical hypothesis that the amount of training and competition undertaken is related to the incidence of injuries and illnesses in competitive athletes⁵⁸⁻⁶⁰. However, to date, investigations into the relationship between workload and injury have been limited to

small sample sizes, with inconsistencies in the variables reported to have a significant association with injury.

A potential modifiable hamstring injury risk is workload (training and match load undertaken by the players). In the past ten years, the number of publications investigating the relationship between training and injury has increased four-fold; yet, our ability to appropriately quantify this relationship is still poorly understood.

CLINICAL IMPLICATIONS

Injury prediction vs risk factor identification

The purpose of any screening strategy is the early detection of pathology or disease (usually in a symptom free population) to allow appropriate and early intervention which hopefully leads to prevention of the pathology, and reduces the morbidity and mortality⁴⁵. In sports medicine, we have adopted this strategy from general medicine, aimed at addressing risk factors to prevent injury. But it seems the interpretation of risk identification has been “lost in translation” in sports medicine. One purpose of the periodic health evaluation (screening) may indeed be to identify risk factors present in individuals that may allow early targeted intervention and prevent injury. However, as demonstrated in Figure 1, even if the group average differs, the distribution of injured and uninjured players completely overlap. We might then question the value of screening, and ask if we can still make meaningful conclusions from the information we collect during the screening process.

Is screening a waste of time?

Co-investigations were performed at the Aspetar Orthopaedic and Sports Medicine Hospital aimed to determine whether screening is useful to identify risk factors for hamstring injury, hip and groin injury, as well as the predictive value of functional movement screening (FMS)^{62,63}. Overall, none of these studies provided any screening test with high predictive value and cannot identify players at high risk of injury successfully. The large variability we identified between seasons in tests results, together with similar distribution of injured and uninjured players emphasise the lack of clinical utility in the current tests used to screen for risk of injury.

However, significant group findings of certain variables associated with increased risk of injury were identified. These findings might assist in how we design our prevention programmes, specifically which factors to include in a multifactorial injury prevention model. Verhagen et al uses the example of previous injury to demonstrate how we may find meaning in identifying at risk players, where the risk interpretation is different for players with a history of previous injury⁶⁸.

A complex and temporal problem

Prospective cohort studies are aimed at identifying certain risk factors associated with injury, thus “explaining” the injury by identifying its cause. Rothman describes a cause as an inciting event - either in isolation or in conjunction with other events - that initiates or allows a sequence of events which results in an effect (i.e. hamstring



injury)⁶⁴. A cause which inevitably produces an effect is described as sufficient. Our findings suggest that both strength and flexibility are perhaps components in a larger sufficient cause of hamstring injury. Therefore, by addressing one component needed to produce a sufficient cause for hamstring injury it is, at least theoretically, possible that the intervention could prevent the injury from occurring.

However, these programmes aimed at one of the identified risk factors are often not adapted in practice⁶⁵. Recently, the context (and complexity) that underly the implementation of prevention programmes has been emphasised (Figure 2)⁶⁵. It is important that we include these components when we plan our prevention strategies. Without it, successful adoption of the intervention remains unlikely.

Clinically, it is likely that the strength of players will change in response to team training and individual strengthening regimens. Risk factors are time-based, and we observe substantial temporal variability. In most prospective risk factor studies, the risk factor identification was determined during a pre-season screening examination, and the players were followed for the

subsequent season. Unfortunately, we do not monitor how the factors we measure change over time, and therefore our analyses are based on the assumption that our screening results are “frozen-in-time”; representative of that factor at the time of injury. The investigation into the stability of these tests support our clinical intuition, that there is substantial variability in these measurements over time. It provides motivation to move away from isolated time-point testing towards continuous monitoring of these risk factors, allowing the clinician to identify changes in these risk factors, and how these changes might be associated with risk of injury. The template for this type of monitoring has been provided in overuse injuries focused around injury burden rather than time loss due to injury⁶⁶, yet the hypothesis of monitoring risk factors as an alternative to once-off screening has not been investigated. As injury risk is influenced by workload⁶⁷, we might expect that strength and other factors would be affected. However, we have yet to establish a better understanding of the interactions between these factors, and how these factors may respond to different fluctuation in applied load over time.

WHAT THESE FINDINGS ADD TO OUR CLINICAL PRACTICE

To assist the clinician with translating this information into clinical practice, we have summarised the findings. The five key points are:

1. Strength and Flexibility are weak risk factors for hamstring injuries and continue to form a small but important part of the causal pathway. Although the evidence for stretching is lacking, multifaceted prevention programmes might consider including these components to be successful in the prevention of hamstring injuries.
2. Intrinsic neuromuscular function may be altered post-injury. Clinicians should focus on returning the player to full function during the rehabilitation of hamstring injuries, which may include specific targeted intervention even after return to play.
3. Our common strength and flexibility tests have poor predictive value, and do not possess the characteristics needed to successfully identify individual players at greater risk of hamstring injury. This is evident in the large amount of variability between seasons,



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and poor sensitivity and specificity demonstrated for these measurements. The wide overlap in distribution of pre-season strength between injured and uninjured players demonstrates the difficulty in identifying a subgroup of at-risk players that might benefit from targeted intervention. It is therefore recommended that prevention programs be implemented for all players.

4. Workload monitoring provide another potential way in which we may reduce the risk of injury. The aggregation of chronic workload, as well as careful planning of acute workload increases, may reduce the risk of hamstring injury. However, high-level evidence to support this is lacking.
5. Understanding the context in which injuries occur and appreciating the complex nature of these injuries are important considerations to better manage players with hamstring injuries.

inciting event we could recreate in a safe way to test risk patterns and behaviour. This would include factors such as fatigue, dual cognitive tasks, and sport specific movements. Unfortunately, many sports medicine research groups continue to work in silos and ultimately answer similar research questions, published as isolated small studies. The clinical indications from these results often differ, and with the discrepancies among studies. A collaborative effort is needed to establish several well-organised successive research studies. This calls for a shared collaboration between institutions and research groups to perform collective data analyses and combine the results of individual projects.

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ADVICE FOR FUTURE RESEARCH

We continue to utilise performance tests when we assess risk of injury. Perhaps we need to consider what elements of the

*References available at
www.aspetar.com/journal*