The hamstrings are by far the most common soft-tissue injury sustained in field-based team sports. Not only are they the most frequently injured site, in the seasons between 2001/02 and 2013/14 in professional soccer Ekstrand et al., (2016) study showed an increasing trend of hamstring injuries in professional soccer players [1].

So what does this mean for a team? Well, this means a professional soccer team can expect ~ 7-9 hamstring injuries in a season of 30 games.

What does that mean individually? If a player does sustain a hamstring injury (HMI) they can expect to be out of action for ~ around 20 days/1000 h of training and match exposure.

What is the primary mechanism?

In field-based team sports you can expect approximately 68% of rugby players, 80% in AFL and 60% in professional soccer who do sustain a HMI (non-contact) to occur during running or sprinting. The overarching conclusion from the research is that the primary mechanism involves rapid acceleration or maximal velocity sprinting [2–4].

Problem

HMI incidence are still somewhat on the rise (dependent on the sport, location etc) and the factors associated with this are wide and varying, however the primary mechanism remains unchanged (accelerating or nearing max. velocity) – the next question is the 'why'?

To try and answer that is very tricky. However, the figure below published in a review from Buckthorpe et al., (2019) does a great job in showing the number of risk factors involved with HMI, and how complex it is in attempting to describe why this specific injury is occurring, and perhaps that is the answer in itself, there is no one specific reason – HOWEVER, some of these risk factors may contribute more or less [5].

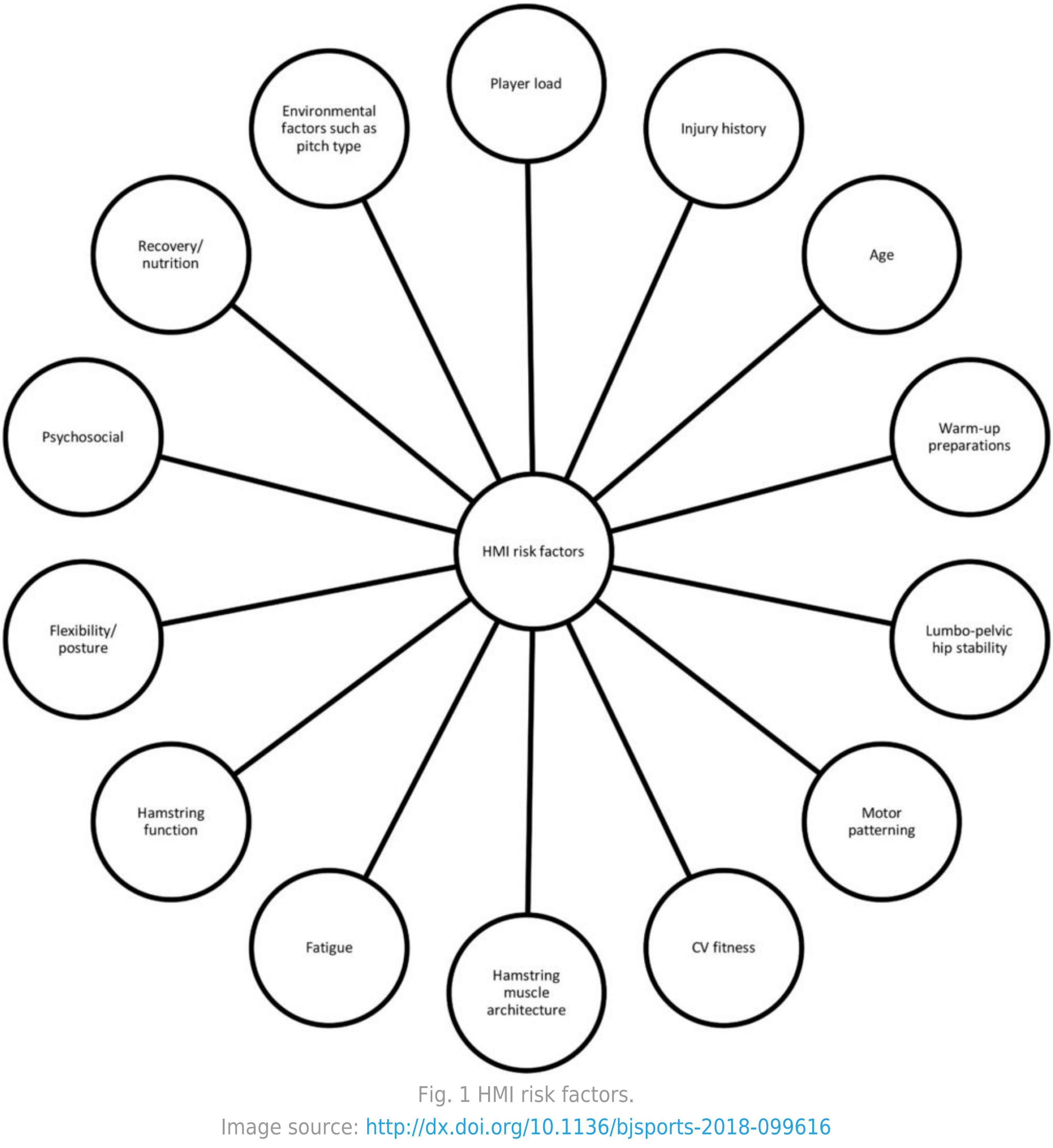

Fig. 1 HMI risk factors.
Image source: http://dx.doi.org/10.1136/bjsports-2018-099616

Let's address these factors:

In terms of prevention strategies a fair amount of research has been published, I won't go through every single component involved but hopefully I can give you a broad idea of what has and hasn't been done.

Isokinetic strength assessments – Much of the research investigating hamstring and quadriceps isokinetic strength identified that if deficits were found, they were extremely weak risk factors for HMI, AND not very accurate in identifying individual players at risk [6]. Basically, isokinetic strength assessments only tell a small story with respect to HMI.

Eccentric training – Performing the Nordic hamstring exercise – or general eccentric exercises decreased HMI rates by 50% in soccer players… success! Do eccentric exercises and all of your HMI concerns will disappear! Let's not get too carried away… Two major meta-analyses and systematic reviews also concluded there was significant variability across training programs, and that only half of the studies reported on subsequent injuries or included an injury index [7,8], AND both reviews maintain that there is still a small body of evidence to conclusively state that this reduction is solely due to Eccentric training. Yes, eccentric training plays a very important role in reducing the incidence of HMI, however…. much of the research is based on isolated risk factors and they do not take into account the multiple risk factors, or how they might interact and their relationship with the sprint action and subsequent HMI. Unfortunately, I have to fall back on the usual saying 'we need more research' – specifically, randomized controlled trials to be able to state the ideal volume, intensity, and rest to illicit meaningful change with respect eccentric training HMI prevention.

Sprinting drills – There is evidence to suggest that sprinting drills which specifically aimed to improve running technique, coordination and hamstring function improve lower limb neuromuscular control during the late swing phase as well as early stance phase (which is thought to be high risk phases for HMI). It is important to note that the 'neuromuscular control' improvement from the HamSprint programme was based on reducing backward leg swing. Meaning that the intervention was successful in changing sprint technique (i.e. 'front side mechanics') [9]. Again, there is limited research which has specifically incorporated sprint drills aimed at reducing the incidence of HMI. However, the current evidence indicates that there is no exercise (or drill) that accurately replicates sprinting from a neuromuscular and biomechanical standpoint (which seems pretty obvious, if you want to improve your sprint… you should sprint!!!). There is a lot more to add to this particular section, for example, resisted sprints. However, I will delve into a little more detail below when I talk about horizontal force production.

Hamstring muscle activity – Drills such as the HamSprint could be especially useful for rehabilitation purposes, particularly when also taking into the recent works from Hegyi et al., (2019) which found that hamstring muscle activity appears to be extremely individualised, however, the pattern remains similar across different running speeds, which could mean that running at submaximal speeds may be important during early hamstring rehabilitation [10]. If hamstring activity is extremely individualised across the elite population it would be a potential headache for many S&C coaches in team-based sports, meaning they might need to individualise many different programs. However, in a perfect world, researchers could aim to develop simpler methods which indirectly measure or are associated with movement patterns that illicit specific muscle activity patterns. This would allow the practioners to create specific programs based on the different 'muscle activity types'. However, more research is also needed to identify if specific muscle activation patterns are more at risk of injury than others. Importantly, this would need to include each of these muscle activity patterns change when fatigued and how this may/may not be associated with HMI.

Horizontal force production – If we take a more holistic approach to the problem we find that different postures in the different sprint phases can provide some insight into HMI. Understanding the forces that are occurring during the acceleration phase and sprinting at maximal velocity can for example, indicate hamstring function through observation of horizontal force production [11]. We can observe this in the force trace during the ground contact phase, where the hip is extending and the knee is slightly flexed (this is often referred to as the pawing motion). Essentially, the foot hits the ground down and backwards and this is where the hamstrings work together with the hip extensors to produce this horizontal force. We can see during the acceleration phase athletes tend to adopt a more forward leaning posture, this results in the centre of gravity (CG) being in front of where the foot contacts the ground, therefore orientates the GRF in a more horizontal direction.What is the relationship between these GRFs and what does this mean for the hamstring muscles? Well, in order to apply force more optimally, faster athletes tend to exhibit higher hamstring muscle activity prior to ground contact, and at the same point in time, present peak eccentric hamstring muscle force. So highly activating the muscles prior to foot-ground contact is important in producing this horizontal force. — This is the point where we introduce resisted sprints –. Essentially, the friction between the ground and sled is determined (in part) by the amount of load added to the sled. Higher loads (relative to body mass) should only be incorporated if the athlete is technically proficient, as with any type of training this requires a progressive approach. So, what is the optimal load? The systematic review and meta-analysis (corrected version) from Alcaraz et al., (2018) states that "the intensity (load) is not a determinant of sprint performance improvement, but the recommended volume is > 160 m per session, and approximately 2680 m per total training program, with a training frequency of 2–3 times per week, for at least 6 weeks" [12]. Morin et al., (2017) have shown that very-heavy loaded sled (~80% of body mass) sprint training does indeed improve horizontal force production. Interestingly, very-heavy sled training does this by increasing the effectiveness in the application of force [13].

Symmetry/Asymmetry – We break down the force applied into vertical, anterior-posterior and medial-lateral GRFs to observe the effectiveness of force transmission to assess sprint technique… AND examine whether there are asymmetries present in the GRFs between each leg. For example, the figure above is an edited version from a study conducted by Nagahara et al., (2018). This study wasn't specifically investigating asymmetries between legs, however, I've placed a few red arrows and a red line on the different force traces, you can identify differences between legs with a naked eye [14]. Differences can be observed in the anterior-posterior forces between left and right leg. If there are between-leg differences, this could increase the force requirement of one leg compared to the other, leaving that leg more prone to injury. This can be assessed by performing sprints or jumping (bilateral broad jumps) and analysing the horizontal component of the force trace.

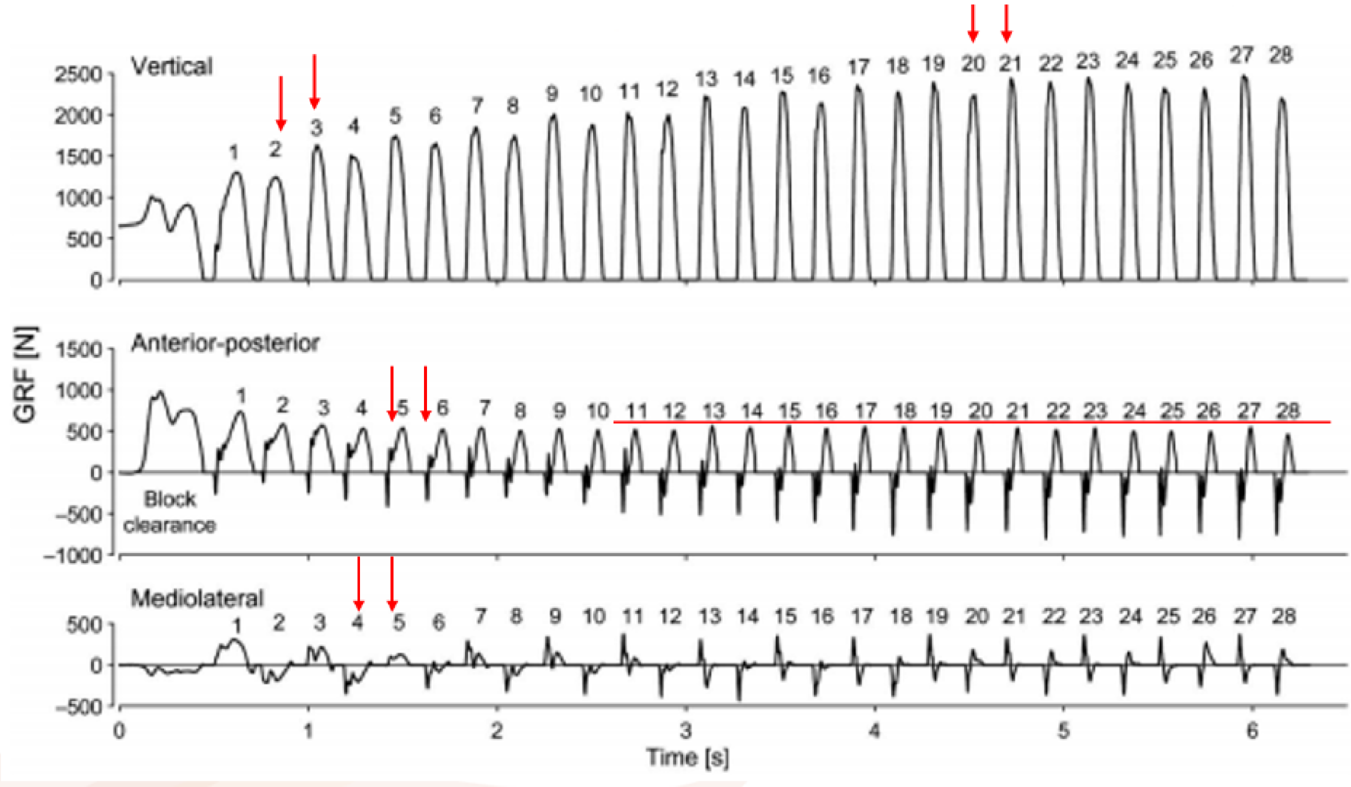

Fig. 2: Asymmetries in GRFs during sprinting.
Modified from: https://doi.org/10.1111/sms.13093

So when are athletes at risk of HMI – duh, the late swing phase, right?

Yes, but why? – Current evidence suggests that hamstrings have a high rate of injury because they work eccentrically to decelerate the thigh and shank during the late swing phase during sprint running, which is thought to be the most likely point at which injury occurs. During this phase, as the hip moves from flexion to extension, essentially 'pushing' the knee joint downwards, by 'pushing' the knee downward this causes the shank to rotate or drift further forward. The hamstrings at this point now have 2 functions, 1. (Positive work) Extending the hip, 2. (Negative work) Decelerating the shank prior to foot ground contact.

Hip Ext + Shank Deceleration – So these 2 specific functions have been shown to be possible risk factors for HMI – for example, Kenneally-Dabrowski et al., (2019) performed a prospective analysis of the late swing mechanics in 10 elite rugby players [15]. 4 of those players suffered a running-related hamstring injury in the subsequent season. They found that the injured athletes tended to have, 1) greater hip extension moment, and 2) greater knee power absorption, but they also found that injured athletes exhibited a 3rd characteristic which was greater thoracic lateral flexion on the ipsilateral side during the late swing phase. This study had some really good findings, however only tested subjects in a non-fatigued state. So we don't know whether their late swing mechanics changed when fatigued, and how this might be associated with HMI.

Anteriorly tilted pelvis – Because of the anatomical connections that exist between the pelvis, spine and femurs, it is likely that the orientation of the pelvis has a significant impact on hamstring kinematics and the overall sprinting technique of an athlete. Schuermans et al., (2017) performed a prospective analysis and compared injured vs uninjured soccer players [16]. The injured group exhibited deficient 'core stability', which led to excessive pelvis and trunk motion – the excessive motion referred to the injured group having greater anterior pelvic tilt and lateral thoracic flexion of the trunk during the entire swing phase when sprinting. Higashihara et al., (2015) compared a more forward leaning posture with a more vertical posture, the participants that leaned more forward also tended to have greater anterior pelvic tilt throughout the entire stride cycle [17]. The authors concluded that the potential for HMI would exist during the late swing phase because the hamstring muscles are being stretched further while contracting eccentrically. This makes sense because during the late swing phase the proximal end of the hamstrings are trying to shorten to extend the hip, while the distal end is working eccentrically to decelerate the shank, this alone would increase the length of the hamstrings, which is also partly due to their biarticular nature. If you add anterior pelvic tilt into the equation, the hamstrings are now stretched even further.

Are the hamstrings even contracting eccentrically during the late swing phase?

Eccentric/isometric? – To throw a slight curve ball into the mix, recently Van Hooren & Bosch (2017) suggest that there may not even be an eccentric contraction occurring, but rather an isometric action of the hamstrings during the late swing phase in high-speed running [18]. If the muscle is acting in an isometric manner, this would mean that the series elastic component would be stretched instead of the muscle itself. The isometric functioning does not necessarily rule out an eccentric muscle action as the cause of hamstring injuries. However, rather than experiencing an eccentric action during every swing phase, the hamstrings may only experience an eccentric contraction at irregular intervals. They suggest this could be due to a loss of coordinative control of the pelvic area which may increase the distance between the attachment points and therefore cause an eccentric muscle action, leaving the muscle vulnerable to injury. They suggest that this loss of coordinative control may be due to the athlete experiencing significant levels of fatigue. This 'change' in running kinematics is sporadic, suggesting that when fatigued, the muscular force produced during an eccentric contraction is also quite variable (if you assume the same running velocity). But this speculative since we cannot actually measure whether muscle fascicles are shortening or lengthening in actions such as sprinting (yet)…further research is needed.

Fatigue?

Much of the research points to fatigue as probable risk factor, but very little research is actually published with respect to how fatigue might influence each of these variables and if there is an association with HMI.

When are these injuries occurring? – for example, when examining match activity profiles in rugby, AFL and soccer we can see that there tends to be a decrease in physical output of ~15-20% toward the ends of the halves or quarters (e.g. no. of accelerations, decelerations and max. vel sprinting distances) [19–22]. In addition, this is also when the majority of soft-tissue non-contact injuries (e.g. HMI). Kinetic and kinematics analyses have shown that significant mechanical stress is imposed on the hamstring muscles during these type of actions [23]. This mechanical stress during repeated sprinting have shown to reduce muscle function (Linklater et al., 2010). One way to observe muscle function is to examine muscle activity [24,25]. The evidence indicates that there is an earlier onset and longer duration of hamstring muscle activity when fatigued – this may be necessary to compensate for the decreased force generating capacity of the fatigued muscles due to these repeated eccentric contractions [26]. A decreased ability of the muscle to generate force is thought to reduce the energy absorption capabilities of the muscle which, in turn, can increase the potential for muscle injury.

Muscle function – okay, so muscle function is reduced, what are the implications? Well, when fatigued, we tend to see fewer cross-bridges formed, lower muscle force, earlier activation of the muscle as it now needs to stretch further to produce the same amount of force (if you're trying to run at the same velocity – i.e. max acceleration or near max. velocity) – the fatigued hamstring muscles have to be stretched further to produce the required force = increased risk of HMI.

Sprint technique when fatigued – So how does this effect sprint technique? Well, in order to produce the required amount of force for the hamstrings to work at longer lengths, you could: a) change your joint kinematics e.g. allow the shank to drift further forward, b) tilt the pelvis forward, c) activate the hamstrings earlier and for longer.

Disclaimer

This is my personal interpretation and/or opinion, meaning I may be completely wrong in some of the statements made. If that is the case, I hope for an honest, rational and calm discussion to unfold.

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