© by IAAF
29:4; 25-32, 2014

Identifying Opportunities for Enhanced Hamstring Health Through Improved Running Mechanics and Proper Loading Progressions

by Derek M. Hansen

ABSTRACT

One of the biggest fears for athletes or other sportsmen and women who engage in high-speed running is the hamstring strain and its effect on performance. One study reports that hamstring injuries make up 26% of all injuries in athletics, with the majority being in the sprint events. A comprehensive approach for the prevention and treatment of hamstring strains must involve an assessment of the causes of the injury. Until we know exactly why hamstring strains occur, it is very difficult to minimise their incidence. Written by an experienced speed, strength and conditioning coach who has worked with sprinters and players from several other sports, this article provides coaches with basic anatomical and functional knowledge of the hamstrings as it relates to sprinting, identifies the risk factors of which they need to be aware and gives clues as to what to observe in order to assess the likelihood of a hamstring injury. The author then gives five recommendations for minimising the chance on injury before concluding that there is no one-size-fits-all programme and the coaches need to create individualised prevention programmes for their athletes.

AUTHOR

Derek M. Hansen, MASc, CSCS, is the strength and conditioning coach for Simon Fraser University in Vancouver, British Columbia, Canada. He has over 20 years experience in working with sprint athletes, including a number of Olympians, as well as sportsmen and sportswomen in North American professional leagues. He is also a regular contributor to the athletic performance website, StrengthPowerSpeed.com.

Introduction

One of the biggest fears for athletes who engage in high-speed running, is the hamstring strain. One study reported that hamstring injuries make up 26% of all injuries in athletics, with the majority being in sprint events[1]. Another study of university-level sprinters and jumpers in the USA found a hamstring strain incidence rate of 24% over a two-year period[2]. Despite advances in training methods, equipment, injury prevention, medical diagnostics and treatment methods, hamstring injuries still appear to be a significant part of sport. Athletes and performers in other sports can be crippled by acute hamstring injuries and, if not addressed properly, such injuries can linger on and create further performance and financial burdens for all involved. A comprehensive approach for the prevention and treatment of hamstring strains must involve an assessment of the causes of the injury, as well as key risk factors for acute strain. Until we know exactly why hamstring strains occur, it is very difficult to minimise their incidence.

The hamstrings are made up of three primary muscles: the biceps femoris, semitendinosus and semimembranosus. Sprinters and other athletes who run at high velocities, tend to strain the biceps femoris more than any other muscle in the hamstrings[3]. In a study that examined 23 European professional football teams and 516 hamstring injuries between 2007 and 2011, it was determined that 83% of injuries affected the biceps femoris, while 11% occurred in the semimembranosus and 5% were found in the semitendinosus[4]. In a study by ASKLING et al.[5], 18 elite male sprinters with acute hamstring strains were examined with magnetic resonance imaging and it was determined that all of them sustained injuries in the long head of the biceps femoris muscle[5]. More specifically, the muscle injury typically occurred at the junction between the muscle and tendon where the forces on these structures is most concentrated[6].

While it is quite evident where the injuries are occurring, it is still not quite clear when they are occurring, particularly within the context of the running gait cycle. The muscles of the hamstring are clearly active through different stages of the running gait cycle, as identified by electromyography. The hamstrings act as knee flexors during the swing phase, hip extensors during the late stance phase and knee stabilisers on ground contact during the early stance phase. It has been hypothesised that the majority of running related hamstring strains occur at the time of the early stance phase, when ground reaction forces are highest, with the hamstring being previously exposed to the high eccentric forces in the late swing phase[7]. Although athletes may not feel the strain until the late stance phase or early swing phase, the actual damage was incurred a fraction of a second earlier at the point of extreme ground reaction forces.

This information on the exact timing of the injury is critical in our assessment of how to correct the problem and take action to minimise the incidence of hamstring strains in sprinting athletes. In my own experience of coaching sprinters, there are distinct circumstances when a hamstring strain occurs. These risk factors for hamstring strains must be taken into consideration when planning workouts and managing sprinting athletes.

Risk Factors for Hamstring Injuries

Over the years, researchers have identified many risk factors for hamstring strains in athletes. One of the most common appears to be the incidence of a previous hamstring muscle injury[8]. One study of European football players noted that a previous hamstring strain increased the chance of re-injury by up to 11 times[9]. In an examination of sub-elite European football players, adult males with a history of acute hamstring injury were twice as likely to sustain a new hamstring injury[10]. The reasons for this greater susceptibility to injury can be multi-faceted including less compliant muscle tissue at the site of injury, scar tissue accumulation, inadequate strengthening following the initial injury and muscle coordination difficulties not addressed through the rehabilitation process.

Independent of prior injury, the age of the athlete has also been identified as a major risk factor. A number of studies have identified players in Australian Rules football[11] and European football (soccer)[12] over the age of 23 years having a higher risk for hamstring injury. Other studies have even identified ethnicity and race as a risk factor for hamstring strain. Two studies identified athletes of African or Caribbean ethnicity[12,13] as being at higher risk, while a third study indicated that Australian Aboriginal athletes are in the high risk category[14].

In the area of training related risk factors, studies have examined strength imbalances (bilateral asymmetry and quadriceps-hamstring ratios), athlete fatigue and poor flexibility as causes of hamstring injuries. Studies examining the impact of bilateral strength differences between legs on hamstring injury have had mixed results. One study of Australian Rules football players found that players with a leg strength difference of 8% or more have an increased risk of hamstring strains[15]. Another study of European football players found that those with a bilateral strength difference of 15% or more have an increased risk of hamstring injury[16]. In contrast, there are a number of studies that have found no connection between individual leg strength differences and hamstring injury, including one by BENNELL et al.[17] observing that the hamstring-to-opposite-hamstring isokinetic strength ratios did not differ between injured and non-injured Australian Rules football players.

Fatigue has always anecdotally been connected to hamstring strains and other muscle injuries. Research has shown that there is a higher incidence of hamstring strains in the latter stages of competitions and training sessions[13,18]. Fatigue can cause not only changes in muscle strength and durability, but also alter running mechanics in a manner that can make an athlete, while running at high velocities, more susceptible to hamstring strain. A study of American professional football (NFL) players over a 10-year period identified common factors associated with hamstring strains[19]. Over the course of the study, 1,716 hamstring strains were reported, with 51.3% of all cases occurring in the seven-week pre-season period. The pre-season period is associated with exceptionally high-volumes of work and less than adequate recovery between repetitions and sessions. Coaches demand that all drills be run at high-speed to simulate game conditions. Additionally, many players may be entering the pre-season period with less than appropriate physical preparation behind them. Three position groups experienced almost 57% of all hamstring strains: the wide receivers (23.1%), defensive backs (20.8%) and special teams (13%). These groups are the most likely to experience not only high running velocities, but also greater running distances per play. These results demonstrate that high running velocities, length of running efforts and fatigue can be a risky combination when it comes to increased probability of hamstring strain.

Flexibility of the hamstrings is often identified as a major risk factor for injury. It is assumed that athletes who cannot easily touch their toes have poor hamstring flexibility and, hence, are at greater risk for hamstring strain[15]. Research studies of Australian Rules football players, using sit-and-reach and toe-touch tests, have shown no connection between poor flexibility and increased risk of hamstring strain[15,20]. However, even though no clear connection between flexibility and hamstring injury has been made, stretching of the hamstrings continues to be a common approach to both preventing and managing hamstring strains. In some cases, however, it could also be argued that excessive, aggressive stretching of the hamstrings could create a circumstance where the hamstrings are at greater risk for injury due to micro-trauma and fatigue.

Prevention Measures for Hamstring Injuries

There have been many efforts to develop training protocols and specific exercises to prevent hamstring injuries in athletes. Research studies have examined specific interventions designed to minimise the risk of hamstring strain. However, the majority of studies have found very little correlation between targeted efforts and fewer hamstring injuries[21]. Recent interventions have focused on strengthening the eccentric abilities of the hamstrings in an effort to reduce the incidence of injury. Theoretically, this approach is in line with the assumption that high eccentric loads experienced by the hamstring in the late swing phase of the stride contribute to injury as the athlete enters the early stance phase of sprinting.

Research on eccentric strengthening protocols, including the Nordic Hamstring Exercise – where athletes are positioned on their knees, with their ankles held down, and slowly lower themselves to the ground – has had mixed results. In one study, European football teams who followed the Nordic Hamstring protocols demonstrated a 65% reduction in hamstring strains as compared with teams that did not implement the protocol[22]. Other studies with Australian football players[23] and European football teams[24] found no benefit to using the Nordic Hamstring exercises.

In practice, many coaches have employed other forms of eccentric strength training exercises in the weight room including Romanian dead-lifts, good mornings and hyperextensions. Often, heavy loads are used with the expectation that greater raw eccentric strength will prevent hamstring injuries. While the hamstrings are being strengthened in terms of the loads being handled, the eccentric force and velocity capabilities required for high-velocity running are not being addressed in a specific manner. This has important implications for athletes who rely on their hamstrings for maximal sprinting tasks.

Examining the Root Cause of Hamstring Strains: High-Velocity Running

With research providing a variety of potential causes and risk factors for hamstring injuries, we are still left with more questions than answers. Hamstring strains persist in equal or greater numbers despite deeper investigation into the causes. My observations on the subject tend to diverge from what I would deem a medical or clinical approach, and focus more on the actual activity of sprinting. This includes a detailed look at the mechanics of running and the planning and preparation that goes into developing an athlete for sprinting at high velocities. If we agree that hamstring strains are more likely to occur at the higher velocities and intensities of a sprint, we can start to identify solutions for preventing and managing hamstring injuries. Before we can address the root causes of hamstring strains, we must embrace some practical realities regarding the act of high-velocity running.

Sprinting is a complex neuromuscular task. We often think of fast running as a genetically endowed ability, with great sprinters being born not made. However, the ability to run fast is a complex skill that requires the activation, relaxation and sequencing of various muscle groups in the lower extremities within milliseconds of each other in the correct order, proportions and magnitudes. As coaches and athletes, we take for granted that any deviation from this carefully orchestrated array of muscular outputs can lead to disaster at any given moment during a maximal sprint. We know from research that prior hamstring injury can lead to altered neuromuscular activation patterns that influence the probability of future hamstring strains[25]. A recent study using functional magnetic resonance imaging (fMRI) technology has found that the actions of the individual hamstring muscles under healthy conditions should have a high level of intramuscular dissociation, with the semitendinosus having a prominent role in producing and controlling the torques around the hip and knee joints[26]. The study found that injured hamstrings displayed more symmetrical muscle activation patterns, implying compensatory and inappropriate neuromuscular coordination patterns, causing the hamstring muscle bellies to contract less efficiently. As a result, the biceps femoris muscle compensates for the functions of the semitendinosus, assuming a higher load beyond its capacity and is placed at higher risk for strain.

High-velocity running repetitions can lead to fatigue and micro-trauma that impacts the function and intramuscular coordination of the hamstrings. If an athlete is exposed to high volumes of high-velocity running, there is a high probability that fatigue and micro-trauma can alter the efficient function of the hamstrings, placing the athlete at higher risk for future injury. High-velocity running is a risky activity. Measures must be taken to ensure that the volumes of work are within the capabilities of the athlete and appropriate volumes of rest between repetitions, sessions, and days of high-speed work are incorporated into the programme. Additional recovery and regeneration work may also be required in the form of manual therapy, contrast therapy and active recovery activities to address high muscle tone, muscle fibre adhesions and waste products associated with fatigue. With all of these variables to consider, proper planning and application of work must be followed, including recovery and regeneration inputs, and adjusted daily to make sure the athlete is recovering adequately and ready for the next dosage of high-speed running.

High-velocity running with inefficient mechanics places athletes at significantly greater risk of hamstring injury. Faster athletes produce greater ground reaction forces and spend less time on the ground with each step[27]. High-level sprinters attain higher running velocities by applying greater vertical forces during the first half, but not the second half of the stance phase of sprinting. Whereas, non-sprinters apply greater forces in the second half of the stance phase[28]. This information provides us with clues as to how efficient high-velocity running is carried out on a mechanical level. Athletes that over-stride and sprint with a lower hip position relative to the ground will not only step further in front of their body centre of mass, creating a braking force and greater friction, but will also spend more time on the ground with each step. This type of running technique will not only lead to less efficient locomotion, but also expose the hamstrings to greater stresses on ground contact, where ground reaction forces are the highest. For the efficient sprinter, the hamstrings help to control the stability of the knee on ground contact, taking advantage of stored elasticity in the lower leg and foot, and assist in powerful hip extension. For less efficient sprinters who over-stride, the hamstrings also take on the role of knee flexors as they pull the athlete's centre of mass over the planted foot. This strategy places the athlete at greater risk for muscle strain, as the hamstring is more likely to fatigue prematurely and incur injury.

High-velocity running is one of the most forceful, complex skills that an athlete will be exposed to in a training and competitive career. Acknowledgement of these characteristics and the risks associated with high-velocity running will go a long way to minimising the incidence of injury.

Recommendations for Minimising Hamstring Injuries

Given the range of risk factors and realities facing sprinting athletes and their hamstrings, some key recommendations for both coaches and athletes can be provided to minimise the incidence of hamstring injury.

Adequate time and effort must be spent on not only developing optimal sprint mechanics, but also maintaining quality technique in high-velocity running. Athletes who are less efficient and exhibit less than optimal running technique will be at greater risk of hamstring strain as they attain top speeds. As athletes fatigue, running mechanics and intramuscular coordination are altered, shifting responsibility for force production and locomotion to muscles that are not equipped to handle the load associated with high velocity running. Special attention must be given to technical execution of sprinting designed at meeting minimum standards for biomechanics every time the athlete runs at or near top speed. Coaches must anticipate a breakdown in technique before it occurs and have the confidence and courage to stop the training session, as an injury may be imminent. Additionally, cues for sprinting technique should focus on vertical force production, as references to horizontal cues (i.e. pushing, pulling or grabbing) can result in over-striding mechanics that increase the risk of hamstring strain.

Overall volumes of work must be monitored closely and gradual progressions followed throughout the training period. Every sprinter will have a finite volume of high-speed work that they are capable of completing. After this volume of work is achieved in a given session, positive adaptations to sprinting are less likely to be accrued. In addition, the probability of hamstring strain will increase significantly as fatigue sets in and mechanics are compromised. It is the job of the coach to closely monitor the volume of work being completed by the athlete to ensure that only positive adaptations are being achieved and injury risk is kept to a minimum. This assessment will primarily be monitored through use of a stopwatch, but will also involve observations of technique, body language and verbal communication with the athlete. Increases in the volume of speed work from session-to-session and week-to-week will proceed gradually to ensure the athlete is never too far outside of his or her abilities and previous accomplishments. The tracking and adjustment of sprinting volumes from workout to workout must be carried out diligently by every coach to not only ensure progress, but also avoid setbacks.

Older athletes will typically respond better to lower overall volumes of high-speed work, as they require longer recovery periods between bouts of high-intensity exercise. As athletes move into the latter stages of their careers, lower speed training volumes are required to advance their performance capabilities. This tendency works hand-in-hand with the observation that older athletes are at higher risk for hamstring injury. Coaches must recognise that older athletes may require less frequent sessions of high-velocity running from week to week. Within individual sessions, more recovery time will be required with overall volumes being trimmed. The intent of such adjustments is to improve the conditions for improvement, without increasing the risk of injury.

Conventional strength training and resistance exercises directed at strengthening hamstrings will only improve general strength qualities and not provide maximal protection against hamstring strain during high velocity running. If we understand that sprinting is a complex neuromuscular skill that involves the contraction and relaxation of involved muscle groups in an organized fashion, it follows that quality high-velocity running must be considered a foundational component of strengthening the hamstrings appropriately. Weightlifting and resistance training exercises can serve as a supplemental hamstring strengthening element, reinforcing muscle fibre recruitment and strengthening connective tissue. However, high-quality sprint training will provide the greatest protection against future hamstring injury. In many ways, measured exposure to the virus is the cure.

Flexibility work should focus not only on hamstrings, but also the muscle groups that are involved in all aspects of the sprinting gait cycle. Optimal mobility through the shoulders, trunk, hips and lower extremities will allow for ease of movement and increase efficiency. Any improvements in removing unwanted tension and restriction in the body will result in gains in performance and a reduced risk of injury. In addition, direct stretching of the hamstrings should be limited to low-intensity tensions, as high volumes of high-tension stretching may be associated with inhibitory responses and impairments when it comes to forceful and explosive muscle actions[29]. Overly forceful stretching may also create micro-trauma in the hamstring muscles that can exacerbate the risk of injury, as individual muscles within the hamstring group may weaken or fatigue, resulting in a less coordinated recruitment strategy during high-velocity running.

Conclusions

It is generally agreed that hamstring injuries are the result of an array of factors, many of which are difficult to remedy in isolation. A comprehensive approach that takes into consideration the many risk factors associated with hamstring strains must be taken. First and foremost, coaches must review the biomechanics of individual athletes, make the necessary adjustments and prescribe a regular dosage of speed work that is compatible with the capabilities of the athlete in question. The solution is not a one-size-fits-all approach. Simply adding in eccentric hamstring strengthening exercises into a training programme is not going to remedy all athletes at all times. Individualisation of work and specific biomechanical prescriptions will yield the greatest improvements in hamstring health and injury prevention. If coaches can incorporate this approach early on in an athlete's career, it will go a long way to eliminate one of the key risk factors in hamstring injuries: the initial hamstring strain.

Please send all correspondence to:

Derek M. Hansen

derek@strengthpowerspeed.com

REFERENCES

1. DREZNER, J.; ULAGER, J. & SENNETT MD. (2005). Hamstring muscle injuries in track and field athletes: a 3-year study at the Penn Relay Carnival (abstract). ***Clin J Sport Med,*** 15 (5): 386.

2. YAMAMOTO, T. (1993). Relationship between hamstring strains and leg muscle strength: a follow-up study of collegiate track and field athletes. ***J Med Sports Phys Fitness,*** 33: 194-99.

3. VERRAL, G.M.; SLAVOTINEK, J.P.; BARNES, P.G. & FON GT. (2003). Diagnostic and prognostic value of clinical findings in 83 sthletes with posterior thigh injury: comparison of clinical findings with magnetic resonance imaging documentation of hamstring muscle strain. ***Am J Sports Med,*** 31 (6): 969-973.

4. EKSTRAND, J.; HEALY, J.C.; WALDEN, M.; LEE, J.C.; ENGLISH, B. & HAGGLUND, M. (2012). Hamstring muscle injuries in professional football: the correlation of MRI findings with return to play. ***Br J Sports Med,*** 46 (2): 112-117.

5. ASKLING, C.M.; TENGVAR, M.; SAARTOK, T. & THROSTENSSON, A. (2007). Acute first-time hamstring strains during high-speed running. ***Am J Sports Med,*** 35 (2): 197-206.

6. CLANTON, T.O. & COUPE, K.J. (1998). Hamstring strains in athletes: diagnosis and treatment. ***J Am Acad Orthop Surg,*** 6 (4): 237-248.

7. ORCHARD, J.W. (2012). Hamstrings are most susceptible to injury during the early stance of sprinting. ***Br J Sports Med,*** 46 (2): 88-89.

8. GABBE, B.J.; BENNELL, K.L.; FINCH, C.F.; WAJSWELNER, H. & ORCHARD, J.W. (2006). Predictors of hamstring injury at the elite level of Australian football. ***Scand J Med Sci Sports,*** 16 (1): 7-13.

9. ARNASON, A.; SIGURDSSON, S.B.; GUDMUNDSSON, A.; HOLME, I.; ENGEBRETSEN, L. (2004). BAHR R. Risk factors for injuries in football. ***Am J Sports Med,*** 32 (Supplement 1): 5S-16S.

10. EMERY, C.A. (2001). Identifying risk facors for hamstring and groin injuries in sport: a daunting task. ***Clin J Sport Med,*** 22 (1): 75-77.

11. ORCHARD, J.W. (2001). Intrinsic and exztrinsic risk facors for muscle strains in Austraian football. ***Am J Sports Med,*** 29 (3): 300-303.

12. WOODS, C.; HAWKINS, R.D.; MALTBY, S.; HULSE; M., THOMAS, A. & HODSON, A. (2004). The Football Association Medical Research Programme: an audit of injuries in professional football-analysis of hamstring injuries. ***Br J Sports Med,*** 38 (1): 36-41.

13. BROOKS, J.H.M.; FULLER, C.W.; KEMP, S.P.T. & REDDIN, D.B. (2006). Incidence, risk and prevention of hamstring muscle injuries in professional rugby union. ***Am J Sports Med,*** 34 (8): 1297-1306.

14. VERRAL, G.M.; SLAVOTINEK, J.P.; BARNES, P.G.; FON, G.T. & SPRIGGINS, A.J. (2001). Clinical risk facotrs for hamstring muscle strain injury: a propsective study with correlation of injury by magnetic resonance imaging. ***Br J Sports Med,*** 35 (6): 435-439.

15. ORCHARD, J.W.; MARSDEN, J.; LORD, S. & GARLICK, D. (1997). Preseason hamstring muscle weakness associated with hamstring muscle injury in Australian footballers. ***Am J Sports Med,*** 25 (1): 81-85.

16. CROISIER, J.L.; GANTEAUME, S.; BINET, J.; GENTRY, M. & FERRET, J.M. (2008). Strength im-balances and prevention of hamstring injury in professional soccer players: a prospective study. ***Am J Sports Med,*** 36 (8): 1469-1475.

17. BENNELL, K.L.; WAJSWELNER, H.; LEW, P. & ET AL. (1998). Isokinetic strength testing does not predice hamstring injury in Australian Rules footballers. ***Br J Sports Med,***32 (4): 309-314.

18. EKSTRAND, J.; HAGGLUND, M. & WALDEN, M. (2011). Injury incidence and injury patterns in professional football: the UEFA study. ***Br J Sports Med,*** 45 (7): 553-558.

19. ELLIOT, M.C.; ZARINS, B.; POWELL, J.W. & KENYON, C.D. (2011). Hamstring muscle strains in professional football players: a 10-year review. ***Am J Sports Med,*** 39 (4): 843-850.

20. BENNELL, K.; TULLY, E. & HARVEY, N. (1999). Does the toe-touch test predict hamstring injury in Australian Rules footballers? ***Aust J Physiother,*** 45 (2): 103-109.

21. GOLDMAN, E.F. & JONES, D.E. (2011). Intervenitons for preventing hamstring injuries: a systematic review. ***Physio,*** 97 (2): 91-99.

22. ARNASON, A.; ANDERSEN, T.E.; HOLME, I.; ENGEBRETSEN, L. & BAHR, R. (2007). Prevention of hamstring strains in elite soccer: an intervention study. ***Scand J Med Sci Sports,***18 (1): 40-48.

23. GABBE, B.J.; BRANSON, R. & BENNELL, K. (2006). A pilot randomised controlled trial of eccentric exercise to prevent hamstirng injuris in community-level Australian Football. ***J Sci Med Sport,*** 9 (1-2): 103-109.

24. ENGEBRETSEN, A.H.; MYKLEBUST, G.; HOLME, I.; ENGEBRETSEN, L. & BAHR, R. (2008). Prevention of injuries among male soccer players: a prospective, randomized intervention study targeting players with previous injuries or reduced function. ***Am J Sports Med,*** 36 (6): 1052-1060.

25. SOLE, G.; MILOSAVLJEVIC, S.; NICHOLSON, H. & SULLIVAN, S.J. (2012). Altered muscle activation following hamstring injuries. ***Br J Sports Med,*** 46 (2): 118-123.

26. SCHUERMANS, J.; TIGGELEN, D.V.; DANNEELS, L. & WITROUW, E. (2014). Biceps femoris and semitendinosus-teammates or competitors? New insights into hamstring injury mechanisms in male football players: a muscle functional MRI study. ***Br J Sports Med,*** 48: 1599-1606.

27. WEYAND, P.G.; STERNLIGHT, D.B.; BELLIZZI, M.J. & WRIGHT, S. (2000). Faster top speeds are achieved with greater ground forces not more rapid leg movements. ***J Appl Physiol,*** 81: 1991-1999.

28. CLARK, K.P. & WEYAND, P.G. (2014). Are running speeds maximized with simple-spring stance mechanics? ***J Appl Physiol,*** 117: 604-615.

29. BEHM, D.G. & CHAOUACHI, A. (2011). A review of the acute effects of static and dynamic stretching on performance. ***Eur J Appl Physiol,*** 111: 2633-2651.