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Hamstrings are most susceptible to injury during the late swing phase of sprinting

Elizabeth S Chumanov,[1] Anthony G Schache,[2] Bryan C Heiderscheit,[1] Darryl G Thelen[3]

[1]Department of Orthopedics and Rehabilitation, University of Wisconsin, Madison, Wisconsin, USA
[2]Department of Mechanical Engineering, University of Melbourne, Victoria, Australia
[3]Department of Mechanical Engineering, University of Wisconsin, Madison, Wisconsin, USA

Correspondence to
Elizabeth S Chumanov, Department of Orthopedics and Rehabilitation, University of Wisconsin, Madison, Wisconsin 53706, USA; easchmerr@wisc.edu

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It is well recognised that the hamstrings are susceptible to acute strain injury during high-speed running. However, the particular phase of the sprinting gait cycle at which hamstring injury occurs remains a debated topic. Video footage and athlete anecdotes have contributed to the discussion, but do not provide sufficient temporal resolution to fully answer the question. In this paper, we briefly review: (A) biomechanical data obtained from healthy athletes; (B) case studies of injuries during biomechanical experiments; and (C) clinical outcomes from intervention studies. We believe all of these support the premise that late swing phase is the likely time when the biarticular hamstrings are most vulnerable to injury.

Early sprinting (ie, high-speed running) biomechanics research showed that during initial stance phase, a sprinter experiences large hip extension and knee flexion moments, leading to the proposition that contact loads may contribute to hamstring injury risk.[1] While hip extension and knee flexion moments are an important factor to consider, it is not possible to discern the biomechanical state (ie, stretch, force and work) of individual muscles from net joint moments alone.[2] Recent research, using biomechanical simulations of sprinting, has shown that the biarticular hamstrings are actually shortening throughout stance,[3] and that stance phase hamstring loading does not vary considerably as a sprinting athlete approaches near-maximal speeds.[4] In contrast, the biarticular hamstrings clearly undergo an active lengthening contraction during the second half of swing, reaching peak stretch just prior to foot-strike.[3] While terminal swing does represent a time in the sprinting gait cycle where neither limb is in contact with the ground (ie, flight phase with no contact loads), the hamstrings are absorbing kinetic energy from the swing limb. The amount of kinetic energy absorbed in the limb is proportional to the running speed squared, such that the negative work done (energy absorbed) by the hamstrings increases substantially with running speed.[5] In addition, research in animal models has shown that active lengthening contractions cause muscle damage, and that the degree of damage is more sensitive to the amount of active mechanical strain and negative work done by the muscle than it is to the amount of force experienced by the muscle.[6,7] Thus, hamstring mechanics in the late swing phase of sprinting are consistent with conditions that are likely to induce muscle injury.

The argument for terminal swing is further substantiated by the findings from two independent case studies of biomechanical data collected when running athletes incurred acute hamstring strain injuries. Despite distinctly different experimental conditions, both studies came to the same conclusion: that the stimulus for the injury most likely occurred in the late swing phase.[8,9]

The main implication from the above-mentioned research studies is that interventions for preventing hamstring strain injuries should be targeted towards exercises that involve active lengthening (eccentric) contractions. To this end, there is evidence demonstrating that not only are eccentric exercises effective in reducing hamstring strain injury incidence,[10–13] but that they are also likely to be more effective than concentric exercises.[14] If we consider that injury prevention programs seek to replicate the musculotendon demands during the mechanism of injury, the apparent success of eccentric training provides indirect, but arguably important support for the late swing phase being the likely time of injury.

We, therefore, conclude that the collective biomechanical and clinical evidence overwhelmingly supports the premise that the hamstrings are most susceptible to injury in the late swing phase of the sprinting gait cycle. While this debate may seem to be an academic exercise, we believe the answer is relevant for scientifically establishing injury prevention and rehabilitation programs that can most effectively mitigate injury risk.

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REFERENCES

1. **Mann RV**. A kinetic analysis of sprinting. *Med Sci Sports Exerc* 1981;**13**:325–8.
2. **Pandy MG**, Andriacchi TP. Muscle and joint function in human locomotion. *Annu Rev Biomed Eng* 2010;**12**:401–33.
3. **Thelen DG**, Chumanov ES, Hoerth DM, *et al.* Hamstring muscle kinematics during treadmill sprinting. *Med Sci Sports Exerc* 2005;**37**:108–14.
4. **Chumanov ES**, Heiderscheit BC, Thelen DG. Hamstring musculotendon dynamics during stance and swing phases of high-speed running. *Med Sci Sports Exerc* 2011;**43**:525–32.
5. **Chumanov ES**, Heiderscheit BC, Thelen DG. The effect of speed and influence of individual muscles on hamstring mechanics during the swing phase of sprinting. *J Biomech* 2007;**40**:3555–62.
6. **Brooks SV**, Zerba E, Faulkner JA. Injury to muscle fibres after single stretches of passive and maximally stimulated muscles in mice. *J Physiol (Lond)* 1995;**488** (Pt 2):459–69.
7. **Lieber RL**, Fridén J. Muscle damage is not a function of muscle force but active muscle strain. *J Appl Physiol* 1993;**74**:520–6.
8. **Heiderscheit BC**, Hoerth DM, Chumanov ES, *et al.* Identifying the time of occurrence of a hamstring strain injury during treadmill running: a case study. *Clin Biomech (Bristol, Avon)* 2005;**20**:1072–8.

9. **Schache AG**, Wrigley TV, Baker R, *et al.* Biomechanical response to hamstring muscle strain injury. *Gait Posture* 2009;**29**:332–8.
10. **Arnason A**, Andersen TE, Holme I, *et al.* Prevention of hamstring strains in elite soccer: an intervention study. *Scand J Med Sci Sports* 2008;**18**:40–8.
11. **Askling C**, Karlsson J, Thorstensson A. Hamstring injury occurrence in elite soccer players after preseason strength training with eccentric overload. *Scand J Med Sci Sports* 2003;**13**:244–50.
12. **Gabbe BJ**, Branson R, Bennell KL. A pilot randomised controlled trial of eccentric exercise to prevent hamstring injuries in community-level Australian Football. *J Sci Med Sport* 2006;**9**:103–9.
13. **Petersen J**, Thorborg K, Nielsen M, *et al*. Eccentric strength training is effective in preventing hamstring injuries in football: a cluster-randomised trial including 942 football players. *Knee Surg Sports Traumatol Arthrosc* 2010;**18**(S1):S56.
14. **Mjølsnes R**, Arnason A, Østhagen T, *et al.* A 10-week randomized trial comparing eccentric vs. concentric hamstring strength training in well-trained soccer players. *Scand J Med Sci Sports* 2004;**14**:311–7.

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