

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

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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.<sup>1</sup> 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.<sup>2</sup> Recent research, using biomechanical simulations of sprinting, has shown that the biarticular hamstrings are actually shortening throughout stance,<sup>3</sup> and that stance phase hamstring loading does not vary considerably as a sprinting athlete approaches near-maximal speeds.<sup>4</sup> 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.<sup>3</sup> 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.<sup>5</sup> 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.<sup>6,7</sup> 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.<sup>8,9</sup>

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,<sup>10–13</sup> but that they are also likely to be more effective than concentric exercises.<sup>14</sup> 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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