Hamstrings are most susceptible to injury during the early stance phase of sprinting

John W Orchard

The first publications which considered the time of onset in the gait cycle for hamstring strains concluded that early stance was the highest risk period.1,2 The rationale proposed was that external joint moments were much higher in stance phases than swing (table 1) because of the presence of high hip and knee joint reaction forces secondary to the ground reaction force (GRF).3–6 Ralph Mann’s original argument has been rejected by many subsequent authors, perhaps because of the dogma that muscles probably strain during eccentric contractions (table 1). This is a widely held belief despite experimental muscle strains being able to be produced during concentric contractions.7

Table 1 shows that the high knee flexion moment (sum of angular forces) in late swing occurs because the hamstrings are highly active and angular forces in the opposite direction (ie, due to quadriceps activity and external forces) are minimal. The hamstring does work hard in late swing to reverse the inertia of the shank angular movement in the opposite direction, but inertia (momentum) itself is not a force. However, in early stance the hamstring is also working hard but against potentially large opposing forces.1–4,6

A ‘smoking gun’ video of a case of calf strain has shown the exact time of disruption of gastrocnemius fibres during late stance/push-off,8 which is conveniently a stance phase but also when the calf is contracting eccentrically. No such direct evidence is available for hamstring strains. Cases which claim to show a hamstring strain occurring in late swing9,10 do so using indirect evidence, looking at change in body mechanics (athlete reaction) to a strain and speculating when the injury occurred prior to the first available indication. For example, in the Heiderscheit et al case, the first indication of change of mechanics is actually seen in the mid-stance phase.9 The authors conclude, based on their assumptions of neuromuscular delay that the injury ‘probably’ occurred during late swing, although the range of possible times for actual injury they give includes early stance. This uncertainty over length of neuromuscular delay means that we are back to speculation and personal (expert) opinion about when the muscle strain occurred in this case.

Just as there is no conclusive video showing the time that actual fibres tear in a hamstring strain, there have been no studies measuring the in vivo forces of hamstring muscles or tendons in human sprinting. However, there have been studies directly measuring in vivo forces in Achilles tendon in sprinting11 and patellar tendon in jumping12 and hopping.13 In these studies, the actual in vivo forces in Achilles and patella tendon are far higher in the stance phases (of sprinting, jumping and hopping) than in the swing phases.11,12 In addition, the in vivo force in the patella tendon during hopping increases slightly in the early concentric phase compared with the late eccentric phase.13 In modeling for running injuries, it is considered that the stance phase is when the vast majority of forces must be absorbed by tissues,14 which is not surprising when one considers that a human leg is about 10% of body weight whereas GRFs during sprinting are more than 300% of body weight.

One could concede that the hamstring muscles’ job starts in late swing and its failure to do its job properly in this phase might result in a strain. However, it is erroneous to assume that the job failure and the injury are the same thing. A faulty parachute fails to activate in mid-air, but the subject dies upon hitting the ground. A gunshot kills when the bullet hits the target, not when the trigger is pulled. Eccentric strengthening may help prevent hamstring strains but it does not necessarily mean the force(s) causing injury are acting in this phase.

That the GRF is the likely culprit for hamstring failure in sprinting (as it is for other tissue failure in other running injuries)14 is further illustrated by the low risk of muscle strains during open-chain (only) activities. Upper limb athletes performing open-chain activities (and hence with far less external force/GRF involvement) do not tend to strain muscles despite high angular velocities in the upper limb joints. Ten-metre platform divers also do not tend to strain hamstring muscles in the pike position despite stretch and high angular velocity. Neither do trapeze artists or aerial skiers mid-jump. Water skiers do—but only when they are holding the rope when the boat is pulling in the other direction and providing the opposing force. It is likely that it is opposing forces (which are greatest secondary to external moments) that lead to muscle strains. These are potentially much greater in early stance than late swing (table 1, items 3–6).

Although now in the minority, there are still researchers who support the original thesis of Ralph Mann1–6: it is a strong force (moment, torque) in the opposite direction(s) (causing hip flexion and knee extension) that strains a hamstring, which is most likely to be due to the GRF. If this is happening in vivo in human sprinting when the hamstring is contracting concentrically, then so be it. Although this would surprise some authors, it probably should not as experimental strains in the laboratory can be created during concentric contractions7 and in vivo musculotendinous forces may be equal or even higher in the early concentric phase compared with the late eccentric phase of contractions.13

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REFERENCES


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### Table 1 Comparison of hamstring and opposing forces in late swing and early stance

<table>
<thead>
<tr>
<th>Phase</th>
<th>Hamstring action and moments</th>
<th>Opposing moments</th>
<th>External</th>
</tr>
</thead>
<tbody>
<tr>
<td>Late swing</td>
<td>Strong eccentric contraction (whilst at sub-maximal length) to decelerate the shank, producing in particular a high knee flexion moment.</td>
<td>Vastus muscles begin to activate at the end of swing producing a weak (early) contraction. Hip flexors are almost inactive.</td>
<td>Minimal opposing forces (the light force of air resistance would actually assist hamstring in decelerating the shank).</td>
</tr>
<tr>
<td>Early stance</td>
<td>Strong concentric contraction to resist opposing forces and help produce a hip extensor moment.</td>
<td>Vastus muscles increase their activation in early stance, producing a stronger contraction, whilst rectus femoris starts to contract.</td>
<td>Potentially large hip flexor &amp; knee extensor joint reaction moments (i.e. GRF vector is anterior to the knee and hip joints, due to forefoot-strike).</td>
</tr>
</tbody>
</table>

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