ACHILLES TENDON FORCES DURING A ROUND-OFF BACK HANDSPRING

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INTRODUCTION

Gymnastics has one of the highest rates of severe injury in sports due to its physical demands on its competitors (Kingma and ten Duis, 1998). One severe injury that has begun to occur more frequently is a rupture of the Achilles tendon. Many such ruptures have been observed in the transition from a round-off back handspring to an airborne element during the floor exercise. There is thus a need to understand the factors that influence the forces in the Achilles tendon during this critical period. One factor that may contribute to increased force on the tendon is a greater approach speed. This study therefore investigated the relationship between approach speed and the forces experienced by the Achilles tendon during a round-off back handspring rebound skill.

METHODS

Twelve women (mean ± SD age: 19.9 ± 1.8 years), all advanced-level gymnasts, gave their informed consent to participate. To simulate a competition setting, a 60 cm x 80.5 cm piece of gymnastics spring flooring was mounted to a pair of force plates. An 8.5 m x 1.2 m runway of spring flooring led to the force plates. Mats were placed around and beyond the plates. The flooring was covered with 3.7 cm-thick foam.

After warming up, subjects performed five trials of a round-off back handspring rebound skill from each of three approaches: standing, jump-hurdle, and step-hurdle. In the latter approach types, the round-off was initiated after a short jump and a step-and-hop, respectively. Subjects were required to land within a marked area over the force plates, then rebound into the air. A motion capture system recorded the positions of 20 markers, attached to the lower limbs and pelvis, at 250 Hz. Force plate data were sampled at 2000 Hz. Trials were blocked by approach type and counterbalanced.

Based on the measured flooring geometry, inertia, and spring stiffness, the ground reaction forces and center of pressure at the spring floor surface were derived from the force plate data. Marker data were low-pass filtered at 15 Hz, and used to determine joint center positions and body segment angles. The bilateral-average ankle plantarflexion moment was computed, with the ground reaction force distributed between the feet based on the center of pressure mediolateral position. The average of the force acting in each Achilles tendon was determined from the ankle moment and the tendon moment arm, and normalized to body weight (BW).

Repeated-measures analysis of variance was used to compare variables between approach types. Analyzed were the peak Achilles tendon force, peak rate of tendon force increase, and approach speed, defined as the forward velocity of the hips over the 100 ms before floor contact. Pearson correlations were computed between the peak Achilles tendon force, the peak ground reaction force, and the minimum foot-floor angle during contact. Positive foot-floor angles correspond to plantarflexion. A significance level of 0.05 was used.
RESULTS AND DISCUSSION

The peak Achilles tendon force during floor contact ranged from 7.2 to 16.0 BW and occurred either shortly after landing or when the ground reaction force peaked at mid-stance (Figure 1). Neither the peak Achilles tendon force nor the peak rate of force increase differed between approach types, despite greater approach speeds for jump- and step-hurdles than for standing (p < .05; Table 1). Peak tendon force was also unrelated to the peak ground reaction force.

A strong positive correlation existed between peak Achilles tendon force and the minimum foot-floor angle during contact (r = 0.91; p < 0.05; Figure 2). In particular, two subjects whose heels never contacted the floor experienced peak tendon forces 40% greater than average, and 198% of the predicted failure load of 4000 N (Komi, 1987). By staying on their toes, these gymnasts had to rely on their plantarflexors more for energy absorption during landing. They also increased the moment arm of their peak ground reaction force arm about the ankle, increasing the opposing plantarflexor moment needed. Of note, these two gymnasts were very skilled tumblers. This suggests that reducing the foot-floor angle to decrease the injury risk may not be a viable option, as it might impair performance.

CONCLUSIONS

Landing technique appears to play a far greater role than approach speed in the risk of Achilles tendon injury during a round-off back handspring rebound. Staying on ones toes during landing markedly increases the peak forces in the Achilles tendon.

REFERENCES


ACKNOWLEDGEMENTS

Equipment donated by Palmer Power Springs and the OSU Gymnastics Team.

Table 1: Mean ± SD approach speed and peak Achilles tendon loading vs. approach type.

<table>
<thead>
<tr>
<th></th>
<th>Standing</th>
<th>Jump-Hurdle</th>
<th>Step-Hurdle</th>
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<tbody>
<tr>
<td>Approach speed (m/s)</td>
<td>3.76 ± 0.26</td>
<td>4.04 ± 0.24</td>
<td>4.07 ± 0.24</td>
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<tr>
<td>Peak force (BW)</td>
<td>10.6 ± 2.4</td>
<td>10.8 ± 2.4</td>
<td>10.4 ± 2.2</td>
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<td>Peak rate of increase (BW/s)</td>
<td>502 ± 54</td>
<td>526 ± 66</td>
<td>533 ± 57</td>
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