INTRODUCTION

In 1990, the discipline of figures (to which the sport of figure skating owes its name) was eliminated from competitions. This precipitated a shift in training time from figures to freestyle, and specifically, to jumping. The rapid increase in jump training volume over the past 15 years may be causing a similar increase in overuse injuries. Dubravcic-Simunjack et al. (2003) determined the injury incidence of elite junior level skaters over a four year period, reporting a 20% stress fracture rate in female junior level singles skaters. Coaches, trainers, and medical experts are concerned that overuse injuries in figure skating appear to be escalating at an alarming rate, as evidenced in less scientific sources (Waldman, 2006). Almost all skating injury studies have suggested a connection between overuse injuries and the stiffness of the current figure skating boot (Bloch, 1999; Brock & Striowski, 1986; Dubravcic-Simunjak et al., 2003; Pecina et al., 1990; Smith, 1990). Modifying the current figure skating boot to include an ankle articulation may help reduce landing forces by increasing the ankle’s range of sagittal plane motion.

The purpose of this project was to examine the effectiveness of an articulated figure skating boot prototype in enabling a skater to attenuate the impact force at landing. Kinetic and kinematic variables were compared to test the hypothesis that articulated boots can effectively help reduce jump landing forces compared to standard boots.

METHODS

An articulated figure skating boot was designed over a one year period and working models were manufactured by Jackson Ultima Skates (Waterloo, ON) for use in the study. Nine individual figure skaters (six females, three males) competing at the US Figure Skating defined juvenile level or higher volunteered to test the boots. Both off-ice and on-ice jump analyses were first performed while the subjects were training in their own standard boots. The skaters were then fitted with articulated skating boots in which to train. After a training time that varied between 3 days and 3 weeks, the analyses were repeated using the articulated boots.

For the off-ice tests, the subjects hopped backwards off of a 30 cm high wood box and landed on one foot on an AMTI SGA6-4 force platform (Watertown, MA) covered with a 3-mm thick sheet of acrylic (artificial ice surface). Force plate data (960hz) and marker position data (240hz) were synchronized and recorded for three trials. Only marker positions (240hz) were collected for the on-ice tests as the subjects performed single axels, double toe loops, and double axels.

RESULTS AND DISCUSSION

The group kinetic results from the off-ice jumps showed a decrease in peak heel force and loading rate with use of the articulated skates (Table 1). Several kinematic variables showed significant differences between boots in the off-ice tests, but only two (heel
acceleration and heel velocity) were significantly correlated with heel force for standard boots, articulated boots, and the difference between the boots.

The on-ice kinematic analysis did not reveal any differences between boots, except for peak knee flexion and jump height. Peak knee flexion increased in all three jump types with use of the articulated skates. Jump height was lower in double axels and trended to be lower in double toe loops. Heel acceleration and heel velocity on-ice were approximately double the value measured off-ice, despite the lower on-ice jump heights.

Results from the off-ice jump simulations support the hypothesis that an articulated skate can be used to decrease landing forces, although the exact individual mechanisms for this are still unclear. While all skaters exhibited a decrease in peak impact force and loading rate in the articulated skates, each skater implemented a somewhat unique strategy to achieve their result. No combination of variables was able to explain the difference in impact forces for a majority of the skaters.

The lack of on-ice kinematic differences suggests that the skaters did not use the articulation in skating jumps. This may be due to the difficulty of the on-ice jumps and the limited training time in the articulated skates. Heel velocity and acceleration correlated well with impact force in the off-ice tests, allowed for speculations on the magnitude of on-ice landing forces. Specifically, estimates of the on-ice impact forces from the heel accelerations yielded peak loads in the range of 8-10 BW. However, direct on-ice measures may be needed to accurately profile the ground reaction forces.

REFERENCES


Bloch, R. (1999). Figure skating injuries. Physical medicine and rehabilitation clinics of North America, 10, 177-188, viii.


Smith, A. D. (1990). Foot and Ankle Injuries in Figure Skaters. The Physician and sportsmedicine, 18, 73-86.


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**Table 1:** Kinetic measurements from the off-ice tests (mean ± SD).

<table>
<thead>
<tr>
<th>Variable</th>
<th>Standard Boots</th>
<th>Articulated Boots</th>
<th>p-value</th>
</tr>
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<tbody>
<tr>
<td>Peak toe force (BW)</td>
<td>$2.6 \pm 0.8$</td>
<td>$2.9 \pm 1.3$</td>
<td>0.150</td>
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<tr>
<td>Peak heel force (BW)</td>
<td>$5.0 \pm 1.0$</td>
<td>$4.1 \pm 1.0$</td>
<td>0.047*</td>
</tr>
<tr>
<td>Loading rate (BW/s)</td>
<td>$111.2 \pm 32.9$</td>
<td>$76.4 \pm 41.0$</td>
<td>0.048*</td>
</tr>
</tbody>
</table>