LOWE BODY JOINT KINETICS IN STANDING BROAD, VERTICAL, AND SQUAT JUMPS

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INTRODUCTION

A major interest in athletics is increasing overall power output. A widely accepted way to determine overall athletic ability and power is the vertical jump test [1]. Much research has been conducted on overall jump power in order to determine possible strategies for training [1, 2], but little research has been conducted on the contributions made by the three leg joints (hip, knee, and ankle) and with multiple types of jumps. In order to produce the most powerful movement possible, all three leg joints must work maximally [3] and assessing the joint contributions in jumping power can help determine specific areas of concentration for strength and conditioning.

METHODS

With approval from the institution’s human subjects review board, 20 female collegiate soccer players (Mean±standard deviation: 19.6±1.3 yrs; 166±7 cm; 60.4±8.1 kg) participated in the study. All subjects performed five trials for the standing broad jump, vertical jump, and squat jump. The subjects were encouraged to jump maximally and could use their arms as desired on the standing broad and vertical jumps. For the squat jump, the subjects were restricted to keeping their hands on their head to reduce arm contribution to the jump. The best jump by each subject was chosen for analysis; the best referring to the longest standing broad jump and the highest vertical and squat jumps. Before jumping, basic anthropometric data was collected and 16 reflective markers were placed on the lower body using the Plug-in Gait model.

All jumps were measured using an 8 camera VICON MX-T40S retro-reflective motion analysis system synchronized with two AMTI Optima force plates. The motion data was sampled at 100Hz, processed using Vicon Nexus 2.1 software, and filtered at 6Hz using a 4th order Butterworth filter. The force plate data was sampled at 1000Hz. Joint moments for the ankle, knee, and hip were calculated using inverse dynamics. Data was analyzed from the point of maximum knee flexion (0%) to toe-off (100%), and total maximum power was determined during the propulsion phase (see Figures 1, 2, & 3). A summation of the total joint moments was calculated, and contributions of each joint to the jump were determined as percentages of the sum at the maximum power output during the propulsion phase [3]. Total support jump differences were determined using a repeated measures one-way ANOVA with post hoc t-tests to determine between jump difference. Jump-by-joint differences were determined using a repeated measures two-way 3x3 ANOVA with post hoc one-way ANOVAs to determine between jump differences.

RESULTS AND DISCUSSION

Mean total support power differed significantly between jumps (F(2, 38)=28.326, p<0.001) (Table 1). Post hoc tests revealed power during the vertical jump was 8.7 W/kg (p<0.001) and 3.6 W/kg (p=0.045) greater than during squat and broad jumps, respectively, and 5.1 W/kg (p=0.001) greater during broad jump compared to squat jump. The difference in mean total joint power in the squat jump can be attributed to the restricted arm movement. The arms act as a driving force, increasing the tension applied to the three leg joints [4]. Thus focusing on the timing of the arm swing with muscle activation of the legs can help produce a greater power output.

There was a significant interaction effect of jump type and joint contribution of total power (F(4, 38)=28.299, p<0.001). Post hoc tests revealed significant between jump differences at the ankle (F(2,38)=14.014, p<0.001), knee (F(2,38)=46.105, p<0.001), and hip (F(2,38)=17.690, p<0.001) (Table 1). Power during broad jump was significantly
greater compared to squat and vertical jumps at the ankle (p<0.001, p=0.006) and hip (p<0.001, p<0.001), but lower at the knee (p<0.001, p=0.006), respectively. Such differences may reflect a difference in countermovement strategy during the loading phase of the broad jump to maximize forward propulsion (Figures 1, 2, 3). The trunk inclines anteriorly, the center of mass moves forward, resulting in greater hip flexion and ankle dorsiflexion, while reducing knee flexion in the broad jump as compared to the vertical and squat jumps [2]. Although there was no significant difference in power contribution between vertical and squat jumps at the hip and knee, ankle power was significantly greater during vertical jump than during squat jump (p=0.029). Such differences may indicate a possible influence of reduced arm movement during squat jump, limiting the anterior displacement of the center of mass and reducing ankle dorsiflexion.

**Figure 1:** Representative hip, knee, ankle, and total power during propulsion phase of standing broad jump of one female subject with skeletal reconstruction and percent joint contribution at point of maximum power.

**Figure 2:** Representative hip, knee, ankle, and total power during propulsion phase of vertical jump of one female subject with skeletal reconstruction and percent joint contribution at point of maximum power.

**Table 1:** Total and distribution of lower extremity joint powers during broad, vertical, and squat jumps. (*significant difference from vertical jump, #significant difference from squat jump)

<table>
<thead>
<tr>
<th>Joint</th>
<th>Standing Broad Jump</th>
<th>Vertical Jump</th>
<th>Squat Jump</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hip (%)</td>
<td>34.5±10.6*#</td>
<td>21.5±9.2</td>
<td>20.9±8.0</td>
</tr>
<tr>
<td>Knee (%)</td>
<td>27.9±10.3*#</td>
<td>45.9±9.3</td>
<td>48.8±7.6</td>
</tr>
<tr>
<td>Ankle (%)</td>
<td>37.7±8.7##</td>
<td>32.6±4.5##</td>
<td>30.3±6.1*</td>
</tr>
<tr>
<td>Total Mean Joint Power (W/kg)</td>
<td>52.0±5.8##</td>
<td>55.6±7.4##</td>
<td>46.9±5.3*</td>
</tr>
</tbody>
</table>

CONCLUSIONS

In conclusion, power contributions of the hip, knee, and ankle differ according to jumping task, with a hip and ankle strategy utilized for broad jump and a knee strategy used for vertical and squat jumps. To increase maximal power output, jump dependent, joint specific training should be utilized. Further studies should include joint kinematics and electromyography to determine the influence of posture and muscle activation on power output.

REFERENCES