Increased use of knee extensors after four weeks of drop jump training

1 Jacob Meyland, 1Peter C. Raffalt, 1Tine Alkjær and 1Erik B. Simonsen

1Department of Neuroscience and Pharmacology, Motor Control Laboratory, University of Copenhagen, Copenhagen, Denmark.
Email: rzk230@alumni.ku.dk

Summary
After a four week period of drop jump training of athletes, we observed an increase in the extensor moment about the knee joint, as well as an increase in both concentric and eccentric power at the knee.

Introduction
The ability to jump and change direction of movement with a short ground contact is important in many types of sports, e.g., athletics, badminton or volleyball. To improve this ability, one example of exercise is the use of plyometric training such as drop jumps. This involves jumping down from a higher plateau and on contact with the ground as fast as possible reverse the movement to achieve the highest possible jump. This is considered an effective way of practicing resilience and explosive strength [3,4,5]. Furthermore, a link between how jumping performance can be improved effectively [3].

We wished to investigate the effect of four weeks of drop jump training in trained athletes. We hypothesized that after four weeks of drop jump training the subjects would increase their performance index (jump height (m)/contact time (s)) (PI), either by improving jump height, contact time, or both. In addition, we wanted to investigate factors which could explain the expected improvement.

Methods
Nine subjects (eight males and one female, mean (SD): age: 24.4 (4.01) years, height: 1.80 (0.08) m, weight: 69.75 (9.00) kg) participated in the study. The subjects were well trained and all had jumping experience, either from athletics or volleyball, but they did not use drop jumps as a part of their daily training.

The study consisted of three parts. A pre- and a post-test including muscle strength measurements and biomechanical movement analysis of the drop jumps. In between the subjects were exposed to four weeks of training which consisted of three weekly sessions, which in weeks one and two included three times eight maximal drop jumps, and in weeks three and four, four times eight jumps. These were supervised, using jump height, contact time, and PI, as motivational factors.

The drop height used for the training was initially found using an infrared grid to estimate the falling velocity just before landing. The grid was placed 10 cm above the force platform, and the time from passing through the grid and touch down was used to calculate the velocity at touch down. The drop height was adjusted to achieve a drop velocity of 2.5 m/s.

Strength measurements were performed using a Kin-Com dynamometer (Kinetic Communicator, Chattanooga, USA) to obtain measurements of isokinetic and isometric strength of plantar flexors, knee extensors, and knee flexors of the right leg. The isokinetic measurements were performed at an angular velocity of 240 °s. For the plantar flexors a range of motion (ROM) of 40° was used, starting at 5° dorsiflexion. For the knee flexors and extensors a ROM of 10° to 90° flexion was used. The subjects were allowed between eight and twelve trials; no further trials were conducted when no further improvement was observed. Isometric strength was measured at 5° dorsal flexion and 70° flexion for plantar and knee extensors/flexors, respectively. The subject was given three trials on verbal countdown to exert as much force as fast as possible.

The subjects performed seven drop jumps which were filmed from the subject’s right side, using a video camera (JVC GR-DVL9800) operating at 120 Hz. Reflective markers were placed on the right side of the body on the fifth metatarsal joint, the lateral malleolus, the lateral epicondyle, the greater trochanter, the anterior superior iliac spine, and on the neck at C5. The drop jumps were performed onto a force platform (AMTI OR6-5-1) with the right foot landing on the platform and the left foot on the floor to avoid misleading calculations of center of pressure (COP). Arms were held akimbo. The six best trials, based on PI, were used for analysis. The time-position data were lowpass filtered using a fourth order Butterworth filter with a cutoff frequency of 6 Hz.

Results and Discussion
The performance index (PI) improved 16.2% (Table 1), which was mainly caused by an increase in jump height of 11.9%. The movement analysis showed that the peak knee extensor moment increased 16.0%, while peak power about the knee increased 17.9% and 21.6% for concentric and eccentric contraction, respectively (Table 1, Figure 1). Furthermore, the peak angular velocity during knee flexion was significantly faster post training (P<0.001). The hip joint did not express a pattern of distinct concentric/eccentric phases, but looking at the first 50% of contact, the peak concentric power increased significantly by 67.0% after training (Table 1). Neither peak hip joint moment nor peak hip angular velocity showed any significant changes, which could explain the increase in hip power. Regarding the ankle biomechanics, we did not observe any significant changes after training. Concerning the strength measurements we found no significant differences in rate of force development (RFD), isokinetic strength or isometric strength. This was the case for all the three groups of muscles tested.
Since there were no differences in any of the strength parameters, we suggest that the improved jumping performance was due to an increased contribution of the knee extensors, which may primarily be explained by a neurological optimization of the movement pattern.

**CONCLUSIONS**

Four weeks of drop jump training significantly enhanced the specific task of jumping higher with short ground contact. This was not caused by an improvement in muscle strength parameters, but rather an improved neuromuscular function which enabled the subjects to develop a higher knee joint moment and hence knee joint power leading to higher jumping height.

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**REFERENCES**


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**Figure 1**: Mean of all subjects (n=9). Top: Moment about the knee joint, peak values were significantly higher (P=0.038). Middle: Knee joint angular velocity, peak flexor velocity was significantly faster (P<0.001). Bottom: Power exerted about the knee, peak during the eccentric (negative) phase (P=0.031) as well as the concentric phase (P=0.030) were significantly increased.

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**Table 1**: Improvement of drop jump performance, values are means (SD).

<table>
<thead>
<tr>
<th></th>
<th>Jump height (cm)</th>
<th>Contact time (ms)</th>
<th>PI</th>
<th>Knee, peak con. power (W)</th>
<th>Knee, peak ecc. power (W)</th>
<th>Knee, peak ext. moment (Nm)</th>
<th>Hip, peak ext. moment, 0-50% of contact (Nm)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Pre training</strong></td>
<td>29.21 (3.70)</td>
<td>181.2 (31.7)</td>
<td>1.65 (0.32)</td>
<td>1374.99 (351)</td>
<td>987.58 (187)</td>
<td>284.64 (64.2)</td>
<td>171.31 (75.8)</td>
</tr>
<tr>
<td><strong>Post training</strong></td>
<td>32.69 (4.18)</td>
<td>172.5 (17.8)</td>
<td>1.92 (0.33)</td>
<td>1621.46 (308)</td>
<td>1200.41 (240)</td>
<td>330.24 (69.7)</td>
<td>286.05 (164)</td>
</tr>
<tr>
<td><strong>P-value</strong></td>
<td>0.012</td>
<td>0.109</td>
<td>0.005</td>
<td>0.030</td>
<td>0.031</td>
<td>0.038</td>
<td>0.041</td>
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