DEVELOPMENT OF MULTISTEP DROP JUMP TEST BY USING DIFFERENT DROP HEIGHTS.

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We used different drop heights to evaluate the drop jump (DJ) test in elite athletes. Male jumpers (n=10) performed the test at 0.3, 0.6, 0.9, and 1.2 m. Jumping motions in the sagittal plane and the ground reaction force were recorded using a high-speed camera and force platform, respectively. The amount of negative work by 3 lower extremity joints increased with increased drop height of the DJ test, mainly at the hip joint. There were different performance patterns on the DJ test and lower extremity power output with an increased drop height according to individual characteristics of elite jumpers, compared with the average pattern. Jump performance was correlated with the DJ index at DJ1.2 and the decreased rate of the index from DJ0.3 to DJ1.2. Thus, to evaluate elite jumpers' performance, various height ranges including a higher drop height should be used.

KEY WORDS: joint work, joint relative work, IAAF Score DJ performance.

INTRODUCTION: During athletic jumping events, the take-off movement is often executed with a ground contact force more than 10 times the athlete's body weight during a very short contact time (0.1–0.2 s). This action involves a stretch-shortening cycle (SSC) movement of agonist muscles. The drop jump (DJ) test is used to evaluate SSC performance ability in athletes. Previously, the DJ test at drop heights of 0.3–0.7 m has been used to compare performance (Jody & Russell, 1985). However, during take-off in jumping events, the ground reaction force can reach more than 10 times the athlete's body weight (Remedy & Williams, 1985). This degree of ground reaction force may exceed that resulting from a DJ test at drop heights of 0.3–0.7 m. Although previous studies have examined the drop heights of DJ tests, the unified optimum height has not yet been clarified (Komi & Bosco, 1978; Walsh et al., 2004). In the present study, to evaluate the performance of elite jumpers, the DJ test was applied with drop heights changing in multiple-step form. Furthermore, the test included a drop height of 1.2 m, higher than the conventional 0.3–0.7 m. Unlike previous studies, our study involved evaluation of DJ performance at multiple drop heights, which was further used to study the power output characteristics in the lower extremities of each athlete. The purpose of this study was to evaluate the usefulness of a new evaluation method, by investigating the change in DJ test performance, ground reaction force, and lower limb joint kinetics with increasing drop height.

METHODS: The study participants were 10 male jumpers (age, 19.5 ± 0.7 years; height, 175.8 ± 6.6 cm; body mass, 68.0 ± 3.3 kg, mean ± SD), including a Japanese high jumper who won a bronze medal in the World Junior Championships with a jump of 2.24 m. All procedures undertaken in the study were approved by the Ethics Committee for the Institute of Health and Sport Sciences, University of Tsukuba, Japan.
The subjects performed the DJ test from 4 drop jump dropping heights (0.3 m, 0.6 m, 0.9 m, and 1.2 m). Subjects were orally instructed to shorten the contact time as much as possible and to jump as high as possible. The DJ index, developed to indicate the mechanical power per unit body weight during take-off (Tauchi et al., 2008), was calculated by dividing the jump height by the contact time (Zushi et al, 1993). The highest DJ-index values at each height were selected for further analysis. The rate of decrease of the DJ index was the slope/intercept (a/b)

of the regression line (y = ax + b). The regression line was constructed from four values of the DJ index at each height for each subject.
Jumping performance was measured at 300 Hz using a high-speed camera (CASIO, EX-F1), and the ground reaction force data were recorded with a force platform (1000 Hz). Twenty-three body points and 4 calibration markers were digitized, and the digitized coordinates were converted into real coordinates using 4 reference markers placed on the ground. To calculate the kinematics data for each joint, a two-dimensional link segment model was used. The model utilized information from hand, elbow, and shoulder joints, and from foot, knee, and hip joints to calculate kinematics data for each joint. The joint angle and angular velocity data for the right leg were calculated from the coordinates, and the joint torque, joint torque power, and joint work of the right leg were calculated by inverse dynamics. Relative work was calculated as the ratio of joint work for each joint. The performance during actual jump events was rated using the International Amateur Athletics Federation (IAAF) scoring tables (IAAF score). One-way ANOVA with the Bonferroni-Dunn correction was used for multiple comparisons. Relationships between the variables were determined by Pearson's correlation test. Statistical significance was accepted at $P < 0.05$.

RESULTS & DISCUSSION: The DJ index, contact time, and jumping height at each drop height (0.3 m = DJ0.3, 0.6 m = DJ0.6, 0.9 m = DJ0.9, and 1.2 m = DJ1.2) are shown in Figure 1. The DJ index was highest at DJ0.6 and lowest at DJ1.2. The contact time was longest for DJ1.2. There was no significant difference in jump height among drop heights. Maximum ground reaction force increased as the drop height increased (DJ0.3, 76.97 ± 9.1 N/kg; DJ0.6, 90.24 ± 14.4 N/kg; DJ0.9, 112.65 ± 12.53 N/kg, DJ1.2, 130.72 ± 20.57 N/kg). The maximum ground reaction force at DJ1.2 was similar to the force generated in a jump event (Remedy & Williams, 1985). These results indicate that if kinetic energy with increased drop height is increase, jump height was not change but increased contact time, thus DJ-index was decreased.

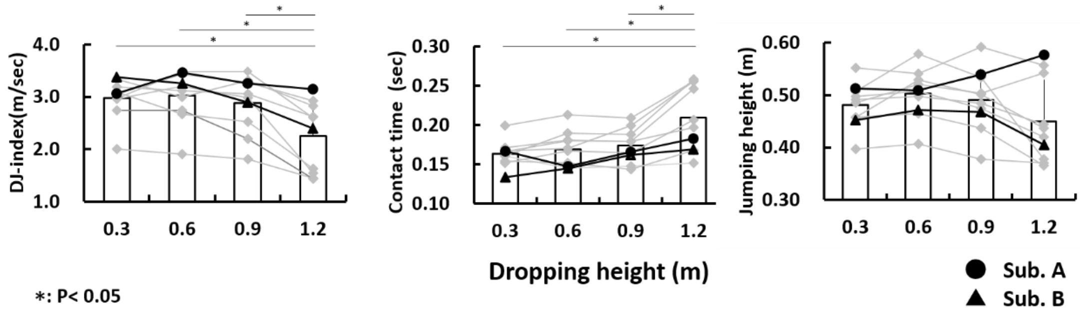

Figure 1: DJ index, contact time, and jumping height for each drop height.

Figure 2 shows the negative and positive work at the ankle, knee, and hip joints for each drop height. Figure 3 shows the relative negative and positive work at the ankle, knee, and hip joints for each drop height. The negative and positive work at the ankle joints larger than other joints at all drop heights, then, a larger tendency recognized in order of the knee, hip joint. There was also tendency in relative work. However, the amount of negative work done by all 3 lower extremity joints increased with an increase in drop height, but the amount of relative work tended to be decreased in the ankle joint and increased in the hip joint. These results indicate that the ankle has the large work at all drop heights, but the work at hip joint increase with increased drop heights, and the contribution of the hip joint at DJ1.2 was large. .
There were differences in the changes in the DJ index with increasing drop height for some individual athletes compared with the average pattern (Figure 1). Subject A (circles in Figure 1), had the highest IAAF score in the study, and had participated in international meetings and won a medal at the World Junior Championships (high jump, 2.24 m). The DJ index for this subject at DJ0.3 was close to the mean value, but at DJ1.2 was the highest among all the subjects. The jump height for this athlete increased with increasing drop height and the positive work in the 3 lower extremity joints differed from the average pattern, and showed a tendency

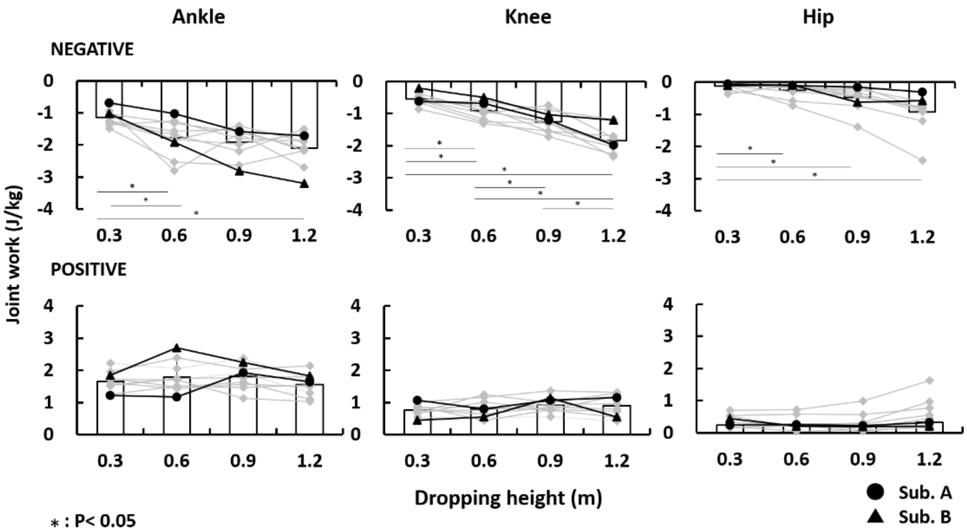

Figure 2: Joint work at each drop height.

to increase with increasing drop height. The relative work in the 3 lower extremity joints showed a tendency to stay about the same with increasing drop height. Therefore, in this athlete, even when the stretch load increased, the characteristics (relative work) did not change and the work in the 3 lower extremity joints increased, resulting in an increase in jump height. In contrast, for subject C, a long jumper with a jump distance of 6.96 m (triangles in Figure 1), the DJ index at DJ0.3 was the highest value among all the subjects. However, the DJ index decreased greatly from DJ0.3 to DJ1.2. Moreover, this subject was showed that the ankle joint work and relative work had been large, but that in the hip joint had been extremely small.
Therefore, in this athlete will guess that resulting in increased contact time, because relative work in the hip joint can't change with an increased stretch load. Thus, DJ performance reduced. These results suggest that an elite jumper could achieve higher DJ test performance at higher drop heights, not at lower drop heights.

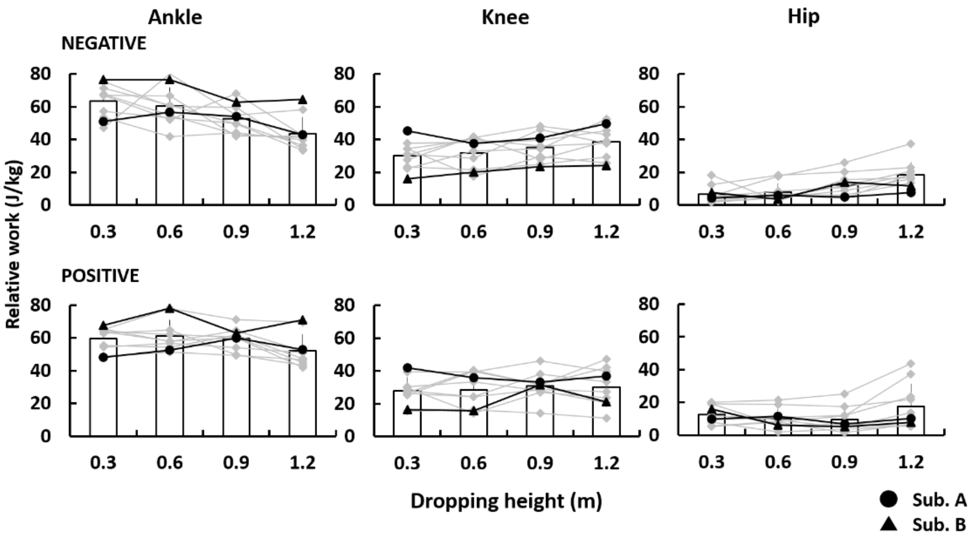

Figure 3: Relative work at each drop height.

The present study investigated the relationship between the IAAF score and the DJ-index at a range of drop heights. There was a significant relationship between these variables only for DJ1.2 (Figure 4). The present study also investigated the relationship between IAAF score and the rate of decrease of the DJ-index (Figure 5). There was a significant relationship between these variables. Therefore, to optimally evaluate lower limb exertion ability in jumpers, it is important to use the DJ test at a higher stretch load (approximately 1.2 m drop height), rather than the DJ test at a lower stretch load. Furthermore, it is important to note that the DJ index did not decrease from a lower stretch load to a higher stretch load.

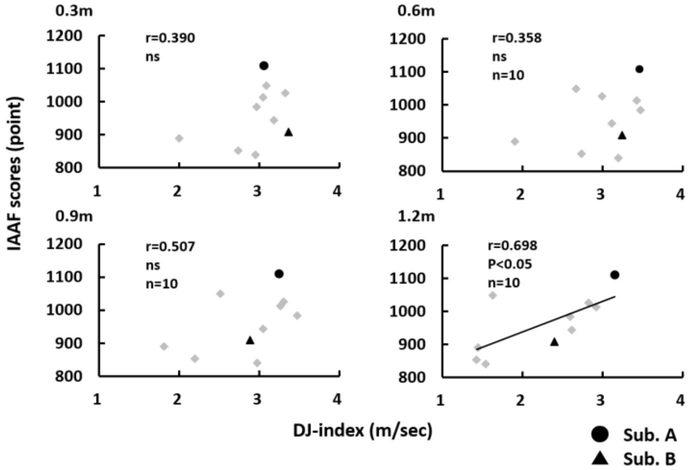

Figure 4: Relationship between IAAF Score and DJ index for each drop height.

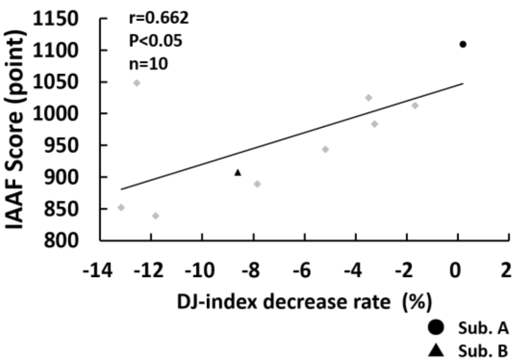

Figure 5: Reletionship between IAAF Score and DJ-index decre ase rate.

CONCLUSION: The main results of this study are as follows：1) The amount of negative work done by 3 lower extremity joints increased with an increase in the drop height of the DJ test, particularly at the hip joint. 2) There were different changes in performance on the DJ test and lower extremity power output with an increase in drop height according to the individual characteristics of elite jumpers. 3) The performance in jump events was correlated with the DJ index at DJ1.2, and the decrease rate of the DJ index from DJ0.3 to DJ1.2. Therefore, to evaluate the performance of elite-level jumpers, it is important to use a various range of heights including a higher drop height (approximately 1.2 m), because the DJ test at just 1 drop height cannot effectively evaluate performance.

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