THE COMPARISON TO THE CHARACTERISTICS OF THREE-DIMENSIONAL JOINT KINETICS BETWEEN SINGLE LEG AND DOUBLE LEG REBOUND JUMP.

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The purpose of this study was to clarify the differences between the SRJ and DRJ in terms of three-dimensional joint kinetics for the takeoff leg. Twenty male track and field athletes were performed repeated rebound jump with single leg (SRJ) and double leg (DRJ). Kinematics and kinetics data were recorded using Vicon T20 system (250 Hz) and force platforms (1000 Hz). When comparing a SRJ to a DRJ, the characteristics of the former are as follows: 1) the jump height by a single leg is significantly higher because of the larger hip joint work around the extension-flexion, especially on the abduction-adduction axes; 2) the hip extension and abduction torque is larger; and 3) in the SRJ, the hip abduction torque is larger than the hip extension torque. Therefore, the joint kinetics of the SRJ is characterized by the large hip abduction torque, in addition to the large hip extension torque.

KEYWORDS: plyometric training, three-dimensional motion analysis, hip abduction torque.

INTRODUCTION: In many sports, high power output at lower extremity is important for improving sports performance. Plyometric training (PT) is widely used for enhancing power output. Many studies examining PT have used double leg rebound jumps in a vertical direction (DRJ) in their experimental tasks. However, many sports require the use of a single leg takeoff. Thus, a single leg rebound jump (SRJ) is often used in PT. Recently, Kariyama et al. (2012) reported that in the sagittal plane (extension-flexion joint axis), the joint kinetics characteristics of a SRJ show a lower ankle joint torque power and a larger hip joint torque and torque power than a DRJ. However, the SRJ and DRJ are also different from each other in another joint axis because the SRJ has a smaller base of support than the DRJ on the left-right side, etc. Thus, three-dimensional motion analysis is necessary for elucidating the joint kinetics characteristics of the SRJ. The purpose of this study was to clarify the differences between the SRJ and DRJ in terms of the three-dimensional joint kinetics of the takeoff leg.

METHODS: Fifteen male track and field athletes (Age, 24.4 ±1.4 years; Height, 174.3 ±5.8 cm; Weight, 70.3 ±4.1 kg) participated as subjects in this study. Informed written consent was obtained from all the subjects prior participation in this study. All procedures undertaken in this study were approved by the Ethics Committee for the Institute of Health and Sport Sciences, University of Tsukuba, Japan.

The subjects performed six repeated SRJs and DRJs. Both jumps consisted of repeated jumps, upward off the ground from a standing posture. The subjects were orally instructed to shorten contact time as much as possible and jump as high as possible. The trials of the highest RJ-index (Zushi et al., 1993), which was calculated from the jump height divided by the contact time, were selected for further analysis.

The three-dimensional coordinates of 47 retro-reflective markers fixed on the body were collected by the Vicon T20 system (Vicon Motion System, Ltd.) using ten cameras operating at 250 Hz. The ground reaction force was obtained with the force platform at 1000 Hz. For the DRJ, two force platforms were used to obtain the right and left leg data.

The angle and angular velocity of the takeoff leg were calculated. The joint torque and torque power of the takeoff leg were calculated using inverse dynamics. The joint angle and joint torque were calculated around the plantarflexion-dorsiflexion and eversion-inversion axes in the ankle joint; around the extension-flexion and external rotation-internal rotation axes in the knee joint; and around the extension-flexion, abduction-adduction, and external rotation-internal rotation axes in the hip joint, based on the anatomical constraint.

A two-tailed paired t-test and one-way multiple comparisons (repeated measure, Bonferroni) were used to determine the differences between the SRJ and DRJ in each dependent measure. The significance was accepted at $p < 0.05$.

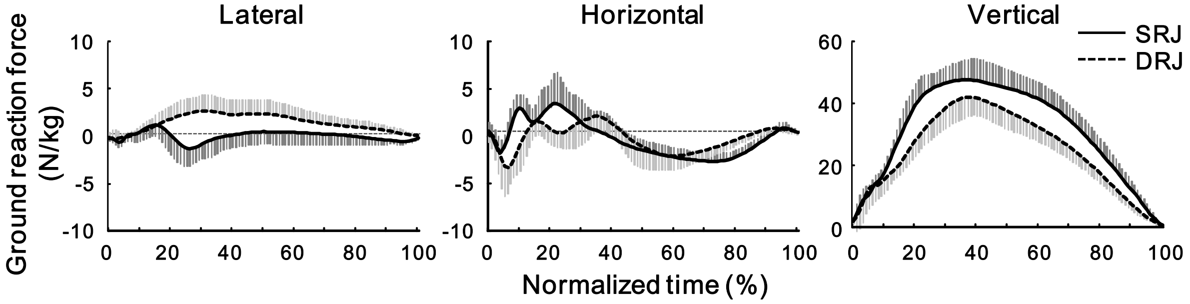
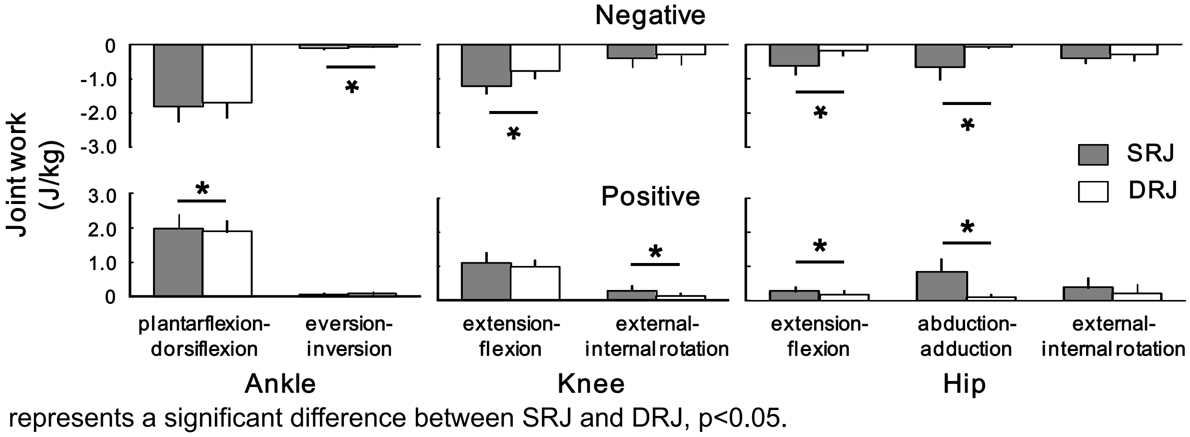


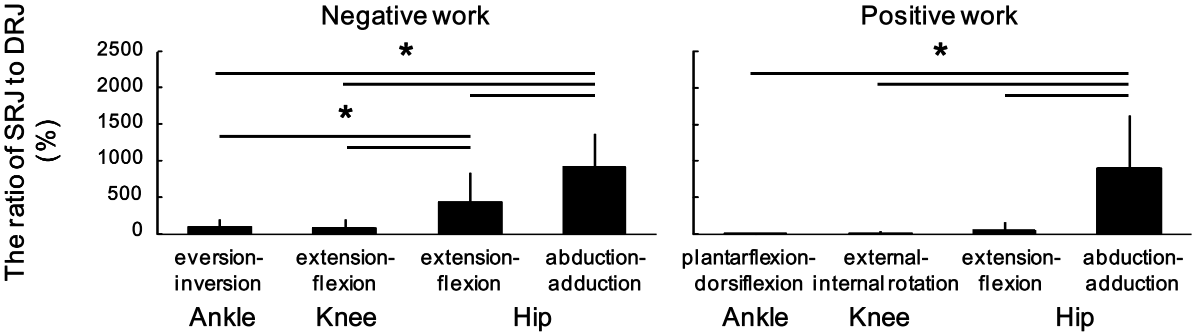
Figure 1: Averaged pattern of lateral, horizontal, and vertical ground reaction forces during takeoff phase in SRJ and DRJ.

RESULTS: The jump height of the SRJ was significantly lower than that of the DRJ (SRJ: 0.299 ±0.037 m vs. DRJ: 0.487 ±0.061 m), and the contact time of the SRJ was significantly longer (SRJ: 0.226 ±0.021 m vs. DRJ: 0.150 ±0.014 m) than that of the DRJ. Although the jump height of the SRJ was significantly lower than that of the DRJ, it was significantly higher than half of that of the DRJ (62.58 %). Figure 1 shows the averaged patterns of the lateral, horizontal, and vertical ground reaction force during the takeoff phase of the SRJ and DRJ. During the takeoff phase, the SRJ showed a higher vertical ground reaction force than the DRJ, but showed a lower lateral ground reaction force. Figure 2 compares the joint work done by the joint torque about the ankle, knee, and hip joints during the takeoff phase, between the SRJ and DRJ. The ankle joint work around the eversion-inversion axis, knee joint work around the extension-flexion axis, and hip joint work around the extension-flexion and abduction-adduction axes showed significantly larger negative values for the SRJ than for the DRJ. The ankle joint work around the plantarflexion-dorsiflexion axis, knee joint work around the external rotation-internal rotation, and hip joint work around the extension-flexion and abduction-adduction axes showed significantly larger positive values for the SRJ than for the DRJ. Figure 3 shows the ratio of the SRJ to the DRJ [$(SRJ_{work} - DRJ_{work})/DRJ_{work} \times 100$] for joint work, with significant differences between the two jumps, as seen in Figure 2. The ratio of the SRJ to DRJ for the hip joint work around the abduction-adduction axis was significantly higher than that for the other joint works. Figure 4 shows the averaged patterns of the joint angular velocity, joint torque, and torque power about the hip joint in the SRJ and DRJ. Large differences were observed between the SRJ and DRJ in the hip extension and abduction torque. In particular, the hip abduction torque was higher during the takeoff phase.



* represents a significant difference between SRJ and DRJ, p<0.05.

Figure 2: Comparison of joint work done by joint torque about the ankle, knee, and hip joints during takeoff phase between SRJ and DRJ.



*represents a significant difference between each joint work, p <0.05.

Figure 3: Comparison of the ratio of SRJ to DRJ of joint work with significant differences shown between SRJ and DRJ in Figure 2 [(SRJ$_{work}$ - DRJ$_{work}$)/DRJ$_{work}$ × 100].

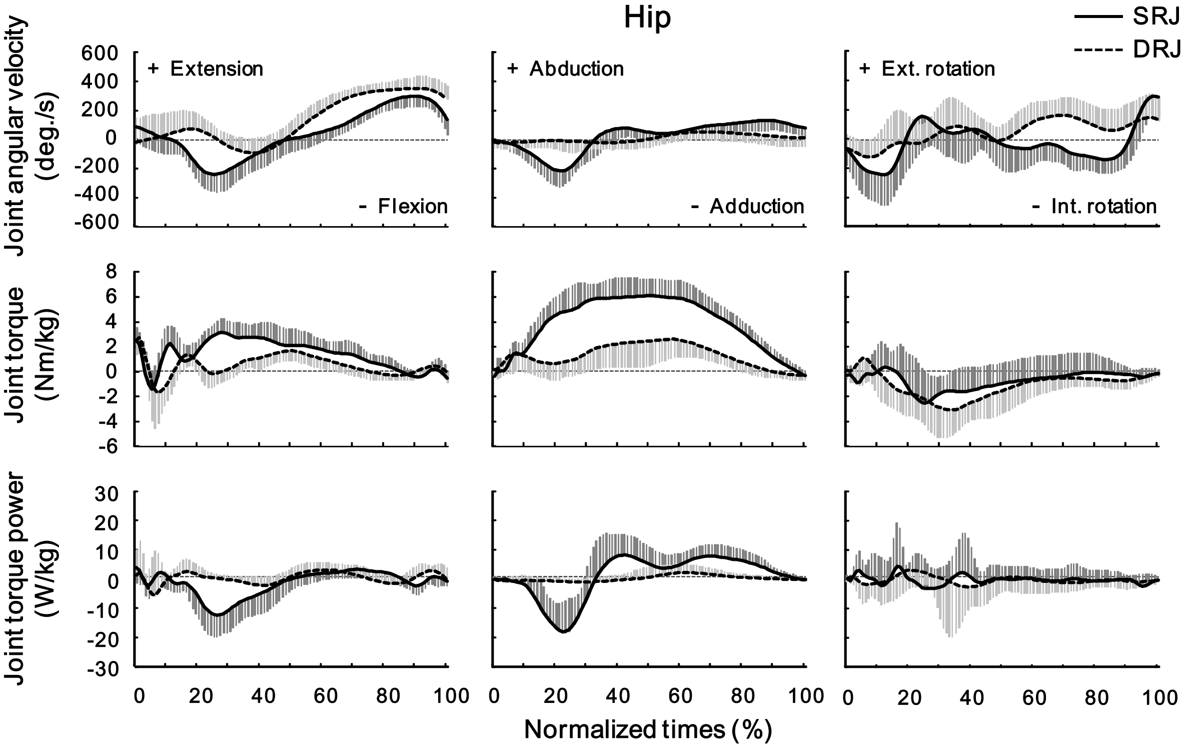


Figure 4: Averaged patterns of joint angular velocity, joint torque and joint torque power about the hip joint during takeoff phase in SRJ and DRJ.

DISCUSSION: Although the jump height was of the SRJ was lower than that of the DRJ, it was higher for the SRJ than for half of the DRJ (62.58 %). This means that the SRJ allows for higher jumps than a single leg of the DRJ. This may be because the hip joint work around the extension-flexion and abduction-adduction axes in the SRJ was larger than that in the DRJ (Figure 2). In this study, the ratio of the SRJ to DRJ in terms of joint work, which showed significant differences between the SRJ and DRJ in Figure 2, was calculated and compared (Figure 3). The ratio of increase of the DRJ to the SRJ about the hip joint work around the abduction-adduction axis was found to be higher than that for all other joint works. Therefore, the joint kinetics around the abduction-adduction axis appears to affect the higher jump height by a single leg. When the hip joint torque was considered, large differences were observed in the extension and abduction torque between the SRJ and DRJ. In particular, the SRJ showed a notably higher abduction torque than the DRJ during the takeoff phase. This result indicated that the hip abduction torque affects the higher jump height by a single leg in the SRJ compared to the DRJ.

This larger hip abduction torque of the SRJ, as compared to the DRJ, may be affected by a larger vertical ground reaction force, but not by a lateral ground reaction force (Figure 1). An example stick figure and ground reaction force vector during the takeoff phase in the SRJ and DRJ are shown in Figure 5 as part of an investigation into the other factors for the larger hip abduction torque in the SRJ than in the DRJ. In the SRJ, the upper body was found to lean toward the takeoff leg side; however, this does not happen with the DRJ. This difference in posture in the SRJ, as compared to the DRJ, affects the longer length of the moment arm from the hip to the ground reaction force vector (average value during takeoff phase: SRJ vs. DRJ = 0.155 ±0.034 m vs. 0.106 ±0.035 m; $p < 0.05$). This affects the larger hip abduction torque of the SRJ, as compared to the DRJ. In the SRJ, this specific motion is caused by concentrating the center of gravity of the body in a base of support in only the takeoff leg, as compared in the DRJ. Moreover, another factor that affects the larger hip abduction torque in the SRJ, compared to the DRJ, is the prevention of fall of the pelvis on the free leg side because the pelvis is supported by both legs in the DRJ, but by only one leg in the SRJ. Therefore, the larger hip abduction torque exertion in the SRJ is a characteristic caused by mechanical and functional-anatomical differences between the SRJ and DRJ.

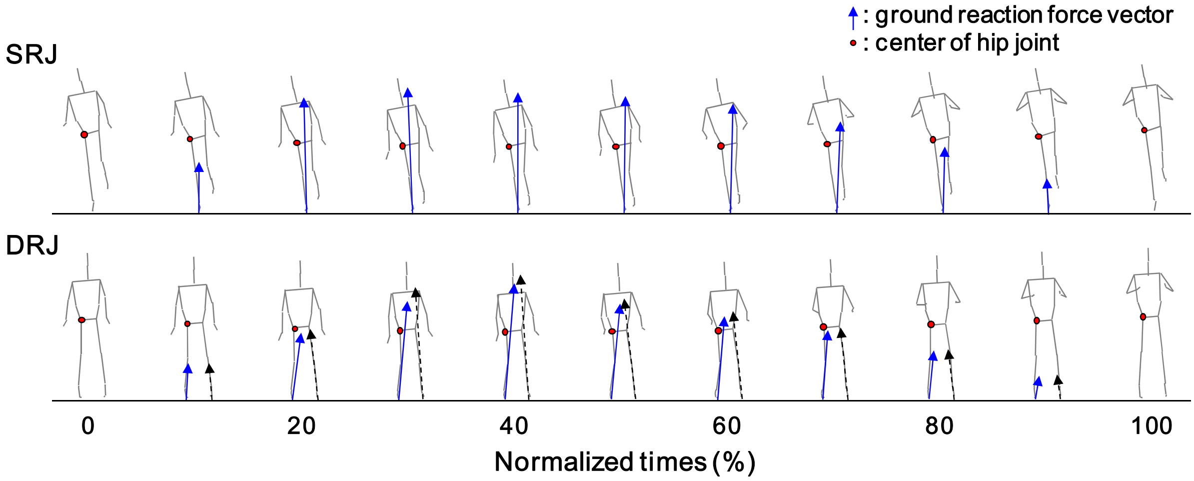


Figure 5: Exemplar stick figure and ground reaction force vector during takeoff phase in SRJ and DRJ.

CONCLUSION: When comparing a SRJ to a DRJ, the characteristics of the former are as follows: 1) the jump height by a single leg is significantly higher because of the larger hip joint work around the extension-flexion, especially on the abduction-adduction axes; 2) the hip extension and abduction torque is larger; and 3) in the SRJ, the hip abduction torque is larger than the hip extension torque. Therefore, the joint kinetics of the SRJ is characterized by the large hip abduction torque, in addition to the large hip extension torque. After considering the findings of Kariyama et al. (2012) and this study, we determine that the SRJ is more suitable for improving the force and power output of the hip extensor, especially on the hip abductor in PT. These findings are useful for clarifying the point of attention and developing an effective method for using the SRJ and DRJ in PT.

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