P01-5 ID142

THE DIFFERENCES BETWEEN HORIZONTAL AND VERTICAL DIRECTION DURING A SINGLE-LEG REBOUND JUMP: OBTAINED USING THREE-DIMENSIONAL MOTION ANALYSIS

Yasushi Kariyama[1], Koji Zushi[2]

[1]Sports Research & Development Core, University of Tsukuba, Japan
[2]Graduate School of Comprehensive Human Sciences, University of Tsukuba, Japan

The purpose of this study was to clarify the differences between single-leg rebound jump for horizontal direction (HSJ) and vertical direction (VSJ) in terms of three-dimensional joint kinetics for the take-off leg focused on frontal plane movement. Eleven male track and field athletes were performed the HSJ and VSJ. Kinematics and kinetics data were recorded using Vicon T20 system (250 Hz) and force platforms (1000 Hz). In HSJ, as compared to VSJ, the joint kinetics characteristics are as follows: 1) the hip abduction torque and torque power around the adduction-abduction axis are larger; and 2) the trunk lateral flexion torque and torque power around the adduction-abduction axis are larger. Therefore, the hip adduction-abduction and trunk lateral flexion-extension movement plays an important role in a single-leg jump. Additionally, this is pronounced in HSJ as compared to VSJ.

KEY WORDS: hip abduction-adduction, trunk lateral flexion-extension.

INTRODUCTION: In many sports, high power output of the lower extremity is important for improving sports performance. Plyometric training (PT) is widely used for enhancing power output. The single-leg take-off is a common execution in several sports, including running and jumping in ball games and athletics take-off. Hence, single-leg rebound jumps in the vertical and horizontal direction (henceforth, referred to as VSJ and HSJ, respectively) are often used for PT. Recently, Kariyama et al. (2012, In Press) reported that hip adduction-abduction and trunk lateral flexion movements play a more important role in VSJ than in the double-leg rebound jump in the vertical direction. Accordingly, the characteristics of the HSJ were shown using three-dimensional motion analysis. However, the characteristics of the HSJ are only in the sagittal plane (Kariyama et al., 2011). The purpose of this study was to clarify the differences between the HSJ and VSJ using three-dimensional motion analysis.

METHODS: Eleven male track and field athletes (Age, 20.27 ± 1.35 years; Height, 177.59 ± 6.04 cm; Weight, 69.82 ± 4.92 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 HSJ and VSJ. VSJ was repeated rebound-type jumps in a vertical direction and with a single-leg from a standing posture. The subjects were orally instructed to shorten the contact time as much as possible and jump as high as possible in VSJ. HSJ was started from a double-leg standing position, and the subjects tried to cover the longest distance by performing a series of 7 forward jumps. The RJ-index, which indicates the mechanical power per weight during take-off (Zushi et al., 1993), was calculated by dividing the jump height by the contact time in VSJ. The trial of highest RJ-index in VSJ and at the 5th jump in HSJ 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.
The joint angle and angular velocity of the take-off leg were calculated. The joint torque and torque power of the take-off leg and trunk were calculated using inverse dynamics. These were calculated based on the anatomical constraint (Kariyama et al., 2012, in press).

Additionally, the joint angle and angular velocity, joint torque and torque power of the trunk joint were calculated around the lateral flexion-extension axis (Kariyama et al., in press). The time series data of all subjects were normalized to the time of take-off phase 0%-100% and subsequently averaged.

A two-tailed paired t-test was used to determine the differences between the HSJ and VSJ in each dependent measure. The significance was accepted at $p < 0.05$.

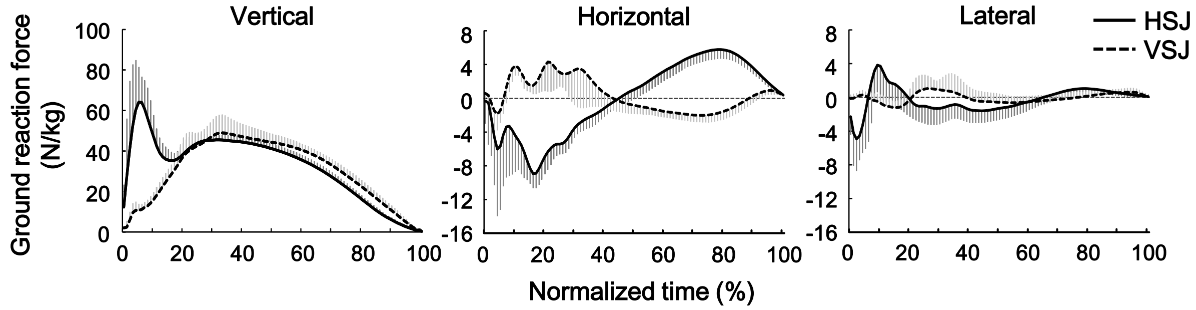

Figure 1: Averaged pattern of vertical, horizontal, and lateral ground reaction forces during take-off phase in HSJ and VSJ.

RESULTS: In HSJ, the jump distance was 3.01 ± 0.20 m and the contact time was 0.183 ± 0.015 s. In VSJ, the RJ-index was 1.222 ± 0.163; the jump height, 0.289 ± 0.030 m; and the contact time, 0.238 ± 0.020 s. Figure 1 shows the averaged patterns of the vertical, horizontal, and lateral ground reaction force during the take-off phase of the HSJ and VSJ. The HSJ showed a higher ground reaction force than the VSJ but showed a lower vertical ground reaction force during the latter duration of the take-off phase (from 50% to 100% of the normalized time). Figure 2 shows a comparison of the joint work done by the joint torque for the ankle joint around the plantarflexion-dorsiflexion (negative value) axis and the knee joint around the extension-flexion (positive values) axis; the figure shows that these values were significantly smaller for the HSJ than for the VSJ. However, the knee joint work around the extension-flexion (negative value) and external rotation-internal rotation (negative and positive value) axes and the hip joint work around the extension-flexion (positive value), abduction-adduction (negative and positive value), and external rotation-internal rotation (positive value) axes showed significantly larger values for the HSJ than for the VSJ. Figure 3 shows the averaged patterns of the joint angular velocity, joint torque, and torque power about the hip joint in the HSJ and VSJ. Large differences in the joint torque and torque power were observed between the HSJ and VSJ around the extension-flexion and abduction-adduction axes. Figure 4 shows the averaged patterns of the joint angular velocity, joint torque, and torque power about the trunk flexion in the HSJ and VSJ. Differences were observed between the HSJ and VSJ in all variables.

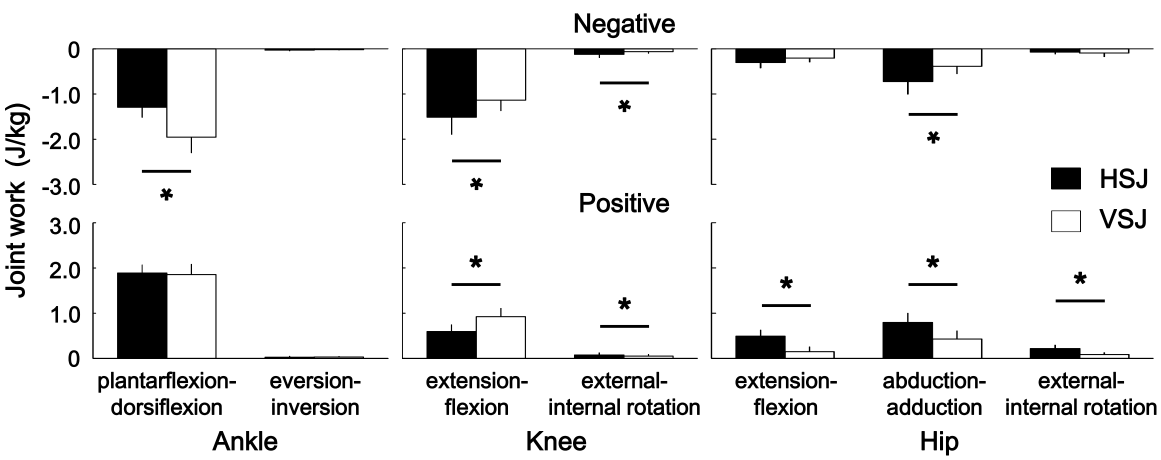

Figure 2: Comparison of joint work done by joint torque about the ankle, knee, and hip joints during take-off phase between HSJ and VSJ.
*** represent a significant difference between HSJ and VSJ, p<0.05.**

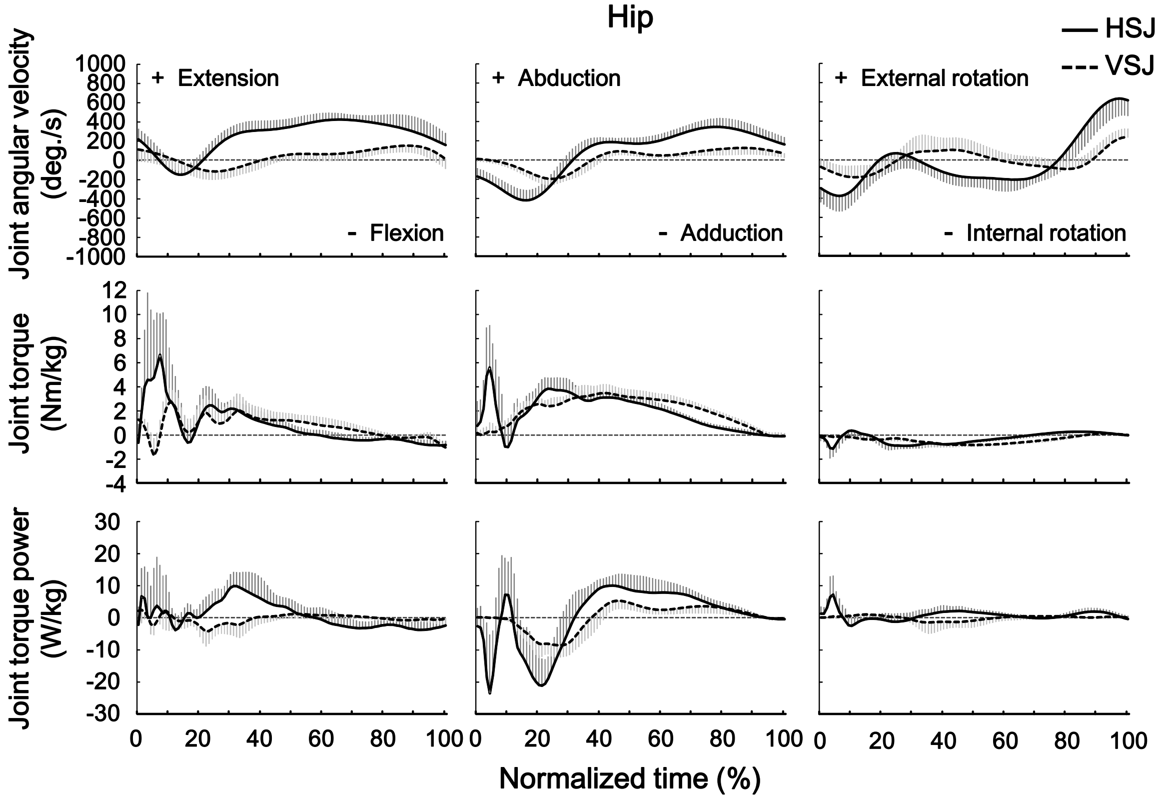

Figure 3: Averaged patterns of joint angular velocity, joint torque, and joint torque power about the hip joint during take-off phase in HSJ and VSJ.

DISCUSSION: Although from the view point of sagittal plane movements (plantarflexion-dorsiflexion and extension-flexion), negative ankle joint work and positive knee joint work were lower for HSJ than for VSJ, the negative knee joint work and positive hip joint work were larger (Figure 1). These results are similar to those of Kariyama et al. (2011), who report that the role of the major joints in absorbing and generating the mechanical energy is responsible for the difference between HSJ and VSJ. However, in this study, from the three-dimensional motion analysis, hip joint work around the abduction-adduction axis showed significantly larger positive and negative values for the HSJ than for the VSJ. This hip joint work was done by the hip abduction torque (Figure 3). In VSJ, the hip abduction torque is larger than that in double-leg rebound jump in the vertical direction. This may have been caused by the anatomical and mechanical differences between both jumps (Kariyama, et al., 2012, in press). Additionally, the hip abduction torque in VSJ may play an important role by controlling the posture and increasing the vertical

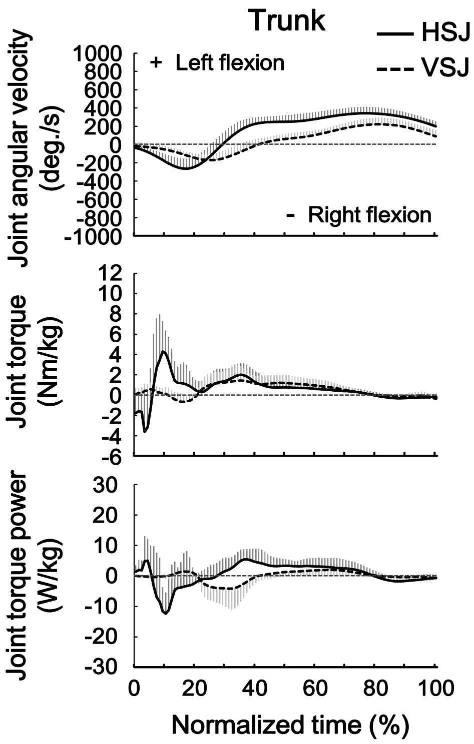

Figure 4: Averaged patterns of joint angular velocity, joint torque, and joint torque power about trunk flexion during takeoff phase in HSJ and VSJ.

ground reaction force (jump height) (Kariyama, et al., in press). In this study, the hip joint angular velocity, joint torque, and torque power around the adduction-abduction axis were larger in HSJ than in VSJ (Figure 3). For the earlier duration of the take-off phase (from 0% to 20% of the normalized time), the HSJ showed a higher vertical and lateral ground reaction force than the VSJ. Additionally, the hip abduction torque in HSJ exerted the same timing to the vertical and lateral ground reaction force (Figures 1 and 4). These results indicated that the hip abduction torque in HSJ may have an important role in resisting the impact force and in maintaining postural control.

Kariyama (in press) reported that the trunk lateral flexion caused by the trunk lateral flexion torque is also important in executing the VSJ. In HSJ, as compared to VSJ, the trunk lateral flexion torque and torque power are larger (Figure 4). Additionally, the patterns are similar to the vertical and lateral ground reaction force. This implies that the trunk joint around the lateral flexion-extension axis is important for resisting the impact force and maintaining the lateral balance together with the hip joint around the adduction-abduction axis. An example stick figure and ground reaction force vector during the take-off phase in the HSJ and VSJ from the frontal plane are shown in Figure 5. In HSJ, hip and trunk movements were more complex than in VSJ. Therefore, the hip adduction-abduction and trunk lateral flexion-extension movements may have a more important role in HSJ than that in VSJ.

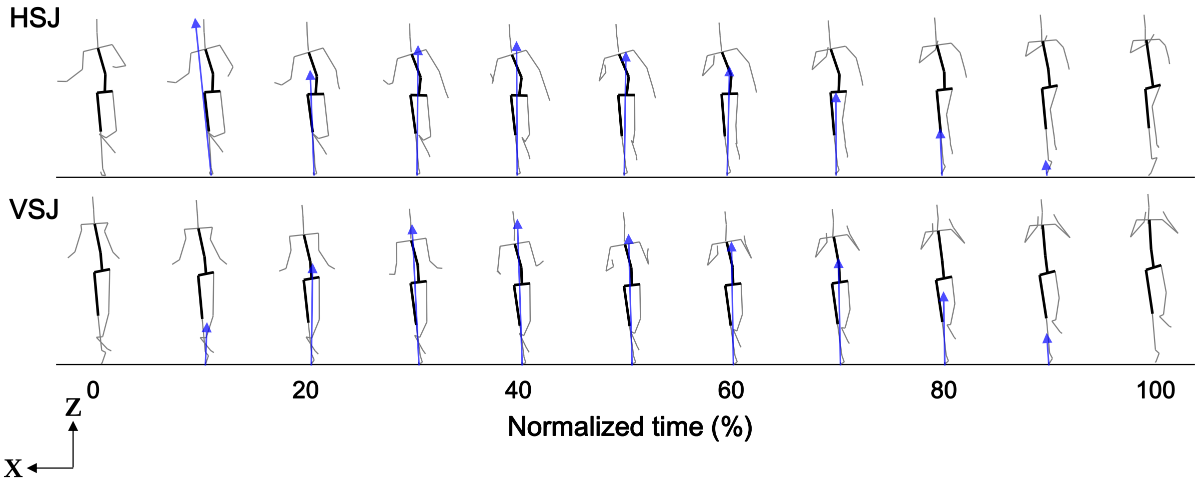

Figure 5: Exemplar stick figure and ground reaction force vector during take-off phase in HSJ and VSJ from the frontal plane.

CONCLUSION: In HSJ, as compared to VSJ, the joint kinetics characteristics are as follows: 1) the hip abduction torque and torque power around the adduction-abduction axis are larger; and 2) the trunk lateral flexion torque and torque power around the adduction-abduction axis are larger. Therefore, the hip adduction-abduction and trunk lateral flexion-extension movement plays an important role in a single-leg jump. Additionally, this is pronounced in HSJ as compared to VSJ.

REFERENCES:

Kariyama, Y., Endo, T., Mori, K. & Ogata, M. (2011). The effects of jumping direction on joint kinetics during rebound-type jumps with a single leg. *Proceedings of the XXIII-th Congress of the International Society of Biomechanics,* Brussels, Belgium.

Kariyama, Y., Fujii, H., Mori, K. & Zushi, K. (2012). The comparison to the characteristics of three-dimensional joint kinetics between single leg and double legs rebound jump. *Proceedings of the XXX-th Congress of the International Society of Biomechanics in Sports,* Melbourne, Australia, 25-28.

Kariyama, Y., Fujii, H., Mori, K. & Zushi, K. (in press). The difference on the characteristics of three-dimensional joint kinetics between single-leg and double-leg rebound jump. *Japan Journal of Physical Education, Health and Sport Sciences*. (in Japanese with English abstract)

Zushi, K., Takamatsu, K. & Kotoh, T. (1993). The specificity of leg strength and power in several sport athletes. *Japan Journal of Physical Education, Health and Sport Sciences*, 38, 265-278. (in Japanese with English abstract)