Portuguese Journal of Sport Sciences
11 (Suppl. 2), 2011

THE DIFFERENCES BETWEEN DOUBLE AND SINGLE LEG TAKEOFF ON JOINT KINETICS DURING REBOUND-TYPE JUMP

Yasushi Kariyama[1], Kenichi Mori[1] and Mitsugi Ogata[2]

Doctoral Program of Comprehensive Human Sciences University of Tsukuba, Japan[1]
Comprehensive Human Sciences, University of Tsukuba, Japan[2]

The purpose of this study was to identify the differences between double and single leg takeoff on joint kinetics during a rebound-type jump. Twelve male track and field athletes performed repeated rebound-type jumps with double legs (DRJ) and a single leg (SRJ). Kinematics and kinetics data were recorded using a high-speed video camera (300 Hz) and force platforms (1000 Hz). The negative and the positive values of the joint torque power about the ankle joint were significantly lower in DRJ than in SRJ. However, the mean joint extension torque, and the negative value of the joint torque power about the hip joint was larger in SRJ than in DRJ. It is suggested that the joint kinetics characteristics, in SRJ as compared to DRJ, reveals a relatively large joint torque and torque power about the hip joint.

KEY WORDS: plyometric training, stretch-shortening cycle, joint torque, joint torque power

INTRODUCTION: High-power output at a low extremity is important for improving sports performance. Plyometric training (PT) is widely used for enhancing the neuromuscular ability related to high-power output since a stretch-shortening cycle (SSC) supplies elastic energy and elicits the stretch reflex for high-power output (Bosco *et al.*, 1982). Many studies that investigated PT used rebound-type jumps in the vertical direction and double leg takeoff (DRJ) such as drop jumps as experimental tasks (Bobbert, 1990; Markovic, 2007; Yoon *et al.*, 2007; Villarreal *et al.*, 2009, 2010). However, single leg takeoff is used in many sports such as running and jumping in athletics and ball sports. Hence, a rebound-type jump with single leg takeoff (SRJ) is often used as PT. However, little effort has been made to investigate the joint kinetics in SRJ. It is necessary to investigate the joint kinetics about the takeoff leg for understanding the training load and training objectives in SRJ. The purpose of this study was to clarify the differences between double and single leg takeoff on the joint kinetics about the takeoff leg during a rebound-type jump.

METHODS: Twelve male track and field athletes (age, 22.0 ± 2.2 years; height, 175.0 ± 6.1 cm; mass, 65.8 ± 4.0 kg) participated in this study as subjects. Written informed consent was obtained from all subjects prior to participation in this study. All procedures undertaken in the study were approved by the Ethics Committee for the Institute of Health and Sport Sciences, University of Tsukuba, Japan.
Subjects performed repeated rebound-type jumps with double (DRJ) and a single leg (SRJ). Both jumps consisted of repeated jumps off the ground in a vertical direction from a standing posture. Subjects were orally instructed to shorten the contact time as much as possible and jump as much as possible. RJ-index that indicates the mechanical power per mass during takeoff (Tauchi *et al.*, 2008), was calculated by dividing the jump height by the contact time. The trials of the highest RJ-index were selected for further analysis.
Jumping motions in the sagittal plane were videotaped with a high-speed video camera (300 Hz), and ground reaction force data (GRF) were recorded with a force platform (1000 Hz). Twenty three body points and four calibration markers were digitized; the digitized coordinates were converted into real coordinates using four reference markers placed on the ground. The joint angle and angular velocity data about the takeoff leg were calculated from the coordinates, and the joint torque and torque power of takeoff leg were calculated by inverse dynamics. The takeoff phase was divided into two parts: the eccentric phase (ECC), from the point at touchdown to the lowest point of the center of gravity of the body (CG), and the concentric phase (CON), from the lowest point of CG to toe-off. The mechanical power

(MP) was calculated from the impulse of vertical GRF divided by the contact time during ECC and CON, respectively, to evaluate the power output. The GRF in DRJ was divided into halves to evaluate the force output characteristics generated by a single leg. These data were used for calculating the impulse (DRJ/2) and joint torque. The impulse, joint torque, and torque power were divided by the body mass and then averaged. The time series data of all subjects were normalized to the time of ECC as 0%-50% and CON as 50%-100% and subsequently averaged. Two-tailed paired t-tests were used for determining the differences in each dependent measure between DRJ and SRJ. One-way multiple comparisons (repeated measure, Bonferroni) were used to compare the statistical differences between the jumps for impulse and MP. The significance was accepted at $p < 0.05$.

Table 1
Contact time and impulse in DRJ, DRJ/2 and SRJ.

Variables	DRJ	DRJ/2	SRJ
Contact time (s)	0.147 ± 0.019	-	0.219 ± 0.022†
ECC (s)	0.061 ± 0.009	-	0.097 ± 0.010†
CON (s)	0.087 ± 0.012	-	0.122 ± 0.015†
Impulse (Ns/kg)	7.61 ± 0.39	3.81 ± 0.20	6.97 ± 0.34†*
ECC (Ns/kg)	3.61 ± 0.39	1.81 ± 0.20	3.39 ± 0.15†*
CON (Ns/kg)	4.00 ± 0.31	2.00 ± 0.16	3.58 ± 0.30†*

†represent a significant difference between DRJ and SRJ, p<0.05.
*represent a significant difference between DRJ/2 and SRJ, p<0.05.

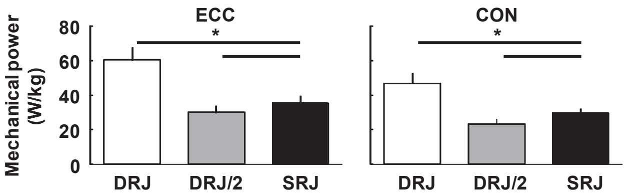

Figure 1: Mechanical power in DRJ, DRJ/2 and SRJ.
*represent a significant difference between DRJ/2 and SRJ, p<0.05.

RESULTS: Table 1 shows the contact time and impulse in DRJ, DRJ/2, and SRJ. The contact time was significantly longer and the impulse was significantly smaller in SRJ than in DRJ. However, in SRJ as compared to DRJ/2, the impulse of both ECC and CON were significantly larger. Figure 1 shows a comparison of MP between DRJ, DRJ/2 and SRJ. Although MP was significantly smaller in SRJ than in DRJ, MP was significantly larger in SRJ than in DRJ/2 during both ECC and CON. Figure 2 shows that a comparison of a joint angular displacement about the ankle, knee, and hip joints during ECC and CON between DRJ and SRJ. The flexion angle about the ankle, knee, and hip joints were significantly larger and the extension angle about the ankle and the hip joints were significantly smaller in SRJ than in DRJ.

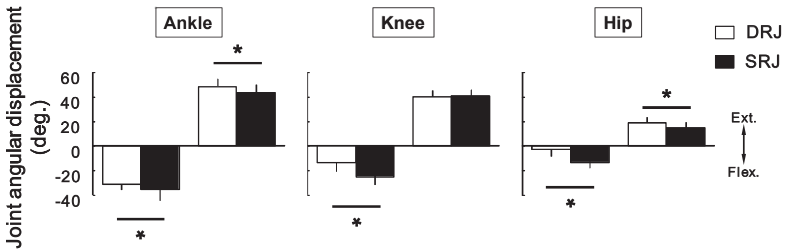

Figure 2: Joint angular displacement of hip, knee and ankle joints in DRJ and SRJ.
* represent a significant difference between DRJ and SRJ, p<0.05.

Figure 3 shows the averaged patterns of the joint angular velocity, joint torque, and torque power about the ankle, knee, and hip joints in DRJ and SRJ. Notable differences were observed in the ankle and hip joint between DRJ and SRJ. In SRJ ascompared to DRJ, the joint angular velocity and the joint torque power about the ankle joint were lower for both the negative and the positive values during the takeoff phase. However, in SRJ as compared to DRJ about the hip joint, the negative value of the joint angular velocity was high during ECC, the joint torque was high during the takeoff phase, and the negative value of the joint torque power was high during ECC. Figure 4 shows a comparison of the mean joint extension torque and the mean joint torque power about the hip, knee, and ankle joints between DRJ and SRJ. Although there were no significantly differences in the mean joint torque about the ankle joint between DRJ and SRJ, the negative and positive values of the mean joint torque power about the ankle joint were significantly smaller in DRJ and SRJ. However, in SRJ as compared to DRJ, the mean joint torque about the hip joint was significantly larger in the cases of both ECC and CON, and the negative value of the mean joint torque power about the hip joint was significantly higher.

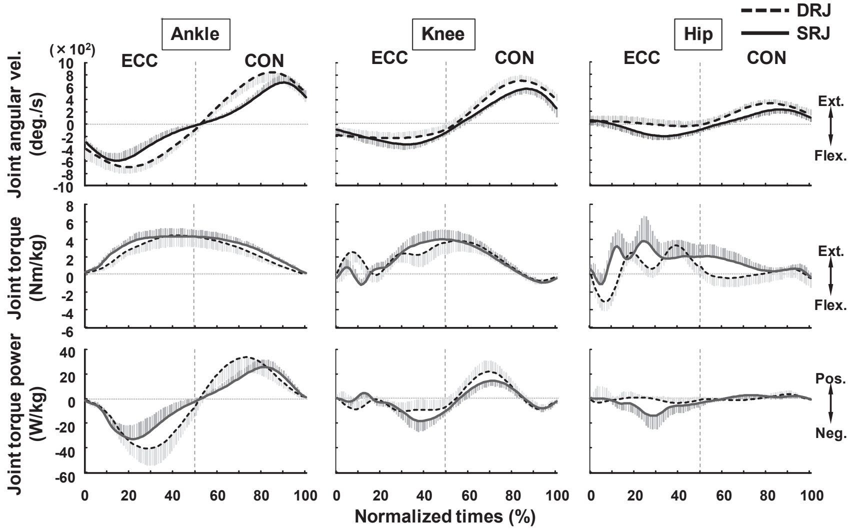

Figure 3: Averaged patterns of joint angular velocity, joint torque and joint torque power of hip, knee and ankle joints in DRJ and SRJ.

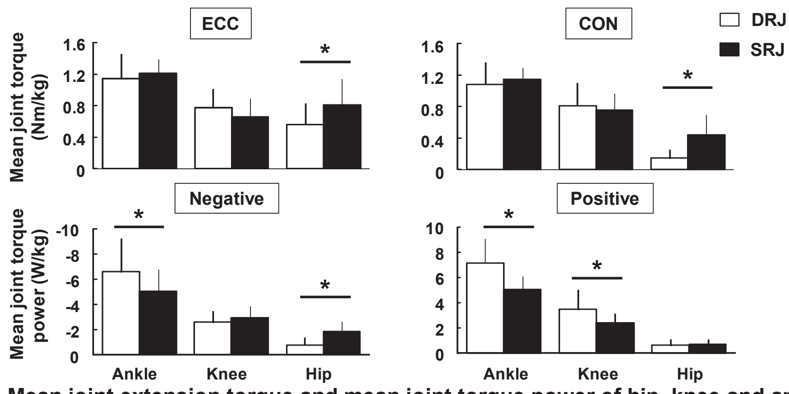

Figure 4: Mean joint extension torque and mean joint torque power of hip, knee and ankle joints in DRJ and SRJ. * represent a significant difference between DRJ and SRJ, $p<0.05$.

DISCUSSION: MP was higher in SRJ than in DRJ/2 during both ECC and CON, although MP was lower in SRJ than in DRJ (Figure 1). This was caused by the fact that the impulse of SRJ was smaller than in DRJ but not in DRJ/2 (Table 1). These results indicate that the power output by a single leg was higher in SRJ than in DRJ.

In a rebound-type jump with double legs, the joint torque and torque power about the ankle joint were substantially higher than those about the knee and hip joint (Bobbert *et al.*, 1987). This is similar to that obtained in our study on DRJ, but not on SRJ (Figures 3 and 4). There is no difference between DRJ and SRJ in terms of the mean joint extension torque about the ankle. However, the negative value of the mean joint torque power about the ankle is lower in SRJ than in DRJ. This result is caused by the relatively low angular velocity about the ankle joint in SRJ (Figure 3). This relatively low angular velocity about the ankle joint was caused by the longer ECC time (Table 1) and the larger flexion angle (Figure 2). It has been reported that when the muscle prestretch speed is high, the effects of SSC is enhanced (Cavagna *et al.*, 1965, 1968; Komi, 1986). It is expected that the muscle prestretch speed is nearly equal to the joint flexor velocity. These results indicate that the SSC function about the ankle joint decreases in SRJ as compared to DRJ. In contrast, about the hip joint in SRJ, the mean joint extension torque in both ECC and CON, and the negative value of the torque power were higher than those in DRJ (Figures 3 and 4). The joint kinetics characteristics, in SRJ as compared to DRJ, reveals a relatively small torque power about the ankle joint and relatively a large joint torque and torque power about the hip joint.

CONCLUSION: In SRJ as compared to DRJ, the force and joint kinetics characteristics of are as follows: 1) the power output by a single leg was relatively high; 2) the mean joint torque power about the ankle was relatively low; and 3) the mean joint torque and the mean joint torque power about the hip were relatively high. Therefore, DRJ is more suitable to improve power output about the ankle joint and SRJ is more suitable to improve power output about the hip joint. Athletes and coaches should understand these differences when using DRJ and SRJ for PT.

REFERENCES:

Bobbert, M.F., Huijing, P.A. & Jan Van Ingen Schenau, G. (1987) Drop jumping. I. The influence of jumping technique on the biomechanics of jumping. Medicine & Science in Sports & Exercise, 19, 332-338.

Bobbert, M.F. (1990) Drop jumping as a training method for jumping ability. Sports Medicine, 9, 7-22.

Bosco, C., Viitasalo, J.T., Komi, P.V. & Luhtanen, P. (1982) Combined effect of elastic energy and myoelectrical potentiation during stretch-shortening cycle exercise. Acta Physiologica Scandinavica, 114, 557-565.

Cavagna, G.A., Saibene, F.P. & Margaria, R. (1965) Effect of negative work on the amount of positive work performed by an isolated muscle. Journal of Applied Physiology, 20, 157-158.

Cavagna, G.A., Dusman, B. & Margaria, R. (1968) Positive work done by a previously stretched muscle. Journal of Applied Physiology, 24, 21-32.

Komi, P.V. (1986) Training of Muscle Strength and Power: Interaction of Neuromotoric, Hypertrophic, and Mechanical Factors. International Journal of Sports Medicine, 1,10-15.

Markovic, G. (2007) Does plyometric training improve vertical jump height? A meta-analytical review. British Journal of Sports Medicine, 41, 349-355.

Tauchi, K., Endo, T., Ogata, M., Matsuo, A. and Iso, S. (2008) The Characteristics of Jump Ability in Elite Adolescent Athletes and Healthy Males:The Development of Countermovement and Rebound Jump Ability. International Journal of Sport and Health Science, 6, 78-84.

Villarreal, E.S., Kellis, E., Kraemer, W.J. & Izquierdo, M. (2009) Determining variables of plyometric training for improving vertical jump height performance: a meta-analysis. Journal of Strength and Conditioning Research, 23, 495-506.

Villarreal, E.S., Requena, B. & Newton, R.U. (2010) Does plyometric training improve strength performance? A meta-analysis. Journal of Science and Medicine in Sport. 13, 513-522.

Yoon, S., Tauchi, K. & Takamatsu, K. (2007) Effect of Ankle Joint Stiffness during Eccentric Phase in Rebound Jumps on Ankle Joint Torque at Midpoint. International Journal of Sports Medicine, 28, 66