EFFECT OF THE SWING MOTION OF THE FREE LEG ON THE TAKEOFF FOR ELITE LONG JUMPERS

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INTRODUCTION

Major objective of long jump takeoff is to obtain upward momentum of the body with minimum loss of forward momentum of the body developed during a run-up. Coordination between the takeoff leg and the free limbs is important to accomplish the objective. The takeoff leg plays the most important role to produce the upward momentum of the body during the takeoff phase. Thus, there have been a large number of studies on the takeoff leg during the takeoff phase. On the contrary, although the swing motion of the free limbs during the takeoff phase is another important factor of long jumping technique, very few have focused on the role of the swing motion in the long jump takeoff. Since the swing motion has various effects on the performance in jump events, it is useful to discuss effects of the swing motion on the takeoff for improving the long jump performance. The purpose of this study was to investigate effects of the swing motion of the free leg for elite long jumpers on the takeoff by using joint forces of the hip as a primary variable.

METHODS

Nineteen elite male long jumpers who participated in one of four competitions in 2001 and 2002 were videotaped from the lateral side of the long jumpers at 250 Hz with a high speed video camera (HSV-500C, Nac) set perpendicular to the run-up. A trial of the best record for each subject was selected for the analysis. Official distances ranged from 7.57 m to 8.49 m. Two dimensional coordinates of the endpoints of the body segment were reconstructed with two dimensional DLT technique. The location of the center of mass, masses and the moments of inertia of the body segments were estimated from the body segment parameters following methods of Ae et al. (1992). Kinematics of the body segments, i.e., angles and angular velocities of the knee and ankle joints of the takeoff leg, and segment angle and angular velocity of the thigh of the swing leg were calculated. Joint forces of the swing leg were calculated by an inverse dynamic approach. Impulse of the joint force acting on the hip joint of the swing leg was calculated by numerical integration of the joint force. To examine the effects of the swing motion on the takeoff, subjects were divided into two groups, based on the decreasing ratio of the thigh angular velocity of the swing leg. These variables were averaged and normalized by the time of the takeoff phase.

RESULTS AND DISCUSSION

Figure 1 shows the averaged horizontal and vertical joint forces (henceforth, HJF and VJF) acting on the hip joint of the swing leg during the takeoff phase. Positive value in the HJF and VJF means the forward direction and the upward direction, respectively. The HJF decreased after the touchdown and changed from the positive to the negative, and the negative HJF remained until the takeoff. The VJF increased sharply after the touchdown and reached to the maximum, and then decreased until the takeoff.

In the first half of the takeoff phase, the vertical velocity of the center of gravity is increased due to the forward rotation of the body about the supporting foot. According to the law of action-reaction, the reaction force of the HJF acting on the rest of the body after 10 % time should be positive and forward direction. This implies that the forward reaction force of the HJF after the touchdown will contribute to the enhancement of the forward rotation of the body and then the acceleration of the body as a result.

Figure 2 shows the averaged angular velocities of the knee and ankle joints of the takeoff leg during the takeoff phase. The knee joint...
angular velocity increased about 70% time and decreased until the takeoff. The ankle joint angular velocity increased about 80% time and decreased until the takeoff.

Figure 2 Averaged angular velocities of the knee and ankle joints of the takeoff leg during the takeoff phase.

In the second half of the takeoff phase, the knee and ankle extensors of the takeoff leg will act in concentric manner (Ae et al., 1989). In the case of concentric contraction, the slower muscle contracts, the larger force the muscle exerts. The knee and ankle extensors of the takeoff leg would contract in the large velocity in the second half of the takeoff phase, because the angular velocities of the knee and ankle joints of the takeoff leg were very large in this phase. According to the law of action-reaction, the reaction force of the VJF acting on the rest of the body after 70% time was positive and upward direction. Ae and Shibukawa (1983) indicated that in vertical jump the effect of the swing motion of the arms was to increase the load on the both legs and to lead to the more extension of the legs just before the takeoff. Thus, these results may imply that the reaction force of the VJF will enhance the body to lift up quickly by decreasing the load impaired on the takeoff leg even in the phase where the extensors of the knee and ankle of the takeoff leg can not exert large force because of the fast contraction velocity.

Figure 3 shows the averaged angular velocity of the thigh of the swing leg during the takeoff phase for two groups: largely-decreased (LD) and small-decreased angular velocity (SD). There was remarkable difference in the decreasing ratio of the angular velocity between LD (71.6 ± 6.7%) and SD (56.9 ± 10.9%). In the first half of the takeoff phase, the angular velocity of LD was larger, and reached to the maximum at earlier time than SD. In the second half of the takeoff phase, the angular velocity of LD was smaller than that of SD.

Figure 4 shows the averaged horizontal and vertical joint forces acting on the hip joint of the swing leg during the takeoff phase for LD and SD groups. The HIF of LD after the touchdown decreased more rapidly than that of SD, and the HIF of LD in the first half of the takeoff phase was smaller than that of SD. The VIF of LD from the maximum to the takeoff was smaller than that of SD, and the VIF of LD changed from the positive to the negative at earlier time than that of SD.

Figure 5 shows the horizontal and vertical impulse of the joint force acting on the hip joint of the swing leg in the first half of the takeoff phase and in the second half of the takeoff phase of LD and SD groups. The negative impulse of the HIF for LD in the first half of the takeoff phase was larger than that of SD (left). The negative impulse of the VIF for LD in the second half of the takeoff phase was larger than that of SD (right). The relationship between the decreasing ratio of the thigh angular velocity of the swing leg and the negative impulse of the VIF in the second half of the takeoff phase was negatively significant (n=19, r=-0.52, p<0.05). The relationship between the decreasing ratio of the thigh angular velocity of the swing leg and the negative impulse of the HIF in the first half of the takeoff phase was negative (n=19, r=-0.41), but not
These results indicated that in the first half of the takeoff phase, the larger the decrease in the angular velocity of the thigh of the swing leg was, the larger the negative HJF and the impulse could be exerted. Since the reaction force of the HJF acting on the rest of the body contributed to the acceleration of the body, it will be suggested that the larger decrease in the angular velocity of the swing leg help the body to rotate quickly. In the second half of the takeoff phase, the larger the decrease in the angular velocity of the thigh of the swing leg was, the earlier the VJF changed from the positive to the negative, and the larger the negative impulse of the VJF tended to be, which implied that the larger positive impulse of the reaction force of the VJF tended to the act on the rest of the body. The action to decrease the velocity of the swing leg quickly during the takeoff phase is often called a stopping action in coaching. Since the reaction force of the VJF will enhance the body to lift up quickly by decreasing the load impaired on the takeoff, it is suggested that larger stopping action of the swing leg will make the load on the takeoff leg less and lead to quick lift of the body.

REFERENCES