KINEMATIC CONTRIBUTION OF THE TAKEOFF LEG JOINTS TO THE VELOCITY OF THE CENTER OF GRAVITY IN THE LONG JUMP

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INTRODUCTION

In the long jump, the velocity of the center of gravity (CG) of the jumper at the takeoff is the most contributing factor to the jumping distance. Horizontal velocity of CG is developed in the run-up and the vertical velocity has to be acquired by the jumper with the minimum loss of the horizontal velocity during the takeoff phase. Since the flexion and extension of the takeoff leg joints play an important role to convert the horizontal velocity to the vertical, it is useful to investigate effects of the angular velocity of the takeoff leg joints on the velocity of CG during the takeoff phase for understanding the mechanism of the long jump takeoff and improving the performance. The purpose of this study was to determine the kinematic contribution of the takeoff leg joints to the velocity of the CG during the takeoff of the long jump.

METHODS

Eleven Japanese male long jumpers participated in this study as subjects. The takeoff motion of the subjects with a full run-up was videotaped with a high speed VTR camera (250Hz). Two dimensional coordinates of the endpoints of the body segments were obtained by digitizing VTR images.

We can assume that the velocity of CG during the takeoff phase is the sum of the tangential and the radial velocities of the segments of the takeoff leg and the torso (CG-hip). The velocity of CG can be expressed by the following equation:

\[ \mathbf{v}_{\text{CG}} = (\dot{\mathbf{r}}_{\text{CG/hip}} \times \mathbf{r}_{\text{CG/hip}}) + (\dot{\mathbf{r}}_{\text{CG/thigh}} \times \mathbf{r}_{\text{CG/thigh}}) + (\dot{\mathbf{r}}_{\text{CG/shank}} \times \mathbf{r}_{\text{CG/shank}}) + (\dot{\mathbf{r}}_{\text{CG/toe}} \times \mathbf{r}_{\text{CG/toe}}) \]

where \( \dot{\mathbf{r}}_{ij} \) is relative angular velocity between segment i and j, i.e. joint angular velocity, \( \mathbf{r}_{\text{CGi}} \) is displacement vector between joint i and CG, \( \mathbf{r}_{ij} \) is linear velocity of the endpoint of the body segment, \( \mathbf{r}_{ij} \) is radial velocity of the segment i. The first term of the equation represents the effect of the angular velocity of the hip joint to the velocity of CG, as well as the second, third and fourth terms represent the effect of the joint angular velocity of the knee, ankle and foot to the velocity of CG.

RESULTS AND DISCUSSION

The horizontal velocity of CG decreased and the vertical velocity increased during the takeoff phase. The horizontal velocity of CG rapidly decreased immediately after the touchdown, while the vertical velocity of CG began to increase from the touchdown. The hip, knee and ankle joints of the takeoff leg flexed in the first half of the takeoff phase and extended until the toeoff. The foot rotated forward about the heel in the initial phase and about the toe in the rest of the takeoff phase.

Figure 1 shows the effect of the joint angular velocity of the hip, knee, ankle and foot, which were represented by the first, second, third and fourth terms of the equation, on the horizontal (a) and vertical velocity (b) of CG during the takeoff phase. These were shown by the averaged data of all subjects. In the first half of the takeoff phase, the hip flexion increased the horizontal velocity of CG, which was very small, while the ankle dorsiflexion and the forward rotation of the foot largely contributed to the positive horizontal and vertical velocities of CG. To the contrary, the knee flexion decreased the horizontal and vertical velocities of CG, because the effect of the knee flexion on the CG velocity was negative. Since there were no big differences in the maximum angular velocities of three joints of the takeoff leg, the difference in velocity components among the joints will be caused by the distance between CG and joints of the takeoff leg.

In the second half of the takeoff phase, the hip extension and ankle plantar flexion decreased the horizontal velocity of CG and increased the vertical velocity of CG. While the extension of the knee and the forward rotation of the foot increased the horizontal velocity of CG, but decreased the vertical velocity of CG in the second half of the takeoff phase.

These results indicate that the knee flexion decreases the horizontal and vertical velocities of CG while the ankle dorsiflexion increases the horizontal and vertical velocities of CG in the first half of the takeoff phase. In the second half, the faster the jumper extends the hip and ankle, the more the vertical velocity of CG increases but the horizontal velocity of CG decreases. To the contrary, the faster extension of the knee decreases the vertical velocity of CG and increases the horizontal velocity of CG.

As indicated the effect of the length of arm on the velocity components, the position of the body relative to CG reflects the effect of the angular velocity of the joints and segments on the velocity of CG.

Figure 1  The effect of the angular velocity of the hip, knee, ankle and foot on the horizontal (a) and vertical velocity (b) of CG during the takeoff phase. The data were normalized...
by the time of the takeoff phase for the subjects and averaged.