Torques, powers and the functions of the takeoff leg muscles in the elite Japanese long jumpers

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Introduction

In long jump, the velocity of the center of gravity (CG) of the jumper at takeoff is the most important factor to determine the distance of the jump. Horizontal velocity of CG increases in the approach phase, and vertical velocity of CG has to be acquired by the jumper with minimum loss of horizontal velocity in the takeoff phase. Since the takeoff leg plays an important role to convert the horizontal velocity to the vertical, the function of the takeoff leg joints in the long jump should be investigated to improve the performance. The purposes of this study were to determine joint torques (JT) and joint torque powers (JTP) of the takeoff leg of the Japanese elite long jumpers for the discussion of the functions of the takeoff leg.

Methods

Six Japanese elite long jumpers during jumping in the training camp were videotaped with a high speed VTR camera (250Hz), and ground reaction forces (GRF) during takeoff phase were collected with a force platform (1000Hz). Two dimensional coordinates of the body landmarks were obtained by digitizing VTR images. LED signal was used to synchronize the GRF data with the VTR data. Torques and powers of the lower limb joints were calculated by an inverse dynamic approach. JT's and JTP's of all the subjects were normalized by the time of the takeoff phase, and averaged. The takeoff phase was divided into two phases: the first phase was from the instant of the foot touchdown (TD) to the instant of the minimum distance (toe-CG distance) between the toe of the takeoff foot and the CG (MID), the second phase was from the end of the first half to the toeoff (TO) of the takeoff leg.

Results & Discussion

During the takeoff phase, the horizontal velocity of CG decreased (1.48±0.67m/s) and the vertical velocity of CG increased (3.29±0.50m/s). The horizontal velocity of CG rapidly decreased immediately after the touchdown while the vertical velocity of CG began to increase in the first phase though the toe-CG distance decreased.

Figure 1 shows change in JT's of the ankle, knee and hip joints of the takeoff leg during the takeoff. Ankle JT was positive (plantar flexion) in the almost whole phase. Although knee JT showed negative (flexion) immediately after touchdown and before toeoff, the extensors of the knee were dominant in the most part of the takeoff phase. Hip JT more abruptly varied during the takeoff than the other joints. The extension torque of the hip joint rapidly increased immediately after the touchdown, followed by the second peak. Hip JT then decreased, fluctuated around zero, with negative phase. It was found that hip and knee JT changed in off-phase manner each other. The extremely large positive hip JT immediately after the touchdown may result from the positional relationship between the impact force vector and the hip joint. In the case the impact force vector directed in front of the hip joint with a longer distance from the hip joint, hip extensors
might have to exert the greater extensor torque to prevent the hip joint from collapsing against the hip flexion moment. While the impact force vector directed close to the hip joint, hip JT might be smaller. JT patterns might indicate that hip extensors resist the impact force and keep the upper body in right position during the takeoff phase.

Figure 2 shows change in JTPs of the ankle, knee and hip joints of the takeoff leg. Positive JTP indicates generation and negative one indicates absorption of mechanical energy. Ankle JTP was negative around 0 to 60% of the takeoff phase, and then very large positive. This indicates that the plantar flexors are a hidden energy absorber and generator. Although knee JTP was positive immediately after the touchdown, the knee joint absorbed energy around 10 to 60%. Knee JTP returned to the positive after 60%, but negative before toeoff. Knee JTP changed from the negative to the positive before ankle JTP did in the second half. This indicates that the leg extension begins first with the knee joint and later in the ankle joint. Although hip extensors exerted large positive power immediately after the touchdown and hip flexors exerted large negative power before toeoff, hip JTP was surprisingly smaller around 10 to 70% of the takeoff phase. Negative ankle and Knee JTP around 10 to 60% of the takeoff phase indicate that the ankle and knee joint absorb the shock and the mechanical energy generated in the approach, which causes the decrease in horizontal velocity of CG which may be mandatory.

The knee joint of the jumpers was bending in the first phase, but they can obtain vertical CG velocity by the forward rotation of the body over the takeoff foot in the first phase, where the knee extensors exerted the support moment for the body and absorb the impact force and mechanical energy, working together with the hip extensors.

![Figure 1](image1.png)

Figure 1: Joint torque patterns of the takeoff leg during the takeoff phase.

![Figure 2](image2.png)

Figure 2: Joint torque power patterns exerted by the takeoff leg.