DYNAMICS OF SUPPORT HIP JOINT DURING MAXIMAL VELOCITY SPRINTING

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The purpose of this study was to investigate the relationship between lower trunk motion and the support leg hip joint torque by three-dimensional (3D) analysis. Eight male sprinters ran 60-m with maximal effort from a standing position. Kinematic and kinetic data at the maximal speed phase were obtained with a 3D motion analysis system (250Hz) and force platform (1000Hz). As a result, there was a marginally significant negative correlation (r = -0.70, p = 0.051) between a running velocity and the peak backward angular acceleration of the support-side lower trunk during terminal support phase. It seems to be necessary for diminishing the backward angular acceleration to exert a large support hip adductor torque during the terminal support phase. These findings might be useful to improve maximal running velocity.

KEY WORDS: running, trunk, hip adduction torque, kinetics

INTRODUCTION: Force production at a hip joint has an important role on sprint running ability. Previous studies have demonstrated some aspects of the importance of hip joint kinetics for better sprinting performance. For example, Ae (2001) verified that an elite sprinter produces a large hip joint force power (inner product of a hip joint velocity and hip joint force) to swing the recovery leg quickly forward during the early recovery phase and speculated an importance of a pelvic rotation for better sprinting performance. However, since Ae (2001) did not analyze 3D motion and did not record the ground reaction forces (GRFs), the relationship between the frontal/transversal motion of the pelvis and the joint torque of support leg remains unknown.
The purpose of this study was to perform a 3D analysis to investigate the influence of pelvic rotation on sprinting ability, and to clarify the relationship between the pelvic rotation and 3D hip joint torque of supporting leg in order to obtain insight into sprinting technique. It would be beneficial to understand the 3D dynamics of a hip joint during sprinting for addressing improvement of sprinting ability.

METHODS: Eight male sprinters (Height 1.77 ±0.08m, body mass 71.4 ±5.4kg) volunteered for the present study. After warm-up, the participants ran 60m with the maximal effort from a standing start position. Ground reaction forces (GRFs) of the right support phase was obtained with a force platform (Kistler, Wintherthur, Swiss), operating at 1000Hz, which was placed at the 50-m mark form the start position. At the same time, 3D coordinates of 47 reflective markers on a body were recorded with a motion analysis system (Vicon, Oxford UK.) using 20 cameras (MX-T20), operating at 250Hz. The fastest trial of each subject was selected for detailed analysis. Coordinates of the markers were smoothed using a fourth-order Butterworth low-pass-digital-filter at cut-off frequencies based on the residual method of Wells and Winter (1980). The cut-off frequencies ranged from 7.5Hz to 15.0Hz.
The lower trunk angle in the horizontal plane was defined as shown in Figure 1. Body segment masses, center of mass of body segment and whole body, and moments of inertia of body segments were estimated with the body segment parameters of Japanese athletes (Ae, 1996). Joint torque and force of the right and left hip, comprising the lower trunk and respective thighs, and the torso joint that divides torso into lower trunk and upper trunk were calculated using an inverse dynamics. The moments of joint force acting on the lower trunk were calculated by the joint force and the position vectors form the lower trunk center of gravity to the both hip joint and torso joint. The joint torque and moment of joint force were normalized by with the subject's body mass. The right hip (support-side) joint torque was

projected to the right hip joint coordinate system which was defined as shown in Figure 2. The time series data of the all subjects were normalized to the duration of right support phase (0-100%). The Pearson's product-moment correlations coefficients were calculated to investigate the relationship between various variables and the running velocity. Significance level was set at $P = 0.05$.

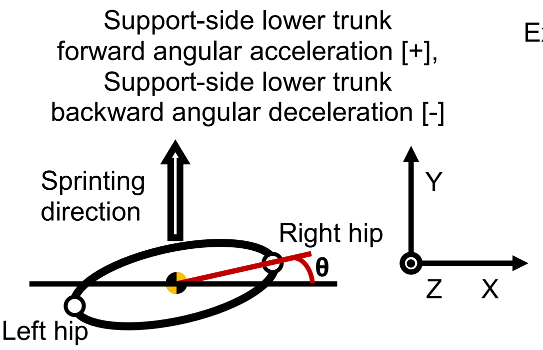


Figure 1: Definition of the lower trunk angle in the horizontal plane

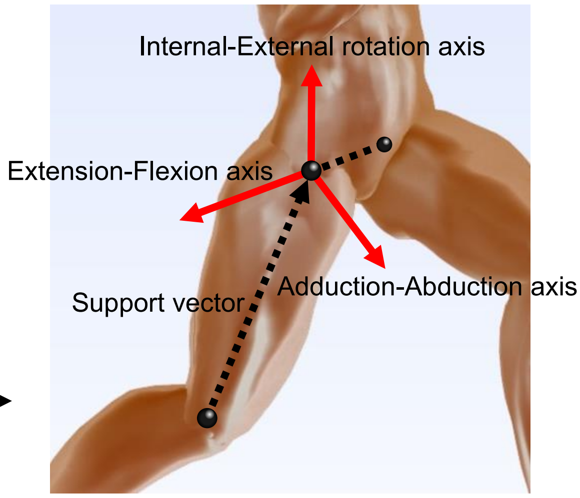


Figure 2: Definition of the right hip joint coordinate system

RESULTS: Running velocity was 9.24 ± 0.33 m/s. Figure 3 shows an averaged pattern for the participants of the lower trunk angular acceleration in the horizontal plane during the support phase. As shown in Figure 3, the backward angular acceleration of the support-side lower trunk was observed during terminal support phase (80-100%), and from 85% to 96% of the support phase, there was a marginally significant negative correlation between running velocity and backward angular acceleration of the support-side lower trunk. Figure 4 shows the relationship between running velocity and peak backward angular acceleration of the support-side lower trunk in the horizontal plane during the terminal support (80-100%). This relationship also showed a marginally significant negative correlation.

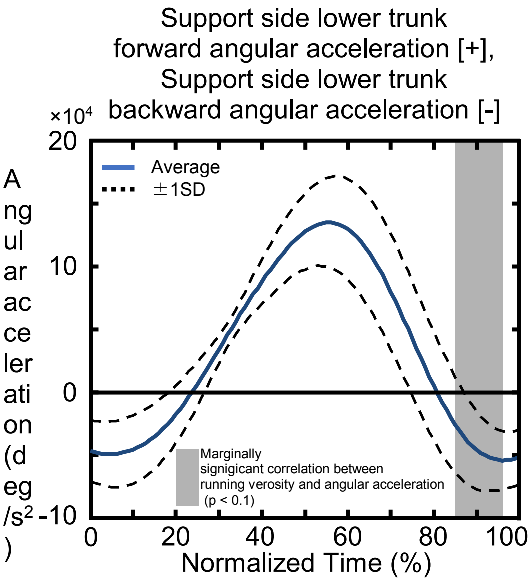


Figure 3: Averaged pattern of the lower trunk angular acceleration in the horizontal plane during the support phase.

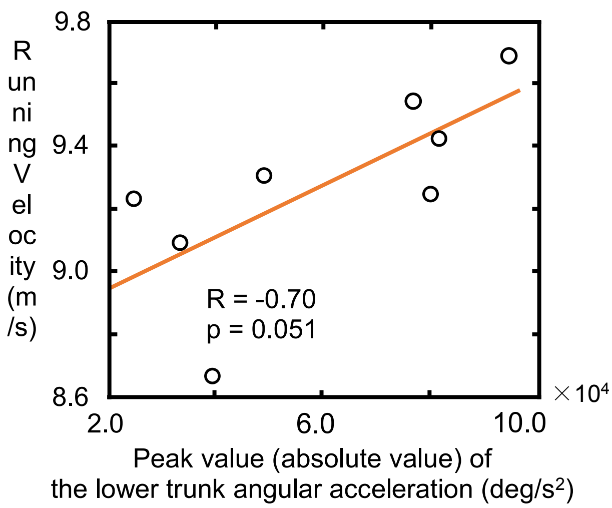


Figure 4: Relationship between running velocity and the support-side lower trunk backward angular acceleration in the horizontal plane in terminal support phase.

Figure 5 shows the averaged pattern of Z-axis (global coordinate system) components of torques (A) at the both hips and torso joints, and the moments of joint forces (B) at these joints acting on lower trunk. During the terminal support, the components of the torso and right hip joint torques were positive. On the other hand, the components of the left hip joint torque and the moment by the both hip joint forces were negative. Figure 6 illustrates the averaged pattern of Z-axis (global coordinate system) components of the right hip joint torques produced in respective three planes of hip joint coordinate system: flexion-extension, adduction-abduction, internal-external rotation. As shown in Figure 6, the right hip joint torque around adduction-abduction axis was positive value during terminal phase (80-100%). Figure 7 shows the averaged pattern of the right hip joint torque around the forementioned three axes. The sprinters exerted hip adduction torque during terminal phase (80-100%).

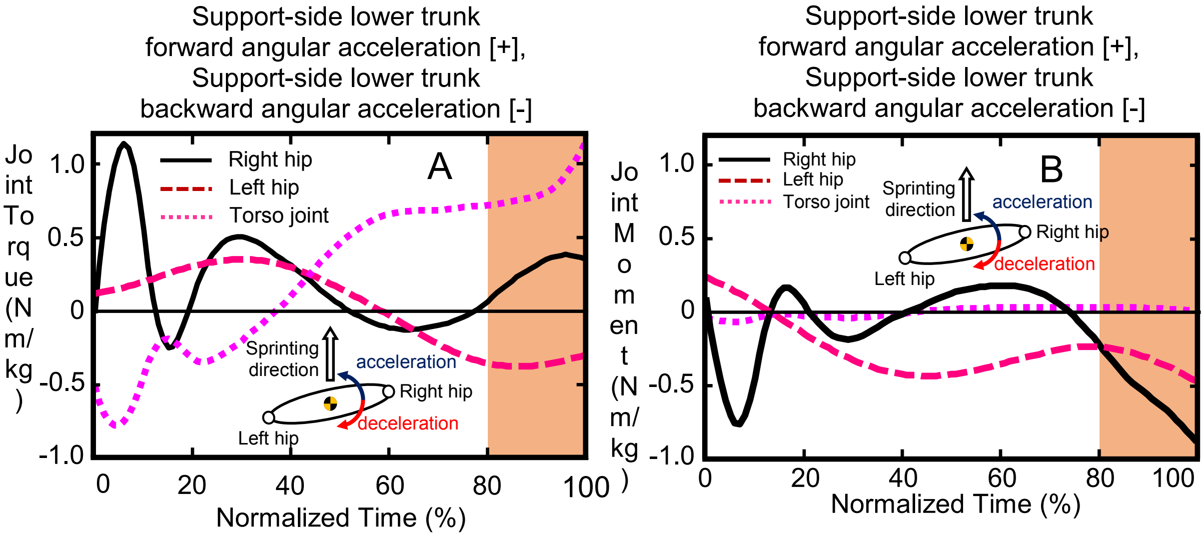
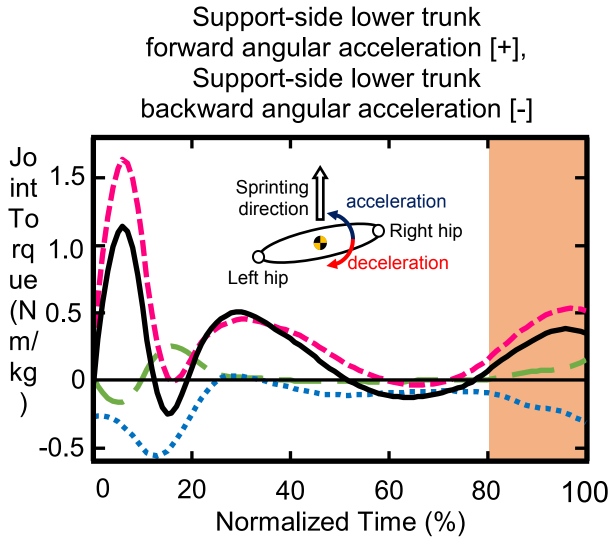
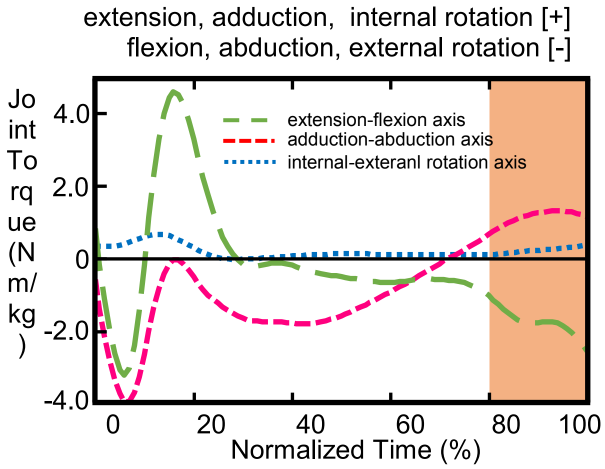


Figure 5: Averaged pattern of joint torque (A) and moment by joint force (B) acting on lower trunk around Z-axis (global coordinate system) during support phase





DISCUSSION: This study aimed to demonstrate the influence of pelvic rotation on sprinting ability and kinetic source of the pelvic rotation.
Base on the results of that there was a marginally significant negative correlation between running velocity and the angular acceleration of the support-side lower trunk in the horizontal plane during the terminal period (80-100%, Figures 3 and 4), It was revealed that small backward angular acceleration of the support-side lower trunk is important. Although this is the first study investigating the relationship of sprinting performance and pelvis rotation, the

result are in line with a previously speculated concept by Ae (2001). From these results, there might be a possibility of improvement in sprint ability by diminishing the deceleration of the lower trunk rotation in the horizontal plane. Accordingly, we focused on the joint torques and the moment of joint force acting on the lower trunk during terminal support phase (80-100%).

The torso and right hip joint torques acting on the lower trunk increased the angular acceleration of lower trunk in the horizontal plane during the terminal support (80-100%, Figure 4). Therefore, large torso and right hip joint torques might be necessary for a high sprinting speed through accomplishing lower trunk rotation. Although the right hip joint torque was smaller than that by the torso joint, the purpose of this study was to investigate the kinetic source about the supporting leg of the pelvis rotation. Accordingly, to consider it, we focused on Z-axis (global coordinate system) component of vectors of the right hip joint torque around three anatomical axes (extension-flexion axis, abduction-adduction axis, internal-external rotation axis). As a result, the torque of abduction-adduction axis had a large influence (80-100%, Figure 6). Sprinters exerted the adduction torque during terminal period (80-100%, Figure 6). From those results, it might be necessary for diminishing deceleration of the lower trunk angular acceleration to exert the large hip joint adduction torque of support leg during the terminal phase (80-100%, Figure 7).

CONCLUSIONS: The important results of this study are as follows: (1) There was a marginally significant negative correlation between running velocity and peak value of the backward angular acceleration of the support-side lower trunk the terminal support phase period. (2) It is necessary for diminishing the backward angular acceleration to exert the larger hip adductor torque of support leg during the terminal phase.

These findings might be useful to improve maximal running velocity.

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