Kinetic Change in The Lower Limb Joints of Distance Runners with Fatigue

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Introduction

Although the changes in kinematics of distance runners with fatigue have been investigated (Elliot and Ackland, 1981; Williams et al., 1991), there is little information on kinetic changes of distance runners. Sprague and Mann (1983) studied the kinetic change in 400 m sprinting and found more significant changes in the support phase rather than the non-support phase, but they didn’t measure the ground reaction forces in the fatigue condition with a force platform. The knowledge on the kinetic change of lower limb joints due to fatigue will give us useful suggestions for the maintenance of the running velocity and the prevention of joint injury in distance running. The purpose of this study was to investigate changes in the kinetics of the lower limb joints, especially in the support phase of distance runners with fatigue.

Methods

Fifteen male competitive distance runners, whose 5000 m personal record ranged from 13 min 52 s to 16 min 39 s, ran 4000 m in even pace which was decided from the 5000 m best record of each subject. Ground reaction forces (GRF) and motion data of all the lap were collected with two force platforms (1.2*0.4 m, 500 Hz) mounted in the running track and a high-speed VTR camera (250 Hz). LED signal was used to synchronize the GRF data with the VTR data. Two dimensional coordinates of the body landmarks were obtained by digitizing VTR images of 1 to 3, 4 to 6, 7 to 9 laps defined as the initial, middle and final stages, respectively. Mass center and moment of inertia of the segments were estimated with the body segment inertia parameters by Ae et al. (1992). Joint torque (JT) of the lower limb joints was calculated by an inverse dynamics approach. Joint torque power (JTP) was calculated by the product of JT and joint angular velocity.

Results & Discussion

Time of the 4000 m run was 12 min. 19 s±28 s. Running velocities at the initial, middle and final stages were 5.78±0.29, 5.63±0.29, 5.40±0.29 m/s, step lengths were 1.75±0.09, 1.73±0.08, 1.70±0.06 m, and step frequencies were 3.32±0.15, 3.25±0.15, 3.17±0.16 Hz, respectively. There were significant decreases in running velocity and step frequency. The support time, especially the time of the first half significantly increased, but the non-support time didn’t change. There was no remarkable change in the magnitude of GRF.

Figure 1 showed the joint torque (JT) of the lower limb joints in the initial and final stages for typical two subjects. Subj. A kept up his running velocity to the final stage and recorded the best time of all the subjects (11 min. 22 s), and subj. B decreased his running velocity largely and his time was 12 min. 32 s. In the initial stage, the hip, knee and ankle JT showed the positive (extension) through the most of the support phase. For all the subjects, there was a large peak in the hip JT and the first peak in the knee JT just after the foot strike. The peak of the hip JT significantly increased at the final stage, although the changes in
the JT with fatigue varied subject by subject. Subj. A showed the increase in the peak hip and ankle JT and the decrease in the first peak of the knee JT just after the foot strike at the final stage. Subj. B increased his peak torque of the ankle and hip joints as well as subj. A. However, the increase in his peak hip JT remarkable and about 200% of that in the initial stage. In addition, the hip extension torque after the first peak decreased for subj. B in the final stage while that of subj. A increased, compared with the initial stage. Sprague and Mann (1983) pointed out that the fatigued poorer sprinter generated larger hip and knee JT in the initial portion of support phase. The results indicate that the similar changes observed in the sprint running may occur in the distance runner with fatigue.

Figure 2 shows GRF vector just after the foot strike in the initial and final stages of subj. A and B. The direction of GRF vector for both subjects in the final stage passed farther from the hip joint and nearer to the knee joint than the initial stage. This is due to the decrease in the initial peak of negative horizontal GRF in the final stage. The magnitude of GRF of subj. A decreased at the final stage, but that of subj. B increased. These results indicate that the increase in the peak of hip JT for subj. A was resulted from the change in the direction of GRF rather than the magnitude.

Figure 3 shows the joint torque powers in the initial and final stages for subj. A and B. Both subjects increased both negative and positive JTP of the ankle in the final stage. This indicate that the runners could still generate...
larger power in fatigued condition than non-fatigued, and that the ankle would not be a limiting segment. Although they increase the peak JT of the hip after the foot strike in the final stage, no increase in the peak JTP of the hip was found in subj. A while subj. B showed the increase in the peak hip JTP. However, subj. A increased the hip JTP during the mid-support portion (30~70 % time) which coincided with the hip JT. These results indicated that the large peak JT of the hip just after the foot strike may generated to resist the large moment of GRF about the hip joint and the second bout of the hip JTP may be used to pull and accelerate the body. However, subj. B could not generate the hip power enough to keep running velocity. These results suggest that the increase in the hip JT may be important in sustaining the moment necessary to support the body just after the foot strike and in adapting to fatigued condition to maintain the running velocity.

References