

## CHANGES IN THE RUNNING MOTION WITH FATIGUE DURING MIDDLE-DISTANCE RUNNING

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The purpose of this study was to investigate the changes in the running motion with fatigue during middle-distance running and get the knowledge about how to maintain the running velocity under fatigued condition by comparing the running motion with fatigue to it with no fatigue. The step length at the fatigued was shorter than the non-fatigued, on the other hand the step frequency was larger than the non-fatigued. The peak ankle joint plantar flexion torque and positive torque power of the support leg at the fatigued were smaller than the non-fatigued, as well as the peak and averaged vertical GRFs. The hip joint torque and power of the recovery leg at the fatigued were significantly larger than the non-fatigued. It is appropriate for maintaining the running velocity to move the recovery leg quickly and increase the step frequency under fatigued condition.

**KEY WORDS:** middle-distance running, fatigue, ground reaction force, joint torque

**INTRODUCTION:** In the 800m middle-distance running, the running velocity reaches the peak in the initial stage of the race, and gradually decreases toward the finish. This pacing strategy is called a positive pacing strategy (Abbis & Laursen, 2008). In the final stage of the race, the running velocity decrease due to the effects of fatigue. So it is important for improving the performance to maintain the running velocity in the final stage of the race against accumulation of fatigue. Therefore it will be useful to investigate the changes in the running motion with fatigue and get the knowledge about how to maintain the running velocity under fatigued condition. Most of the previous studies tried to investigate the changes in the running motion with fatigue by comparing the running motion in the initial and final stage of the race (Chapman, 1982; Sprague & Mann, 1983). But it is difficult to identify the changes in the running motion with fatigue by comparing the initial and final stage because the changes from the initial to final stage of the race can be influenced not only fatigue but also the running velocity. Williams et al. (1991) tried to investigate the changes in the running motion with fatigue by comparing the running motion in the final stage of the distance race to the running motion at the same running velocity with no fatigue. The purpose of this study was to investigate the changes in the running motion with fatigue during middle-distance running and get the knowledge about how to maintain the running velocity under fatigued condition by comparing the running motion with fatigue to it at the same running velocity with no fatigue.

**METHODS: Data Collection:** Six male middle-distance runners (height,  $1.77 \pm 0.07$  m; body mass,  $64.2 \pm 7.1$  kg; 800 m personal best record,  $1 \text{ min } 48.77 \pm 1.33$  sec) participated in this study. The subjects were asked to perform two running trials, i.e. an all-out 600m run and an 80m run. The first trial was an all-out 600 m run with a positive pacing strategy in that the running speed reached the peak during the initial stage of the 600 m run and gradually decreased toward the end of the run. The subject's running motion at the 550m mark of the 600m run was videotaped with a high speed digital movie camera (Exilim EX-F1, Casio, Japan) operating at 300 Hz from the lateral side of the subjects for at least one full running cycle, and the ground reaction forces (GRF) were recorded at a sampling rate of 500 Hz with three force platforms (Kistler Instrument AG) embedded in the running track. An LED signal trigger was used to synchronize the high-speed movie data with the GRF data, with pulse signals input to a personal computer along the GRF data. The second trial, 80m run with no

fatigue at the same velocity as the 550 m mark of 600 m run. The subjects started at 50m away from the force platforms so that they would enter the videotaping area with a constant velocity using their natural running motion. The subject's running motion and the GRF were recorded with the same procedures as that for the all-out 600 m run.

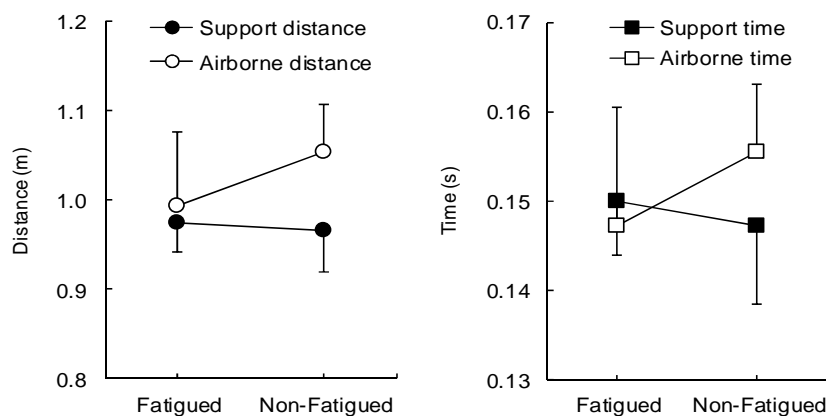
**Data Processing:** Twenty-three body landmarks were digitized at 150 Hz, and real-scale coordinate data were reconstructed. The coordinate data were smoothed by a Butterworth digital filter at cut-off frequencies ranging from 6.0 to 7.5 Hz, as determined by a residual method. The linear and angular kinematics of the joints and segments were calculated from the smoothed coordinate data, and the location of the center of mass and the inertial properties of each segment were estimated from body segment parameters typical of Japanese athletes (Ae, 1996). The step time was defined as the average time of two steps and step frequency was defined as the reciprocal of the step time. The step length was defined as the horizontal distance that the center of gravity travelled during one step. The running speed was calculated as the product of the step frequency and the step length. The running motion itself was divided into a support phase and an airborne phase. The joint torques at the ankle, knee, and hip joints were calculated using an inverse dynamics method. The joint torque power of the leg joints was calculated as the product of the joint torque and the joint angular velocity. The GRF, joint torque, and joint torque power were divided by the runner's mass. A dependent t-test was used to test for significant differences in the variables between the 550m mark of the 600m run and 80m run with no fatigue. The level of significance was set at 5%.

**RESULTS:** Table 1 shows the running velocity, step length and step frequency at the 550m mark of 600 m run (i.e. fatigued) and 80m run with no fatigue (i.e. non-fatigued). The step length at the fatigued was shorter than the non-fatigued, on the other hand the step frequency at the fatigued was larger than the non-fatigued.

**Table 1 The running velocity, step length and step time at the fatigued and the non-fatigued.**

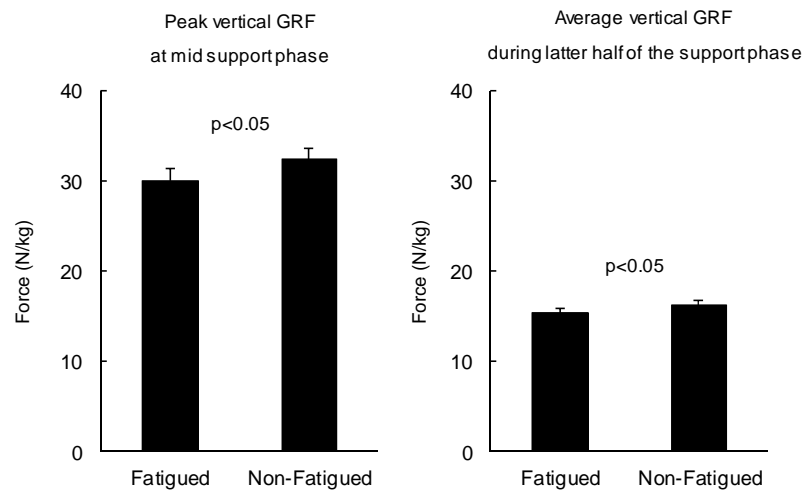
Variables		Fatigued	Non-Fatigued
Running velocity	(m/s)	6.63 ± 0.19	6.67 ± 0.14
Step length	(m)	1.97 ± 0.09	2.02 ± 0.05
Step frequency	(steps/s)	3.37 ± 0.18	3.31 ± 0.11

Figure 1 shows the distance and time during the support and airborne phases. The airborne distance and time at the fatigued were shorter than the non-fatigued, on the other hand the support distance and time at the fatigued were almost the same at the non-fatigued.

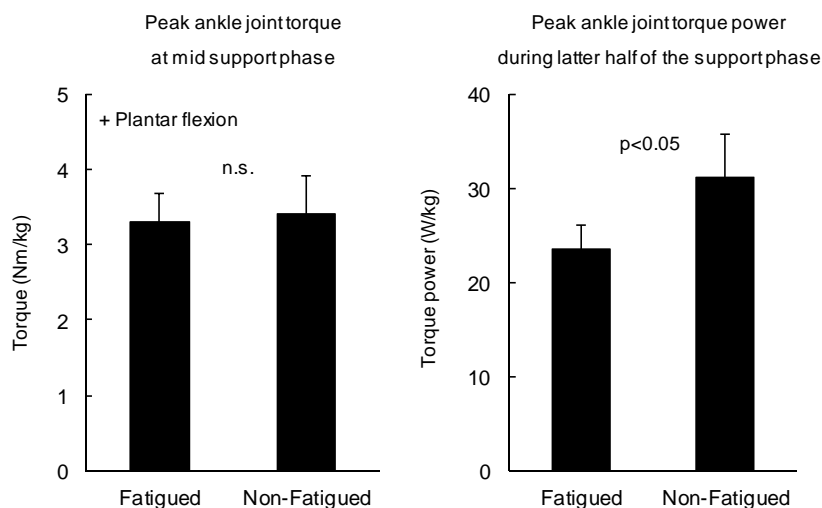


**Figure 1 The distance and time during the support and airborne phase at the fatigued and the non-fatigued.**

Figure 2 shows the peak vertical GRF at the mid support phase and the average vertical GRF during the latter half of the support phase. The peak vertical GRF and the average vertical GRF at the fatigued were significantly smaller than the non-fatigued ( $p < 0.05$ ). Figure 3 shows the peak ankle joint torque at the mid support phase and the peak ankle joint torque power during the latter half of the support phase. The peak ankle joint plantar flexion torque at the fatigued was smaller than the non-fatigued, and the peak ankle joint positive torque power at fatigued was significantly smaller than the non-fatigued ( $p < 0.05$ ). Figure 4 shows the average hip joint torque from the toe off to the end of the follow through, and the average hip joint torque power from the end of the forward swing to the foot contact. The average hip joint torque and torque power at the fatigued were significantly larger than non-fatigued.

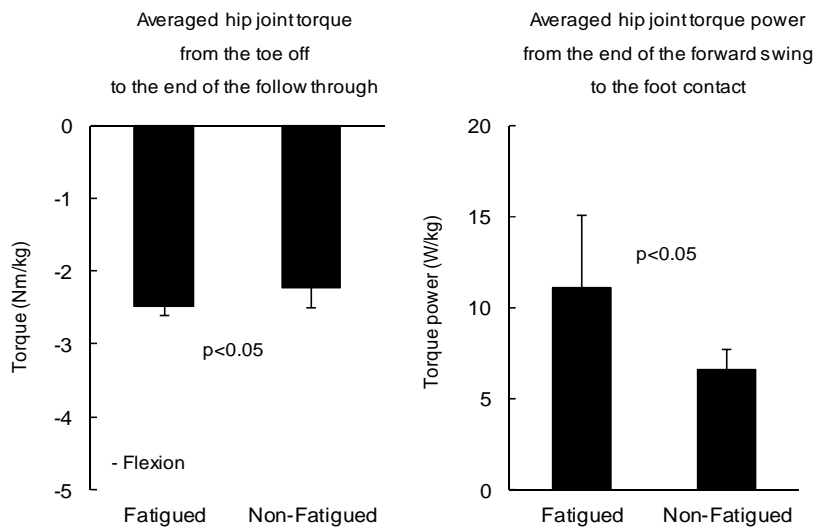


**Figure 2** The peak and averaged vertical GRF at the fatigued and the non-fatigued.



**Figure 3** The peak ankle joint torque and power at the fatigued and the non-fatigued.

**DISCUSSION:** The step length at the fatigued was shorter than the non-fatigued, on the other hand the step frequency was larger than the non-fatigue. The decrease in the step length results from decrease in the airborne distance, and the increase in the step frequency results from decrease in the airborne time.



**Figure 4** The averaged hip joint torque and power at the fatigued and the non-fatigued.

The joint torque of the support leg plays an important role in supporting and driving runners forward because the support leg directly exerts a force to the ground and receives the reaction forces from the ground. The peak ankle joint plantar flexion torque and positive torque power at the fatigued were smaller than the non-fatigued, as well as the peak and averaged vertical GRFs. The results indicate that the ankle joint plantar flexion torque and power decreased due to the fatigue of the ankle joint plantar flexors, furthermore the subjects were unable to exert a large force to the ground during the support phase, which was likely to cause the shorter airborne distance and step length. The hip joint flexion torque from the toe off to the end of the follow through, and the hip joint positive torque power from the end of the forward swing to the foot contact at the fatigued were significantly larger than the non-fatigued. The hip joint flexion torque relate to switch the motion of the recovery leg from backward to forward, and the hip joint positive torque power before the foot contact relate to quickly moving of the recovery leg to the foot contact. Therefore this quickly moving of the recovery leg made it possible to shorten the airborne time, and to increase the step frequency under fatigued.

**CONCLUSION:** Under fatigued condition, the step length and the airborne distance decreased because the subjects were unable to exert a large GRF due to the fatigue of the ankle plantar flexors. Consequently, moving the recovery leg quickly and shortening the airborne time are appropriate for maintaining the running velocity than extending the step length by thrusting against the ground with the support leg.

#### REFERENCES:

- Abbis, C. R. & Laursen, P. B. (2008). Describing and understanding pacing strategies during athletic competition. *Sports Medicine.*, 38, 239-252.
- Ae, M. et al (1983) The inertia parameters of the body for Japanese children and athletes. *Japan Journal of Sports Sciences.*, 15, 155-162.
- Chapman, A. E. (1982). Hierarchy of changes induced by fatigue in sprinting. *Canadian Journal of Applied Sport Sciences.*, 7, 116-122.
- Sprague, P. & Mann, R. V. (1983). The effects of muscular fatigue on the kinetics of sprint running. *Research Quarterly for Exercise and Sport*, 54, 60-66.
- Williams, K. R., Snow, R. & Agruss, C. (1991). Changes in distance running kinematics with fatigue. *International Journal of Sport Biomechanics.*, 7, 138-162.