RUNNING ECONOMY AND MECHANICS IN TRIATHLETES vs. RUNNERS

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The purpose of this study was to compare running economy (RE) and distance running mechanics between triathletes and runners to examine an energy-economical running form. Physiological measures were obtained, including maximal and submaximal O_2 consumptions and blood lactate concentration. Biomechanical measures for running at several speeds (210-290 m/min) were obtained for the triathletes and runners. The RE in the triathletes was higher than that in the runners at most speeds (210-270 m/min). The maximal angle of shoulder extension was associated with RE and greater in the triathletes at lower speeds (210-250 m/min). The training and running form of triathletes are potentially useful for improving the RE in runners.

KEY WORDS: running economy, kinematics, triathlon

INTRODUCTION: The determinants of successful distance running performance include maximal aerobic power ($\dot{V}O_2max$), lactate threshold (LT), and running economy (RE). RE is defined as the energy demand for a given velocity of submaximal running (Cavanagh et al., 1985). Factors that influence RE are anthropometric, physiological, biomechanical, environmental, and psychological elements (Anderson, 1996; Morgan et al., 1989; Saunders et al., 2004). The contribution of biomechanical variables to RE is more than 50% (Williams and Cavanagh 1987).

Although many studies have been conducted on RE and running kinematics, little is known about the running kinematics at race pace or high speeds. As running kinematics changes with the change in running speed (Kyrolainen et al., 2001; Williams, 1985), running kinematics should be examined at several running speeds. Although studies have been conducted with track and field athletes as subjects, few studies have been conducted with triathletes.

In the start condition of triathlon running, energy is consumed by swimming and cycling. Thus, in triathlon running, energy expenditure must be minimized. Triathletes are accustomed to running after cycling training, or swimming and cycling training. Thus, triathletes are thought to have specific running techniques. We considered that new knowledge in running kinematics can be obtained by comparing RE between triathletes and runners.

The purpose of this study was to compare RE and distance running mechanics between triathletes and runners in order to determine an energy-economical running form.

METHODS: The subjects included 7 male university triathletes (age, 21.3 ± 1.3 years; height, 172.6 ± 7.4 cm; weight, 60.2 ± 4.4 kg; 10,000m personal best record [min:s], 36:42 ± 0:37) and 6 male university long-distance runners (age, 20.2 ± 1.0 years; height, 165.6 ± 4.7 cm; weight, 54.8 ± 3.9 kg; 10,000m personal best record [min:s], 35:16 ± 0:20). The subjects were explained the purpose of the study and agreed to participate by providing informed consent. The study was approved by the Research Ethics Committee at the Hiroshima University.

The subjects performed two tests. After familiarization with running on a treadmill, the subjects initially performed a running $\dot{V}O_2max$ test. The first 3 min of running at the 10,000-m race pace was performed at a 0% grade slope; thereafter, the treadmill elevation was increased by 2% every 2 min until exhaustion. After completion of the $\dot{V}O_2max$ test, the subjects performed a running RE test on another day. RE test was performed at a 0% grade slope. The subjects performed five 4-min exercises at 210, 230, 250, 270, and 290 m/min, with a 3-min recovery time between each exercise. The measurement at the final 1 min of each running exercise was recorded for the analysis. At the recovery period, blood samples for blood lactate (BLa) analysis were drawn from a finger (Lactate Pro, Arkray Inc., Japan).

Each subject was filmed with a high-speed camera (EXILIM EX-SC100, Casio, Japan) at a sampling rate of 240 fps. Measurements in last 30 s of each exercise were recorded.

RE was evaluated by running cost (RC), which were measured at each speed. To calculate the energy expenditure, an energy equivalent of 20.202 kJ/O_2L was applied when the respiratory exchange ratio (R) was 0.82. A change of ±0.01 in R caused the respective ±0.05kJ/O_2L changes in energy expenditure (McArdle et al., 2010). Finally, RC was computed by multiplying the oxygen consumption to the energy equivalent per unit distance and body mass (kcal/kg/km).

Ten reflective markers were placed on the right side body (tiptoe, heel, ankle, knee, hip, shoulder, elbow, wrist, and tragus) and vertex. Coordination of the markers was calculated by using a two-dimensional motion analysis system (ToMoCo-VM Toso System Inc., Japan) for each joint angle and angular velocity (ankle, knee, hip, shoulder, and elbow). The analysis ranged from the initial right-foot contact to the next right-foot contact for three running cycles.

Statistical analysis were performed for the 5 exercise conditions by using the Mann-Whitney or non paired *t*-test, with a p value of <0.05 considered as statistically significant. Considering the multiplicity of the test, we adjusted the significance level by using Bonferroni correction. A multiple regression analysis was used to evaluate the overall relationship between running kinematics and RE.

RESULTS: Figure 1 shows the $\dot{V}O_2max$ in the two groups, which did not significantly differ between the groups ($p = 0.08$). Figure 2 shows the BLa levels in the two groups, which also did not significantly differ between the groups. Figure 3 shows the RC in the two groups. The RC at 210, 230, 250, and 270 m/min were higher in the triathletes than in the runners ($p < 0.05$). Figure 4 shows the maximal angle of shoulder extension for the two groups. The maximal angle of shoulder extension at 210, 230, and 250 m/min were larger in the triathletes than in the runners ($p < 0.05$). No significant differences were found between the two groups in the other joint kinematics. In the multiple regression analysis, the maximal angle of shoulder extension was selected at 210, 230, and 250 m/min.

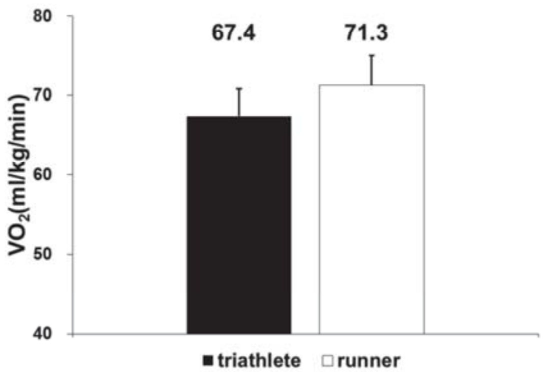

Figure 1 $\dot{V}O_2max$ in the triathletes and runners.

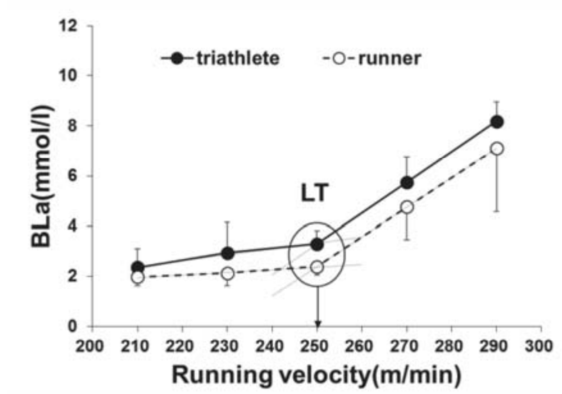

Figure 2 BLa of the five running velocities.

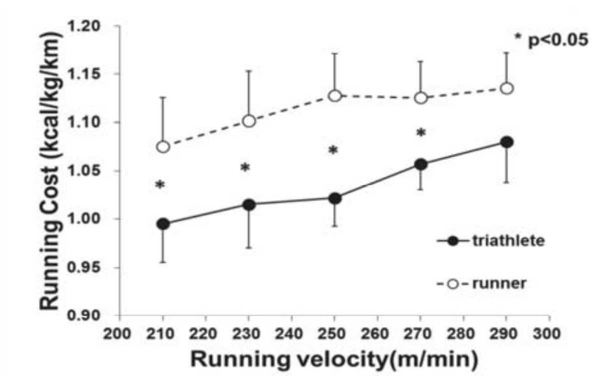

Figure 3 Running Cost of the five running velocities.

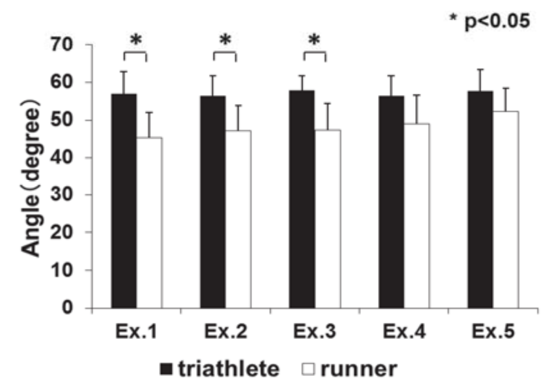

Figure 4 Maximal angle of shoulder extension.

DISCUSSION: The determinants of successful distance running performance include $\dot{V}O_2max$, LT, and RE (Joyner, 1991). In this study, the $\dot{V}O_2max$ of the runners tended to be high. The running velocity was 250 m/min when the accumulation of BLa concentration was started in the triathletes and runners. The LT in the two groups may be estimated to be equal. The RC in the triathletes was low (i.e., high RE). Based on the results of $\dot{V}O_2max$, LT, and RC, we proved that specifically RE was improved in the triathletes.

Shoulder extension was associated with RE, and the maximal angle of shoulder extension at 210, 230, and 250 m/min was larger in the triathletes than in the runners; that is, the range of backward swing in the triathletes was wider. The role of the arms in running is to cancel the vertical angular momentum of the legs in horizontal plane (Hinrichs, 1987). The angular momentum of the arms and trunk cancels the angular momentum of the legs. If the arm range of motion is increased, the angular momentum of the arms is also increased but the angular momentum of the trunk is decreased. Therefore, the range of the center of body mass in the transverse direction is thought to decrease. This could result in a reduction in energy cost. However, whether this kinematics in running can be applied to runners is unclear because the physical characteristics of runners differ from those of triathletes. Therefore, it is essential to investigate the relationship between arm swing and RE in detail.

CONCLUSION: In this study, RE was compared between triathletes and long-distance runners. We demonstrated that RE was higher in the triathletes than in the runners, although the two groups had similar running performance. The angle of shoulder extension could be a key kinematical factors related to energy-economical running. The training and running form of triathletes are potentially useful for improving the RE in runners.

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