Effects of Technical Training on Mechanical Energy Flows between Body Segments in Sprint Running

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Introduction

In sprint running, as well as the generation of a great amount of mechanical energy, running techniques, i.e. effective use of the mechanical energy are required to achieve high running velocity. Although sprinters aim to improve their running technique by various technical trainings, few investigations have be done about the effects of technical training on biomechanical parameters of sprint motion. The purpose of this study was to investigate effects of the technical training on the running motion and mechanical energy flows in sprint running.

Methods

Eleven sprinters of club team level, 4 females and 7 males were participated in the technical training session for three weeks (3days a week), which designed to improve the running motion and maximal running velocity. Examples of the instruction provided in the technical training were “bringing the free leg forward quickly”, “not bending the knee of the free leg too much”, “not raising the thigh too high”, “catching the ground vigorously” and so on. Running motion of the subjects was videotaped with a high-speed video camera (250Hz) and ground reaction forces were measured with force platforms (500Hz) in the pre- and post-training. To evaluate the effects of the technical training from a viewpoint of energy flows, $W_w$, the mechanical work of the whole body which assumed no energy transfer between body segments (Pierrynowski, 1980), $W_{joint}$, the mechanical work done by the joint torques, $T_b$, a transferred energy between the body segments were calculated by the following equations.

$$W_w = \sum_{j=1}^{s} \sum_{i=1}^{n} |\Delta E_{ij}|$$

$$W_k = \int_{t_s}^{t_e} |T_k \cdot \omega_k| \, dt$$

$$W_{joint} = \sum_{k=1}^{m} W_k$$

$$T_b = W_w - W_{joint}$$

Where, $\Delta E_{ij}$ is the change in mechanical energy of the i th segment in the j th time interval, $T_k$ and $\omega_k$ are the torque and the angular velocity of the k th joint, s, n, and m are the number of time intervals, segments and joints, respectively. $t_s$ and $t_e$ are the times of start and end of running cycle time. Joint force power ($JFP_k$)
and segment torque power (STP<sub>k</sub>) were calculated by a model showed in figure 1, where, F is the joint force, V is the joint velocity, S<sub>ω</sub> is the segment angular velocity. Positive JFP<sub>k</sub> means the power transferred from the neighbor segment via the k th joint, and positive STP<sub>i/k</sub> means the power flowed into the i th segment by the torque of the k th joint. The rate of mechanical energy change of each body segment is a summation of JFP and STP. These powers were averaged in the movement phase, defined in figure 2, where, R and L mean right and left foot, on and off mean the instant of touch down and takeoff, mid means the instant of that center of gravity passed over the metatarsal joint.

Results and Discussion
Ten out of eleven subjects increased their running velocity after the technical training of three weeks (Pre: 8.26 ± 0.94 m/s; Post: 8.43 ± 0.95 m/s; p<0.01). The result means that the training program used in this study was appropriate to the subjects in the level of club team. Figure 3 shows the relationships of change in running velocity (ΔV) to mean output power (m-power= W<sub>joint</sub> / cycle time) and mean transferred power (t-power = T<sub>b</sub> / cycle time). Although there was a significant correlation between ΔV and Δm-power, there was no correlation between ΔV and Δt-power. This result means that the increase in the total output power was the major factor to increase the running velocity. Figure 4 shows the correlation coefficients between changes in joint power and running velocity. There were two notable power flows, which showed high correlation with the increase in the running velocity. The first one was observed in the support leg at the second half of the support phase (R2). Increases of STP<sub>foot/ankle</sub>, JFP<sub>ankle</sub> and JFP<sub>knee</sub> in this phase showed significant correlations to the increase in running velocity. This suggests that it is important for running velocity to increase the energy flowed to the foot by the planter flexors and to
transfer it from the foot to the thigh via the shank. The second one was observed in the recovery leg during swing-back phase (N2). Increases of STP<sub>shank/knee</sub> and JFP<sub>knee</sub> in this phase showed significant correlations with running velocity. This suggests that it is important to increase the power flowed into the shank by knee flexors and transfer it from the shank to the thigh. One of the effects of technical training on sprint running was the acquisition of running technique which could increase the energy flow to the distal segments by the joint torque and energy transferred from the distal to the proximal segments.

Reference

![Figure 3](image1.png)  
**Figure 3**: Relationships of change in running velocity to mean output power and the transferred power during one cycle of running.

![Figure 4](image2.png)  
**Figure 4**: Power which showed high correlation with the increase in running velocity. The value in the parenthesis is correlation coefficient.