MECHANICAL ENERGY CHANGE OF WORLD ELITE RACE WALKERS DURING 20KM RACE

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INTRODUCTION

Race walking is an endurance event of the athletics whose distance ranges from 3,000m to 50,000m. Effective use of mechanical energy generated is necessary to maintain high walking speed over the race distance. Williams and Cavanagh (1987) suggested in distance running that the mechanical energy flow between the body segments might enhance the effective use of physiological energy. Hoga et al. (in press) found that the amount of the mechanical energy flow in the recovery leg for the elite race walkers was significantly related to the walking speed in the first half of official 20km races. However, there is no information how the walking speed and mechanical energy change with the increase in the distance of race. The purpose of this study was to investigate the change in the mechanical energy of the world elite race walkers with the progress of the men’s 20km official race.

METHODS

Eight male race walkers including a winner of the men’s 20km of the world race walking cup in 1995, participated in the men’s 20km walking race of the East Asian Games in 2001, which was held in a 2.8km-course. Seven walkers who have finished without disqualification in that race (Age: 28.6 ± 5.4 yrs, Height: 1.77 ± 0.07m, Weight: 63.7 ± 3.9kg, Race record: 1 hr 25 min 28 sec ± 1 min 39 sec) were videotaped at every lap with two VTR cameras (60Hz). VTR images of the race walkers at 8 and 17 km marks were digitized over one walking cycle.

Three-dimensional coordinates of the body segment endpoints were obtained by using a DLT technique. A 15-link-segment model was used to calculate linear and angular kinematics and kinetics of the joints and the body segments, and the mechanical energy of the body segments. The location of the centers of mass, masses and the moments of inertia of the body segments were estimated from the body segment parameters after the methods of Ae et al. (1992). Joint force power was computed as an inner product of the joint force and the joint velocity of the recovery leg, and joint torque power was computed as an inner product of the joint torque and the joint angular velocity.

The mechanical work of the whole body which assumes the energy exchange within each segment and the mechanical energy transfer between the body segments was calculated as follows (WWb, Pierrynowski et al., 1980):

\[ W_{WB} = \sum_{j=1}^{N} \sum_{i=1}^{S} (\Delta E_{i,j}) \]  

Where \( \Delta E_{i,j} \) is the total mechanical energy change of the ith segment during the jth period of time, N is the number of frames during one stride and S is the number of segments.

The mechanical energy transfer between the segments of the whole body (Tb) was calculated as follows:

\[ T_b = W_{WB} - W_W \]

Mean mechanical powers of the whole body (MW W , MW Wb , MT b ) were obtained by dividing WW , WWb , T b by the step time of each subject.

Pearson’s product moment correlation coefficients for the walking speed to the step length and frequency, and indices for the mechanical work of the whole body were calculated with a level of significance at 5%.

RESULTS

Walking speed (3.88 ± 0.12m/s) was not significantly related to the step length (1.16 ± 0.04m, r=0.69) and the frequency (3.35 ± 0.08Hz, r=0.33) at 8km mark. However, there was significant relationship (r=0.87, p<0.05) between the walking speed (3.88 ± 0.23m/s) and the step frequency (3.39 ± 0.17Hz) at 17km mark. The step length at 17km mark (1.14 ± 0.03m, r=0.51) was not significantly related to the walking speed. The difference in the walking speed between 8 and 17km mark (0.002 ± 0.19m/s) was significantly (r=0.85, p<0.05) related to the difference in the step frequency (0.05 ± 0.12Hz).

Table 1 shows mean MW W , MW Wb , and MT b of all subjects and correlation coefficients to the walking speed at 8 and 17km and for differences between the 8 and 17km marks

<table>
<thead>
<tr>
<th></th>
<th>8 km</th>
<th></th>
<th>17km</th>
<th></th>
<th>Difference</th>
</tr>
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<tbody>
<tr>
<td></td>
<td>Mean</td>
<td>SD</td>
<td>r</td>
<td>Mean</td>
<td>SD</td>
</tr>
<tr>
<td>MW W   (W/kg)</td>
<td>36.4</td>
<td>3.0</td>
<td>0.42</td>
<td>34.8</td>
<td>4.6</td>
</tr>
<tr>
<td>MW Wb  (W/kg)</td>
<td>10.2</td>
<td>2.6</td>
<td>-0.45</td>
<td>8.4</td>
<td>1.9</td>
</tr>
<tr>
<td>MT b   (W/kg)</td>
<td>26.2</td>
<td>2.9</td>
<td>0.84*</td>
<td>26.4</td>
<td>4.6</td>
</tr>
</tbody>
</table>

*Correlation relationships with walking speed: *p<0.05, **p<0.01
The MTb was significantly related to the walking speed at 8km (r=0.84, p<0.05) and 17km (r=0.88, p<0.01), and to the difference in the walking speed (r=0.79, p<0.05). There was significant relationship between the walking speed and the MWw at 17km (r=0.79, p<0.05). Although the difference in the MWW between 8 and 17km was not significantly related to the difference in the walking speed, it was positive relationship.

Figure 1 shows the relationships between the differences in the walking speed and the MWW, MWwb, and MTb between 8 and 17km marks. Two subjects increased walking speed in the 17km mark. Although their ∆MWW and ∆MTb were positive, their ∆MWwb were close to zero. Figure 2 shows patterns of mechanical power (ΔE/Δt) of the support and recovery legs during the support phase at 8 and 17km marks for subject A and B, who increased walking speed largely at 17km mark, and subject C, who reduced walking speed largest. The mechanical powers of the recovery leg for three subjects were positive in the beginning of support phase and decreased in the second half of support phase. The negative mechanical powers of the support leg changed to the positive in the middle of support phase and increased during the second half of support phase. The positive mechanical power of the support leg in the middle of support phase for subject A was larger at 17km than at 8km. Subject A increased the negative mechanical power of the recovery leg in the middle of support phase at 17km. The positive mechanical power of the support leg for subject B at 17km was larger than that at 8km in the middle of support phase. However, there was only slight difference in the negative mechanical power of the recovery leg in the middle of support phase for subject B between 8 and 17km. In the final part of support phase, the positive mechanical power of the support leg and the negative mechanical power of the recovery leg for subject C at 17km were smaller than that at 8km.

Figure 3 shows patterns of the joint force power at the recovery hip during support phase of the contra lateral support leg at 8 and 17km marks for subject A, B and C. The negative joint force power at the recovery hip for subject A at 17km was larger than that at 8km in the middle of support phase, when the positive mechanical power of the support leg at 17km was larger than at 8km. The negative joint force power of subject B at 17km was not different from that at 8km, when subject B increased the positive mechanical power of the support leg at 17km. The negative joint force power of subject C at 17km was smaller than that at 8km in the end of support phase, when the positive mechanical power of the support leg and the negative mechanical power of the recovery leg decreased at 17km.

DISCUSSION

Subjects A and B, who obtained larger walking speed at 17km, increased the mechanical energy change of the whole body by the mechanical energy transfer between the body segments because the ∆MWwb of these two subjects were close to zero. Subject C, who decreased the walking speed largest, reduced MWwb and MTb at 17km. However, the ∆MWw may depend more largely on the ∆MTb than the ∆MWwb because of the significant relationship between the ∆speed and the ∆MWwb.

The positive mechanical power of the support leg and the negative mechanical power of the recovery leg increased in the same part of support phase for subject A for 17km mark. Subject C had larger mechanical energy of the support and recovery leg in the same part of support phase at 8km mark. In those phases for each subject, the joint force power at the recovery hip was larger at the mark of the larger speed during the race. These results indicate that the mechanical energy of the support leg largely increased in the phase where the large mechanical energy of the recovery leg transferred from the recovery hip joint. Then, the change of the mechanical energy transfer from the recovery leg to the support leg may relate to the change of the mechanical power of the support and recovery leg for subject A and C. Since the change of the mechanical power of the support and recovery leg was larger than that of the arms and trunk, the difference in the change of the mechanical energy of the whole body between 8 and 17km may depend on the
mechanical energy flow between the recovery and support leg.

Although, the negative mechanical power of the recovery leg and the negative joint force power at the recovery hip at 17km for subject C was larger than those at 8km, the positive mechanical power of the support leg at 17km was larger than that at 8km in the middle of support phase. The increase of the mechanical power of the support leg for subject B at 17km may not depend on the mechanical energy flow from the recovery leg.

REFERENCES


Figure 2: Patterns of mechanical power ($\Delta E/\Delta t$) of the support and recovery legs during the support phase at 8 and 17km marks for subject A and B.