CHANGES IN MECHANICAL POWER AND RUNNING ECONOMY IN DISTANCE RUNNERS

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The purpose of this study was to investigate the relationships between changes in running economy and running mechanics by using a segment kinematics approach. Six male university distance runners performed treadmill running before and after the 4 month period, while oxygen consumption and running motion were also measured. Mechanical power was calculated by a segment kinematics approach, the data for 4 of 6 subjects were analysed. Running economy for 2 of 4 subjects were improved and mechanical power were decreased. Running economy for the other 2 subjects deteriorated but change in mechanical power was different for one subject which decreased while for increasing for another subject. The relationships between changes in running economy and running mechanics varied with the individual runner.

KEY WORDS: mechanical power, running economy,

INTRODUCTION: A number of factors influence running economy, such as physiological factors, environmental factors, training and biomechanical factors. The biomechanical characteristics of economical runners have been reported by some researches (Williams & Cavanagh, 1987; Heise et al., 2011). Storen et al. (2011) found significant correlations between the sum of horizontal and vertical peak ground reaction force and running cost, and they suggested that runners should minimize the vertical oscillation and horizontal braking in each step to improve running economy and running performance. Tartarga et al. (2012) found significant correlations between running economy and biomechanical variables, and concluded that changes in running technique can influence running economy and lead to improved running performance. However, it is not known really if running economy is improved by changing running mechanics. The purpose of this study was to investigate how does it change the running economy with changing running mechanics by using a segment kinematics approach (Pierrynowski et al., 1980; Martin et al., 1992).

METHODS: Six male university distance runners participated in this study. The subjects took part in experimental sessions before and after the 4 month period. They performed multi-stage incremental treadmill running tests, which protocol with speed at an initial stage of 12.6 km/h and in which, speed was increased by 1.2 km/h at each stage. The treadmill incline was fixed at 1 %. The subjects ran for 4 min at constant speeds at each stage with 2 min recovery between each stage until they signalled that they had reached exhaustion. The highest value attained for the final stage was considered as VO_{2peak}. Oxygen consumption data were measured with exhaled gas measurement system (Aero Monitor, AE310-S, Minato, Japan). The subject's running motion during treadmill running test was videotaped with a digital video camera recorder (HDR-CX630X, Sony, Japan) operating at 60 Hz from the lateral side of the subjects. The subject's twenty-three body landmarks during one running cycle (2 steps) were digitized at 60 Hz, and real-scale coordinate data were reconstructed. The coordinate data were smoothed by a Butterworth digital filter at cut-off frequencies ranging from 3.2 to 6.6 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). Mechanical power was calculated by a segment kinematics approach (Pierrynowski et al., 1980; Martin et al., 1992) as follow. Instantaneous total mechanical energy of ($E_{i,j}$) of the i th segment at time j was calculated by the following equation (1):

$$E_{i,j} = m_i g h_{i,j} + \frac{1}{2} m_i V_{i,j}^2 + \frac{1}{2} I_i \omega_{i,j}^2 \quad (1)$$

where, m_i = segment mass; g = acceleration of gravity (9.81 m/s^2); $h_{i,j}$ = height of segment center of mass; $V_{i,j}$ = translational velocity; I_i = the moment of inertia about the segment center of mass; and $\omega_{i,j}$ = the angular velocity for segment. Mechanical work by assuming the transfer of energy both within and between segments, mechanical work (Wwb) was calculated by equation (2) :

$$W_{wb} = \sum_{j=1}^{n-1} \left| \sum_{i=1}^{s} \left(\Delta E_{i,j} \right) \right| \quad (2)$$

Mean power was calculated by dividing the mechanical work by a cycle time.

RESULTS: Table 1 shows height, weight and those change ratios for each subject before and after the 4 month period. Mean change ratio of height was -0.2±0.2 % and it of weight was -0.4±2.6 %. Table 2 shows VO_2 and mechanical power at 15.0 and 16.2 km/h and VO_{2peak} for each subject before and after the 4 month period. VO_2 at 15.0 and 16.2 km/h for subject 1 and 2 increased from before to after, while for subjects 4, 5 and 6 decreased from before to after. Mechanical powers of subject 1 and 2 who's VO_2 increased and subject 4 and 5 who's VO_2 decreased were calculated at after. Mechanical power at 15.0 and 16.2 km/h for subject 1, 2 and 5 decreased from before to after, while subject 4 increased from before to after. Figure 1 shows the relationship between change ratio in VO_2 (ΔVO_2) and it in mechanical power (ΔMechanical power). Both ΔVO_2 and ΔMechanical power for subject 4 and 5 were negative values, and these for subject 2 were positive values.

Table 1
Height and weight before and after the 4 month period.

Subject	Before		After		Change ratio	
	Height	Weight	Height	Weight	Height	Weight
1	177.4	58.8	177.2	59.1	-0.1	0.6
2	168.5	53.0	168.5	51.6	0.0	-2.6
3	166.5	56.8	166.2	55.1	-0.2	-3.0
4	169.0	58.0	168.5	58.5	-0.3	0.9
5	165.5	56.3	164.5	55.3	-0.6	-1.8
6	164.4	53.9	164.5	55.9	0.1	3.7
Mean	168.6	56.1	168.2	55.9	-0.2	-0.4
SD	4.7	2.3	4.7	2.7	0.2	2.6

Heigh units: cm, Weight units: kg, Change ratio units: %

Table 2
VO_2 and mechanical power before and after the 4 month period.

Subject	Before					After				
	VO_2 @15.0km/h	VO_2 @16.2km/h	VO_{2peak}	Mechanical power @15.0km/h	Mechanical power @16.2km/h	VO_2 @15.0km/h	VO_2 @16.2km/h	VO_{2peak}	Mechanical power @15.0km/h	Mechanical power @16.2km/h
1	47.4	51.2	66.2	15.7	17.5	52.0	55.7	71.1	12.7	13.5
2	52.8	55.6	77.9	12.3	11.5	54.0	61.0	89.0	14.9	14.3
3	48.4	55.6	78.4	11.8	11.8	46.6	61.0	79.3	-	-
4	54.0	62.8	69.2	14.1	12.6	49.3	55.0	78.6	9.0	11.7
5	52.6	56.7	72.8	10.9	12.1	48.2	54.4	73.7	7.9	9.3
6	55.8	60.8	73.9	11.6	9.5	52.2	60.5	76.8	-	-
Mean	51.8	57.1	73.1	12.7	12.5	50.4	57.9	78.1	11.1	12.2
SD	3.3	4.1	4.8	1.8	2.7	2.8	3.2	6.2	3.2	2.2

VO_2 units: ml/kg/min, Mechanical power units: W/kg

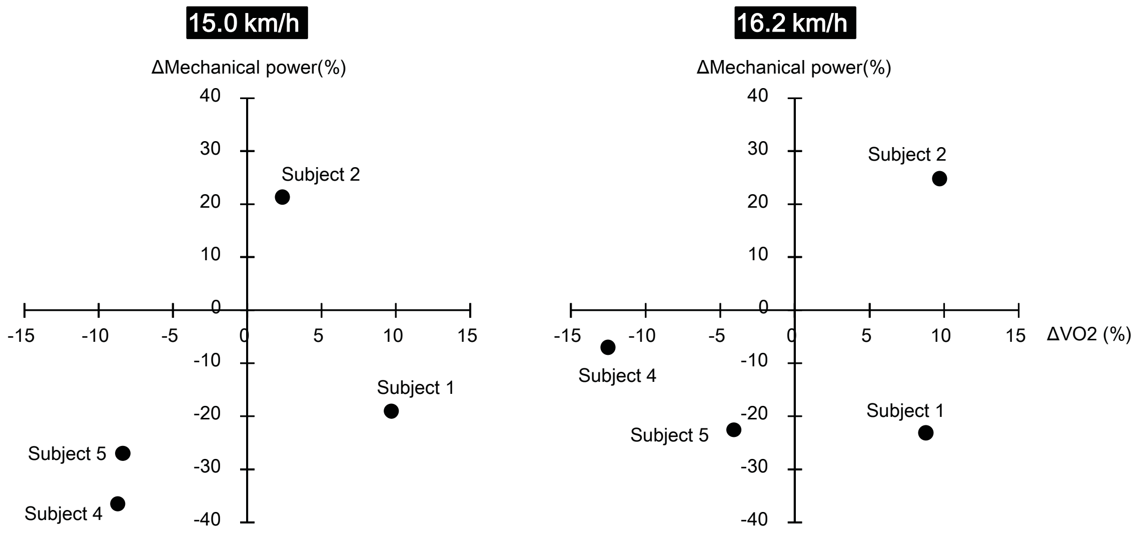

Figure 1 Relationships between change ratio in $\dot{V}O_2$ ($\Delta\dot{V}O_2$) and in mechanical power (Δ mechanical power) for four subjects at 15.0 (left) and 16.2 km/h (right).

DISCUSSION: Anthropometric characteristics have the potential to affect running economy and mechanics. Both height and weight for subject 1, 2, 4 and 5 showed very little change (Table 1). Therefore, these changes have little effects on changes in running economy and mechanical power in this study. Running economy at 15.0 and 16.2 km/h for subject 4 and 5 were improved and mechanical power at those velocities were decreased (Figure 1). This suggests that improved running economy for subject 4 and 5 are affected by improving running mechanics. Especially, in spite of VO_{2peak} for subject 4 was increased from 69.2 to 78.6 ml/kg/min, his running economy was markedly improved. Running economy for subject 1 and 2 were deteriorated but changed in mechanical power was different as it for subject 1 was decreased while it for subject 2 was increased (Figure 1). Subject 2 is a runner who deteriorated running economy by deteriorating running mechanics and increasing VO_{2peak}. On the other hand, subject 1 is a runner who deteriorated running economy in spite of improving running mechanics. One reason of deteriorated running economy for subject 1 is increased his VO_{2peak} from 66.2 to 71.1 ml/kg/min.

CONCLUSION: The relationships between changes in running economy and running mechanics are varied with individual runners. The changes in running economy are affected by not only running mechanics but also other factors as VO_{2peak}. This study indicated that improving running mechanics is one of the factors affected to changes in running economy, and it has the potential to improving running economy.

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