RELATIONSHIPS OF MECHANICAL POWER TO PERCEIVED EXERTION AND VARIOUS PHYSIOLOGICAL PARAMETERS MEASURED IN ELITE YOUTH DISTANCE RUNNERS AND CONTROLS

Eugene W. Brown, Paul Vogel,
Byeong Hwa Ahn and Sharon Evans

In many studies of human movement, calculations of mechanical energy and physiological energy costs of exercise (Aleshinsky, 1986; Bhambhani & Singh, 1985; Cavagna, Thys & Zamboni, 1976; Robertson & Winter, 1980; Pierrynowski, Winter & Norman, 1980; Saito, Ohkuwa, Ikegami & Miyamura, 1983; Sakurai & Miyashita, 1985; Williams & Cavanagh, 1983; Williams, 1985; Winter, Quanbury & Reimer, 1978; Zurrugh, 1981) have been used as tools to describe and compare performance. The purpose of the present study was to expand upon these comparisons by drawing relations between mechanical power and ratings of perceived exertion as well as relations between mechanical power and physiological costs of exercise.

Methods

Subjects

The subjects for this study were a sub-sample of participants in a longitudinal, interdisciplinary study of elite young distance runners (Seefeldt & Steig, 1986). Specifically, data used in this study were cross sectional and were obtained from the fourth year of data collection in the longitudinal study of elite young distance runners. Therefore, subjects were familiar with their performance requirements in the data collection process. In addition to the sub-sample of elite young distance runners, a sub-sample of control subjects was selected from the population of subjects used in the longitudinal study. This resulted in an age and gender distribution for this study of elite young runners and controls as shown in Table 1.

Collection of Physiological and Psychological Data

During each exercise bout, carbon dioxide produced and oxygen uptake were measured using the traditional Douglas bag method as described by Consolazio, Johnson, and Pecora (1963). Gas collections were fractionated into 1 minute bags. Heart rate was also monitored throughout the stress test. Heart rates were recorded for each subject at the end of the first, second, and third minute of each exercise bout.

At the start of each rest interval and at the end of the stress test, blood pressure, blood lactate, and ratings of perceived exertion (Borg & Noble, 1974) were measured. Blood pressure was measured with a sphygmomanometer. Blood lactate was measured by taking arterialized blood samples from the prewarmed finger tip and analyzed in a Roche 640 Analyzer.

Cinematographic Data Collection

Standard cinematographic procedures, using a 16mm LOCAM camera, were employed to record the running pattern exhibited by the subjects during their stress test. Commencing at the middle of the third minute (150 seconds) into each complete exercise level, cinematographic records of 3 or more strides were obtained at 100 frames per second on each subject.

A Vanguard Motion Analyzer was used to project the processed film images onto a screen surface. For each level, a complete stride, beginning and ending with left heel strike, was digitized to obtain kinematic information essential for the calculation of mechanical power. A model for the calculation of mechanical power during distance running (Williams & Cavanagh, 1983) was used and standardized by body mass (power/mass). According to Williams and Cavanagh, the model determines "the total cycle mechanical power adjusted for energy transfer, elastic storage and recovery of energy, the relative metabolic cost of negative and positive muscular work, and contributions of non-muscular sources to negative power." In using this model, coefficients a, b, c, and d were set to equal 0.63, 0.35, 0.85, and 3, respectively. It should be noted that if different coefficients were set for all of the subjects, the calculated magnitudes of power standardized by subject mass would have changed. However, their correlations to the physiological and psychological parameters would not differ.

Results

Table 3 is a summary of the performance times (level and

Table 1. Age and gender distribution of subjects

	Boys		Girls		Entire
	Runners	Controls	Runners	Controls	Population
N	3	3	8	1	15
Average Age (mo.)	185.3	176	183.3	208	
Age Range (mo.)	169-196	156-195	167-190	208	156-208

Stress Test

A stress test was administered to each of the 15 subjects chosen for this study. The stress test protocol consisted of alternating 3 minutes of running on a treadmill and 3 minutes of rest. Between each exercise bout, the treadmill speed and grade were systematically increased as shown in Table 2. Subjects, tested with this protocol, were asked to run to exhaustion.

Table 2. Stress test protocol

	Exercise/Rest Protocol	Treadmill (% Grade)	Treadmill Speed (m/s)	Time (min)
Level 1	Exercise	0	2.68	3
	Rest	-	-	3
Level 2	Exercise	5	2.68	3
	Rest	-	-	3
Level 3	Exercise	6	3.13	3
	Rest	-	-	3
Level 4	Exercise	7	3.58	3
	Rest	-	-	3
Level 5	Exercise	8	4.02	3
	Rest	-	-	3
Level 6	Exercise	9	4.47	3
	Rest	-	-	3

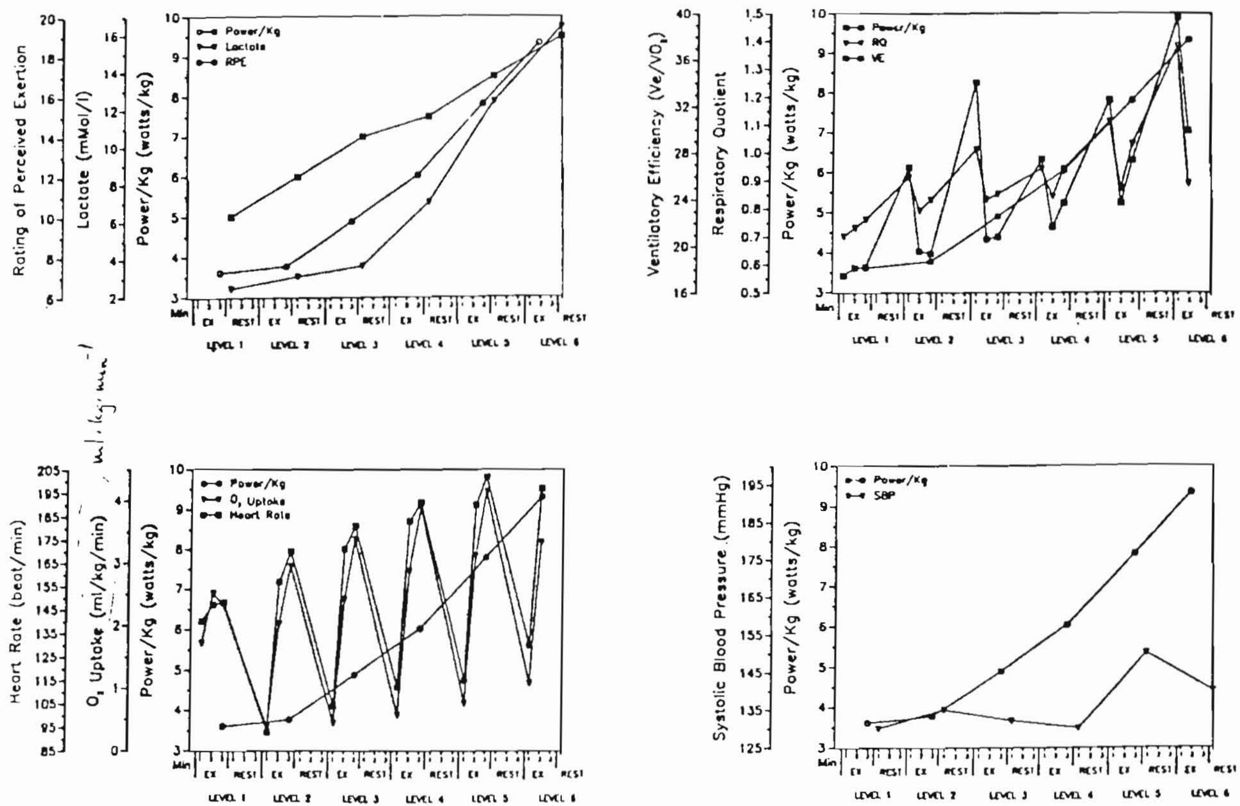
minute) which were achieved by the male and female runners and controls. It should be noted that 8 of the 15 subjects discontinued their stress test at a time other than the end of a level.

Table 3. Number of subjects achieving designated performance times

Performance Time (level/minute)	Boys		Girls		Entire Population
	Runner	Control	Runner	Control	
4/1		1	1		2
4/2		1	1		2
4/3			2	1	3
5/1	1		2		3
5/2		1	1		2
5/3					0
6/1			1		1
6/2	2				2

Figures 1 through 4 are results obtained for a male runner. These patterns, however, are typical for all subjects tested. It can beseen that the values for oxygen uptake ($\dot{V}O_2$) respiratory quotient ($VCO_2/\dot{V}O_2$), vanilatory equivalent of oxygen uptake ($Ve/\dot{V}O_2$), and heart rate behave in an inclined, saw-toothed pattern. During rest, the magnitude of these parameters tends to decrease. During exercise, the magnitudes increase from one minute to the next. However, the magnitude of these parameters tend to increase from one level to the next.

Figures 1 - 4. Results obtained for a male runner. (Note that these results were typical of those found in all subjects.)



Measures for lactate, ratings of perceived exertion, and blood pressure were taken immediately after each bout of exercise. The patterns tended to increase from one measure to the subsequent measure. The values of mechanical power calculated for a complete stride occurring during the third minute of each level behaved in a similar manner to the values obtained for lactate, ratings of perceived exertion, and blood pressure.

In an attempt to establish relationships between mechanical power and the other physiological and psychological parameters, it was decided to only use data which was obtained either during the third minute of exercise or at the start of a rest interval. Thus, four data sets were obtained for a subject who achieved a performance time of the second minute of the fifth level. This approach resulted in four subjects with three sets of data, eight subjects with four sets of data and three subjects with five sets of data. Sets of correlations were calculated for each subject. These were averaged by sex and experimental group and are reported in Table 4. From Table 4, it is evident that relatively high average correlations existed between mechanical power and all other parameters except for blood pressure.

Table 4. Correlations of mechanical power with physiological and psychological parameters

Parameter		Boys R	Boys C	Girls R	Girls C	Entire Population
Oxygen Uptake	Average	.94	.80	.86	.89	.87
	Range	.92-.97	.74-.87	.57-.94	.89	.57-.97
Respiratory Quotient	Average	.93	.92	.95	.94	.94
	Range	.90-.98	.89-.95	.84-.99	.94	.84-.99
Venilatory Equivalent	Average	.95	.78	.96	.99	.92
	Range	.87-.99	.44-.98	.85-.99	.99	.44-.99
Heart Rate	Average	.92	.80	.87	.96	.87
	Range	.91-.94	.69-.87	.65-.95	.96	.65-.95
Lactate	Average	.96	.94	.97	.78	.95
	Range	.94-.98	.87-.98	.86-.99	.78	.78-.99
Perceived Exertion	Average	.95	.90	.90	.99	.91
	Range	.91-.99	.88-.93	.58-.99	.99	.58-.99
Blood Pressure	Average	.61	.90	.70	.19	.69
	Range	.23-.86	.76-.97	.12-.98	.19	.12-.98

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