Comparison of incremental treadmill exercise and free range running

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ABSTRACT

CROUTER, S., C. FOSTER, P. ESTEN, G. BRICE, and J. P. PORCARI. Comparison of incremental treadmill exercise and free range running. *Med. Sci. Sports Exerc.*, Vol. 33, No. 4, 2001, pp. 644–647. **Purpose:** The aim of this study was to compare physiological responses during incremental treadmill exercise and free range running. **Methods:** Fifteen competitive cross-country runners performed an incremental treadmill test and an unpaced 1-mile run on an indoor 200-m track. Physiological variables ($\dot{V}O_{2peak}$, HR_{peak}, $\dot{V}O_2 \cdot HR^{-1}{}_{peak}$, $\dot{V}_{Epeak}$) were measured using a portable metabolic analyzer. Blood lactate was measured post exercise. Outcome variables were analyzed with repeated measures ANOVA. **Results:** Although directionally similar to previous studies with cycle ergometry, the observed peak values (track vs treadmill) for $\dot{V}O_2$ (63.0 ± 7.4 vs 61.9 ± 7.2 mL·kg^{-1}·min^{-1}), $\dot{V}_E$ (147 ± 37 vs 144 ± 30 L·min^{-1}), HR (188 ± 5 vs 189 ± 7 beats·min^{-1}), and $\dot{V}O_2 \cdot HR^{-1}$ (22.1 ± 4.4 vs 21.5 ± 4.5) were not significantly different. The observed peak values for blood lactate (14.4 ± 3.3 vs 11.7 ± 3.0 mmol·L^{-1}) were significantly ($P < 0.05$) different. **Conclusions:** The results are not in full agreement with previous findings from cycling studies with the exception of post exercise blood lactate. Whether this represents a fundamental lack of effect of free range exercise or is related to mode specificity remains to be determined. **Key Words:** EXERCISE TESTING, SPORTS PHYSIOLOGY

Incremental ergometry is the ordinary laboratory technique for evaluating physiological responses to exercise and for evaluating diagnostic markers, such as peak oxygen uptake ($\dot{V}O_{2peak}$), ventilatory threshold (V_T), and peak heart rate (HR_{peak}), which have been shown to be well correlated to endurance performance (4,7,9,10,13,17,21,26). The concept of using incremental ergometry for measuring exercise capacity is based on early work suggesting a plateau in oxygen uptake $\dot{V}O_2$) despite increasing workloads (16,25) and on studies demonstrating that continuous incremental exercise protocols produce $\dot{V}O_{2peak}$ values comparable to those observed in the classical discontinuous protocols (14).

However, incremental exercise is not how humans ordinarily perform exercise. Most typically, athletes are trying to minimize the time to achieve a fixed amount of work (e.g., get to the finish line as quickly as possible). Recent studies in which this (free range) pattern of exercise was used have demonstrated a greater magnitude of physiological responses than observed during conventional incremental exercise (5,6,11,20,22–24). These studies call into question, at a fundamental level, the reasoning behind the concept of maximal oxygen uptake ($\dot{V}O_{2max}$) and similar concepts based on incremental ergometry. Studies of free range exercise have, until now, primarily been limited to cycle ergometry simply because ergometric technology has facilitated competitive simulation with specialized cycle ergometers. Treadmills have generally been too slow to respond to intended variations in velocity to allow for meaningful competitive simulations. However, with the advent of lightweight, portable respiratory gas analysis systems, it is now feasible to perform competitive simulations in the field rather than in the laboratory. Thus, the purpose of this study was to compare physiological responses ($\dot{V}O_{2peak}$, HR_{peak}, peak oxygen pulse ($\dot{V}O_{2peak} \cdot HR{-}1_{peak}$), peak blood lactate ($BLa_{peak}$), and peak ventilation ($\dot{V}_{Epeak}$)) between incremental exercise (a horizontal treadmill $\dot{V}O_{2max}$ test) and free range exercise (a 1-mile run) to test the hypothesis that free range exercise would provoke greater physiological responses than conventional incremental ergometry.

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METHODS

Subjects. Fifteen collegiate runners (10 male, 5 female) volunteered to participate. The subjects were cross-country runners and had consistently trained on a regular basis (≥5 d·wk^{-1}). The average (± SD) weekly volume of training was 110 ± 9 and 82 ± 6 km·wk^{-1} for the male and females subjects, respectively. Descriptive data of the subjects are presented in Table 1. All subjects were informed of the testing procedures and requirements and provided informed consent before testing. The protocol had been previously approved by the University IRB.

Protocol. Respiratory metabolism was measured using open-circuit spirometry with a lightweight portable metabolic system (K4b^2, Cosmed, Rome, IT). Heart rate (HR) was monitored using radiotelemetry (Polar Vantage XL, Polar Instruments, Port Washington, NY). Oxygen consumption ($\dot{V}O_2$), ventilation, HR, and RER were recorded continuously and expressed as min values based on a rolling

TABLE 1. Characteristics of subjects (± SD)

	Male	Female
Age (yr)	19.4 ± 1.6	19.6 ± 1.5
Height (cm)	184 ± 5	167 ± 4
Weight (kg)	68.4 ± 5.4	57.4 ± 2.4
VO_{2peak} ($L{\cdot}min^{-1}$)*	4.51 ± 0.50	3.10 ± 0.26
VO_{2peak} ($mL{\cdot}min^{-1}{\cdot}kg^{-1}$)[a]	65.9 ± 4.6	54.0 ± 3.7
HR_{peak}*	188 ± 8	191 ± 6
% VO_2 at VT*	76.3 ± 9.1	75.2 ± 8.9
% VO_2 at RCT*	91.4 ± 5.1	92.4 ± 7.1
Peak treadmill velocity ($m{\cdot}s^{-1}$)	5.88 ± 0.34	5.25 ± 0.44
Mile PR (s)	271.40 ± 10.30	340.4 ± 17.76

[a] Treadmill max test.

1-min integration of the data. Preliminary data of gas exchange measurements with this metabolic system suggest its general validity (15). The portable metabolic system was used for both the treadmill and free range exercise studies and was calibrated using reference gases and a calibration syringe. Each subject completed, in random order, both an incremental treadmill test to fatigue and a 1-mile (1609 m) time trial.

The incremental test was performed on a motor driven treadmill. Before testing, the subjects warmed up by walking for 5 min at 1.6 $m{\cdot}s^{-1}$ and 5% grade. The subjects then performed a treadmill protocol at a constant 1% grade which started at 3.3 $m{\cdot}s^{-1}$ and 2.8 $m{\cdot}s^{-1}$ for the men and women, respectively. Every 2 min the speed was increased by 0.6 $m{\cdot}s^{-1}$ and 0.4 $m{\cdot}s^{-1}$ for the men and women, respectively, until fatigue. After the test, a blood sample was taken from a fingertip at 1, 3, 5, and 7 min of recovery (walking) and analyzed for blood lactate concentration using an enzyme electrode system (YSI Sport, Yellow Springs, OH). Peak blood lactate concentration was derived by interpolation.

The 1-mile time trial was performed on a 200-m indoor track. The mile was run solo and was conducted with the metabolic system and HR monitor in place as described for the treadmill protocol. The subjects were instructed to run as hard as they could with the intent of completing the mile in minimal time. To facilitate pacing, intermediate times were called to the subjects and recorded after each 200-m segment. At the conclusion of the run, blood samples were taken at 1, 3, 5, and 7 min of recovery for blood lactate analysis.

Statistical treatment. Mean values of relevant outcome measures were compared with repeated measures analysis of variance. Pearson correlation coefficients were used to support the means testing.

RESULTS

The subjects completed both exercise protocols without problems. The average time for the mile run (5:14 ± 0:37) was only slightly slower than the best competitive mile performance by the subjects (4:54 ± 0:35). Considering that the focus for training at the time of the studies was on much longer events, all subjects felt that they had returned a near competitive level performance. During the mile run, running velocity was usually greatest during the first 200 m, then decreased through the 1200 m before an acceleration during the last 400 m (Fig. 1, top). During the mile run, $\dot{V}O_2$ increased over the first 400 m and then essentially leveled off with only slight variation for the next 1200 m (Fig. 1, middle). During the mile run, the pattern of $\dot{V}O_2$ changes did not seem to be related to variations in velocity in that $\dot{V}O_2$ did not change during the slow down during the middle of the run, nor during the terminal acceleration (Fig. 1, bottom).

The serial response of $\dot{V}O_2$ during the incremental laboratory test is presented in Figure 2A. Serial responses of the group averages during the 1-mile run versus the incremental laboratory test for $\dot{V}O_2$ are shown in Figure 2B. The observed peak values (track vs treadmill) for $\dot{V}O_2$ (63.0 ± 7.4 vs 61.9 ± 7.2 $mL{\cdot}kg^{-1}{\cdot}min^{-1}$), $\dot{V}_E$ (147 ± 37 vs 144 ± 30 $L{\cdot}min^{-1}$), HR (188 ± 5 vs 189 ± 7 $beats{\cdot}min^{-1}$), and $\dot{V}O_2{\cdot}HR^{-1}$ (22.1 ± 4.4 vs 21.5 ± 4.5) were not significantly different. The peak values for BLa (14.4 ± 3.3 vs 11.7 ± 3.0 $mmol{\cdot}L^{-1}$) were significantly different ($P < 0.05$).

DISCUSSION

Contrary to previous studies, the physiological responses during free range exercise were not significantly different

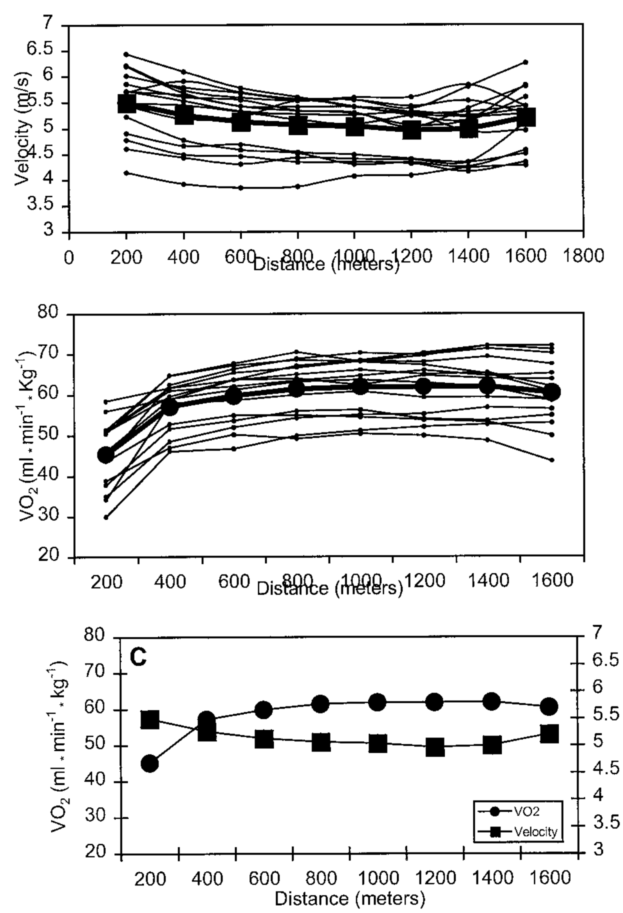

FIGURE 1—Top: Serial responses of velocity during the 1-mile run, measured every 200 m. The *thick line with circles* represents the mean response, and the *thin lines* represent individual responses. Middle: Serial response of $\dot{V}O_2$ during the 1-mile run, measured every 200 m. Bottom: Average responses of $\dot{V}O_2$ and velocity measured every 200 m during the 1-mile run. Note the lack of correspondence in changes in $\dot{V}O_2$ and velocity during after the first portion of the run is completed.

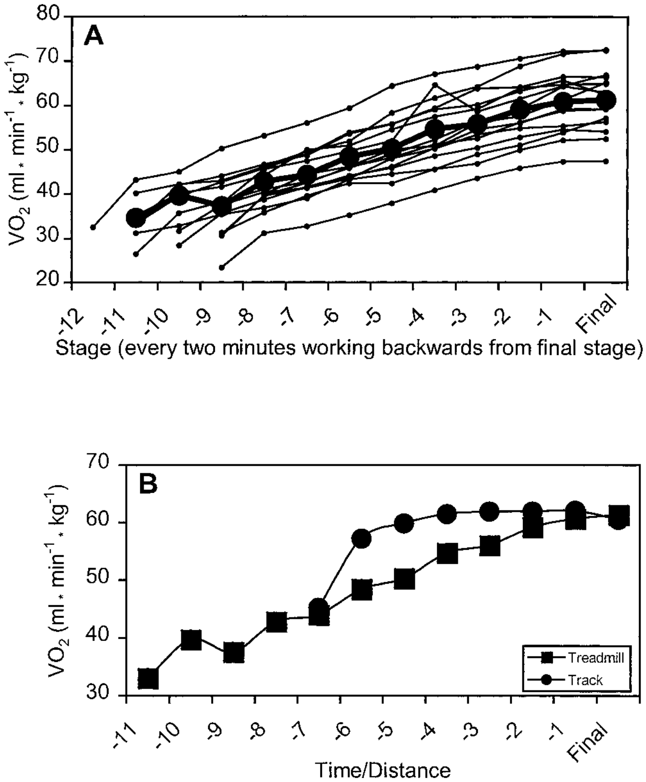

FIGURE 2—A: Serial responses of $\dot{V}O_2$ during the incremental treadmill test, measured every minute, starting with the final minute and working backward. The *circles* and *thick line* represent the mean, and the *thinner lines* represent individual responses. B: Mean responses for $\dot{V}O_2$ during the 1-mile run and the incremental test. Final represents the last 200 m for the 1-mile run and the last stage for the incremental test. The stages are 200 m for the 1-mile run and every minute for the incremental test.

than during incremental treadmill ergometry (5,6). Whether the failure to match previous studies is related to differences between cycling and running or to other factors remains to be determined. In agreement with previous studies, postexercise blood lactate concentration was significantly greater during free range exercise. This is likely attributable to the longer period at heavy exertion during free range exercise.

Three decades ago, Karlsson and Saltin (12) demonstrated relatively constant muscle lactate concentrations during exhaustive cycling exercise, with durations ranging from 2 to 6 min, with only slightly lower muscle lactate concentrations during exhaustive work of 15-min duration. These data imply that accumulation of metabolites (probably hydrogen ions) within the muscle was largely responsible for the fatigue experienced by the subject. We have interpreted our previous free range exercise results with reference to Karlsson and Saltin's data, suggesting that very brief reductions in power output during free range exercise could be used to manage the rate of muscle lactate accumulation without being so large as to cause decreases in central oxygen transport (5,6). According to this reasoning, during incremental exercise when muscle lactate concentration reaches critical levels, exercise must stop even if maximal cardiorespiratory stress has not been achieved. The failure to observe significant differences in most physiological outcome measures in the present data challenges this interpretation. However, on the basis of the reduced duty cycle during running (~10%), compared with cycling (~40%), and the generally smaller degree of muscular loading during running, it may be that there is less of a tendency to reach critical muscle lactate concentrations during incremental running, in which case our earlier discussion might still be valid during cycling. Support for this concept is provided by our earlier observations of reduced $\dot{V}O_{2peak}$ and accelerated lactate accumulation during speed skating, where high muscular forces and a prolonged duty cycle combine to compromise muscle blood flow (8). To the degree that the duty cycle and muscular forces during cycling or rowing might restrict blood flow, this would provide a rationale for understanding the apparent advantage of free range exercise during cycling and rowing but not during running.

Recently, there has been renewed interest in the concept of $\dot{V}O_{2max}$ with Noakes (18,19) suggesting that the traditional concept of a $\dot{V}O_{2max}$ plateau is not supported by adequate experimental data. Others (1–3) have argued for the traditional concept. The present data, along with previous data (5,6,11,20,22–24), suggest that the highest $\dot{V}O_2$ observed during incremental exercise is not always the greatest $\dot{V}O_2$ that an individual is capable of demonstrating. In that sense, the present data support the arguments put forth by Noakes. In the present study, 8 of the 15 subjects demonstrated a plateau of $\dot{V}O_2$ during incremental exercise (rate of increase in $\dot{V}O_2 < 50\%$ of the average rate of increase during the clearly submaximal portions of the test). Of the eight subjects that reached a plateau, during the incremental laboratory test, six reached higher values during free range exercise (subgroup mean = 63.6 ± 7.7 vs 61.1 ± 7.8 $mL \cdot kg^{-1} \cdot min^{-1}$). In the seven subjects that did not reach a plateau during the incremental laboratory test, only two achieved a higher value during free range exercise (subgroup mean = 62.3 ± 7.5 vs 62.8 ± 7.0 $mL \cdot kg^{-1} \cdot min^{-1}$). These data support the concept that the achievement of a plateau during incremental exercise may be an artifact of the incremental protocol.

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