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ORIGINAL ARTICLE

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Specificity of treadmill and cycle ergometer tests in triathletes, runners and cyclists

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Abstract The objective of this study was to evaluate the viability of using a single test in which cardiorespiratory variables are measured, to establish training guidelines in running and/or cycling training activities. Six triathletes (two females and four males), six runners (two females and four males) and six males cyclists, all with 5.5 years of serious training and still involved in racing, were tested on a treadmill and cycle ergometer. Cardiorespiratory variables [e.g., heart rate (HR), minute ventilation, carbon dioxide output ($\dot{V}CO_2$)] were calculated relative to fixed percentages of maximal oxygen uptake ($\dot{V}O_{2max}$; from 50 to 100%). The entire group of subjects had significantly ($P < 0.05$) higher values of $\dot{V}O_{2max}$ on the treadmill compared with the cycle ergometer [mean (SEM) 4.7 (0.8) and 4.4 (0.9) $l \cdot min^{-1}$, respectively], and differences between tests averaged 10.5% for runners, 6.1% for triathletes and 2.8% for cyclists. A three-way analysis of variance using a $3 \times 2 \times 6$ design (groups × tests × intensities) demonstrated that all factors yielded highly significant *F*-ratios ($P < 0.05$) for all variables between tests, even though differences in HR were only 4 beats $\cdot$ min^{-1}. When HR was plotted against a fixed percentage of $\dot{V}O_{2max}$, a high correlation was found between tests. These results demonstrate that for triathletes, cyclists and runners, the relationship between HR and percentage of $\dot{V}O_{2max}$, obtained in either a treadmill or a cycle ergometer test, may be used independently of absolute $\dot{V}O_{2max}$ to obtain reference HR values that can be used to monitor their running and/or cycling training bouts.

Key words Performance test · Specificity · $\dot{V}O_{2max}$ · Monitoring of training

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Introduction

Maximal oxygen uptake ($\dot{V}O_{2max}$) is generally accepted to be the best indicator of endurance performance capacity (Mitchell et al. 1958; O'Toole and Douglas 1995; Sleivert and Rowlands 1996; Taylor et al. 1955; Weltman et al. 1990). Consequently, this variable is frequently used to determine training intensities in numerous endurance sports. $\dot{V}O_{2max}$ is assumed to be highly dependent upon the mode of testing, with the highest values normally attained during treadmill running. Therefore, to optimize the effectiveness of a training program, training activities need some specificity with regard to mode, duration and intensity (Bouchard et al. 1979; Kohrt et al. 1987). Training effects also appear to be specific to the mode of training used by an athlete; therefore differences between testing modes vary with training (Pechar et al. 1974; Sharkey 1988). Because of this specific adaptation, runners are generally tested on a treadmill, and cyclists on a cycle ergometer. However, triathletes engage in three aerobic modes of exercise that use the same muscle groups. Therefore, to take into account testing mode specificity, triathletes should preferably use three different tests to monitor their training program.

However, there is a possibility that a cross-training effect occurs when a high volume of training is performed regularly with different modes of exercise (Flynn et al. 1998; Schneider and Pollack 1991). If cross-training effects are real, then it may be possible to monitor various training activities with a single indicator of work intensity without having to undergo multiple testing sessions using each training mode.

Numerous studies have shown that heart rate (HR) and oxygen uptake ($\dot{V}O_2$) are strongly correlated in cycling as well as running (Barbeau et al. 1993; Coast and Welch 1985; Foster et al. 1978; Van Handel et al. 1988; Veicsteinas et al. 1985). Since the availability of lightweight monitors makes HR very easy to monitor continuously during training bouts, HR is now the variable of choice used to control work intensity during training bouts (Boulay 1995; Boulay et al. 1997; Gilman 1996; Weltman et al. 1990). In trained endurance athletes there is a possibility that HR values would be similar in different exercise modalities when exercise intensities are equivalent. Thus, the purpose of this study was to evaluate the feasibility of using a single exercise test to establish training guidelines in running and/or cycling training activities.

Methods

Subjects

Six triathletes (two females and four males), six runners (two females and four males) and six male cyclists gave their written informed consent (in compliance with Laval University's Ethics Committee regulations) to participate in this study, which was performed in the preparatory phase of their training year. All subjects were active athletes and had been competing at the provincial and national levels for periods ranging from 2 to 15 years; some had participated in international events. Some of the physical characteristics of these subjects are presented in Table 1.

$\dot{V}O_{2max}$ test

Subjects underwent continuous, incremental tests to volitional exhaustion on both a treadmill and a cycle ergometer. These two maximal tests were carried out randomly, with a minimal interval between tests of 2 days, and a maximal interval of 7 days. The test protocols were designed to yield similar test durations. The running test was conducted on a motor-driven treadmill (Quinton Instruments, Seattle, Wash., USA). After a 5-min warm-up at a speed of 3.5 km · h^{-1}, the starting speed was set at 5.5 km · h^{-1}. The grade was set at 5%, and was increased every 2 min by 1.1 km · h^{-1} until it reached 13.1 km · h^{-1}, after which it was raised by 3% every 2 min until exhaustion. The cycle ergometer test was performed on an electromagnetically braked cycle ergometer (Warren E. Collins, Braintree, Mass., USA). Subjects were asked to choose a familiar and comfortable pedaling rate equal or higher than 60 rpm and to maintain that rate throughout the test. After a 4-min warm-up period at 100 W, the test was initiated at an initial power output of 100 W. Increments of 25 W were made every min until 200 W was reached; thereafter, 25-W increments were made every 2 min until exhaustion.

Physiological measurements

During the tests, $\dot{V}O_2$, minute ventilation ($\dot{V}_E$), carbon dioxide output ($\dot{V}CO_2$) and respiratory exchange ratio (*R*) were recorded continuously with an automated open-circuit gas analysis system using O_2 and CO_2 analyzers (Model S-3A and Anarad AR-400, Ametek, Pittsburgh, Pa., USA), and a turbine-driven digital spirometer (Model S-430, Vacumetrics/Vacumed, Ventura, Calif., USA) that had a 5.3-l mixing chamber. HR was recorded by electrocardiography in the CM5 position (Model M200, Burdick, Milton, Wisc., USA). The criteria used to confirm that $\dot{V}O_{2max}$ had been reached were plateauing of $\dot{V}O_2$ in spite of an increase in speed or work rate, and an *R* value greater than 1.1. HR at exhaustion was taken as maximal heart rate (HR_{max}).

Statistical analysis

Simple linear regression analysis was used to determine the relationship between tests and cardiorespiratory values. A three-way (three groups × two tests × six intensities) analysis of variance (ANOVA) with repeated measures was used to test significant differences between dependent variables. Significant *F*-ratios were followed by post-hoc comparison using Newman-Keul's procedure. Homogeneity of variance was tested with the Levene procedures (Steel and Torrie 1980). For all statistical tests, a probability level of $P < 0.05$ was considered significant. All values are expressed as means (SEM), unless specified otherwise.

Results

The maximal power output values obtained at exhaustion for both exercise tests are presented in Table 1, and other measures of performance are given in Table 2. All groups exhibited a significantly ($F_{1,15} = 22.79$; $P < 0.05$) higher $\dot{V}O_{2max}$ on the treadmill than on the cycle ergometer, with cyclists exhibiting higher values than both the runners and the triathletes in both tests. Differences between tests averaged 2.8% for cyclists, 10.5% for runners and 6.1% for triathletes. Subjects differed substantially in absolute $\dot{V}O_{2max}$, with values ranging from 2.3 to 6.1 l · min^{-1} for the cycle ergometer, and from 3.0 to 5.7 l · min^{-1} for the treadmill. These large inter-individual differences were due mainly to gender. If the values provided by the female runners and triathletes were removed from the analysis, the average absolute $\dot{V}O_{2max}$ values were 5.0 and 5.1 l · min^{-1} for the runners and 4.4 and 4.6 l · min^{-1} for the triathletes in the cycle ergometer and treadmill tests, respectively.

In separate groups, HR_{max} values were higher on the treadmill than on the cycle ergometer. $\dot{V}_E$ was higher on the treadmill for the cyclists and runners, while $\dot{V}CO_2$ was higher on the treadmill only for the cyclists.

Table 1 Physical and physiological characteristics of the subjects. Data are presented as the mean (SEM). Metabolic equivalents of energy expended above metabolic rate (*METS*) = 3.5 mlO$_2$ · kg^{-1} · min^{-1}

Subjects	Physical characteristics				Test results			
	Age (years)	Mass (kg)	Height (m)	Expertise (years)	Ergocycle		Treadmill	
					Maximal power (W)	Duration (min)	Metabolic rate (METS)	Duration (min)
Cyclists	24.3 (7.5)	72.5 (3.7)	1.78 (0.06)	6.2 (4.1)	439.6 (42.3)	21.3 (1.4)	20.8 (1.4)	19.8 (1)
Runners	21.0 (2.4)	64.8 (13.8)	1.72 (0.1)	6.0 (2.2)	320.8 (78.1)	15.3 (6.3)	19.6 (1.6)	20.3 (1.9)
Triathletes	21.3 (1.6)	65.7 (5.6)	1.73 (0.05)	4.3 (2.8)	375 (31.6)	18.5 (3.2)	20.0 (1.5)	19.7 (1.4)
All groups	22.2 (5.0)	67.7 (9.1)	1.74 (0.07)	5.5 (3.2)	378.5 (71.5)	18.4 (4.7)	20.1 (1.5)	19.9 (1.4)

Table 2 Physiological measurements at exhaustion. Data are presented as the mean (SEM). (*HR* Heart rate, $\dot{V}O_2$ oxygen uptake, $\dot{V}O_{2max}$ maximal $\dot{V}O_2$, $\dot{V}_E$ minute ventilation, $\dot{V}CO_2$ carbon dioxide output)

Subjects	Ergocycle					Treadmill				
	HR (beats·min^{-1})	$\dot{V}_E$ (l·min^{-1})	$\dot{V}O_{2max}$ (l·min^{-1})	$\dot{V}CO_2$ (l·min^{-1})	$\dot{V}O_{2max}$ (ml·kg^{-1}·min^{-1}) (range)	HR (beats·min^{-1})	$\dot{V}_E$ (l·min^{-1})	$\dot{V}O_{2max}$ (l·min^{-1})	$\dot{V}CO_2$ (l · min^{-1})	$\dot{V}O_{2max}$ (ml · kg^{-1} · min^{-1}) (range)
Cyclists	201 (3.2)	169.6 (6.4)	5.2 (0.5)	5.9 (0.2)	71.2 (3.9) (63.8–76.4)	204 (3.5)*	163.6 (7.4)*	5.3 (0.4)*	5.7 (0.1)**	75.3 (3.8)* (70.5–80.3)
Runners	185 (4.1)	139.7 (15.8)	4.0 (1.1)	4.6 (0.4)	61.7 (5) (52.8–68.1)	191 (2.9)*	148.4 (14.6)*	4.5 (1.1)*	5.1 (0.5)	68.4 (4.1)* (57.7–72.4)
Triathletes	194 (3.4)	146.1 (6.7)	4.2 (0.6)	4.4 (0.3)	64.6 (2.6) (58.4–68.7)	197 (3.2)*	147.9 (6.4)*	4.4 (0.4)*	4.9 (0.2)	66.9 (3.7)* (59.5–73.3)
All groups	193 (2.5)	154.6 (30.2)	4.4 (0.9)	4.9 (0.2)	65.8 (4.6)	197 (2.2)*	152.2 (23.2)*	4.7 (0.8)*	5.2 (0.2)	70.2 (4.3)*

* Significantly different between tests; ** significantly different between groups

The differences in HR between tests varied from 3 beats · min^{-1} for the cyclists and triathletes to 6 beats · min^{-1} m for the runners. Figure 1 illustrates the evolution of HR relative to absolute values of $\dot{V}O_2$. There were large inter-individuals differences, but in all three graphs, individuals values for the treadmill test are almost superimposed upon those of the cycle ergometer test, as demonstrated by the nearly identical regression lines.

Figures 2 and 3 present graphs of $\dot{V}_E$ and $\dot{V}CO_2$, respectively, plotted against absolute values of $\dot{V}O_2$. The inter-individual differences were much smaller than those observed for HR, especially at lower $\dot{V}O_2$ values. The dispersion of $\dot{V}_E$ values at high $\dot{V}O_2$ values was related to the inter-individual differences in $\dot{V}O_{2max}$ that were observed as subjects reached their ventilatory threshold at different values of $\dot{V}O_2$. This was especially evident in the runners' data, as the two female runners had $\dot{V}O_{2max}$ values of around 3.0 l · min^{-1}.

Figure 4 shows mean HR plotted against fixed percentages of $\dot{V}O_{2max}$ (50–100%) for the cyclists (left panel), runners (middle panel) and triathletes (right panel). There were large differences in individual HRs (data not shown), but differences between tests in individual athletes were much smaller. Significant differences ($F_{1,15} = 9{,}54$; $P < 0.05$) were found between tests for mean $HR_{max,}$ and ANOVA revealed significantly different mean submaximal HR values between tests for all groups ($F_{1,15} = 7{,}82$; $P < 0.05$). Post-hoc analysis indicated that HRs were not different between tests at values of under 90% $\dot{V}O_{2max}$ for the runners and under 60% for the triathletes, while cyclists showed differences at each stage. Submaximal HRs were significantly higher on the treadmill than on the cycle ergometer, however these differences were small, reaching about 4 beats · min^{-1}.

The statistical relationships between the HRs achieved on the cycle ergometer and those achieved on the treadmill at various percentages of $\dot{V}O_{2max}$ in all athletes are presented in Fig. 5. HRs achieved on the cycle ergometer were highly correlated with those achieved on the treadmill when calculated at fixed percentages of $\dot{V}O_{2max}$. The correlation coefficients were similar for the three groups and reached $r = 0.96$ for the cyclists, $r = 0.97$ for the runners and $r = 0.98$ for the triathletes.

Discussion

Comparisons between exercise tests or between laboratory and field tests have been conducted since the birth of exercise physiology and have been the topic of numerous publications. Such comparisons generally used protocols that were very similar or that generated very similar physiological responses. Nagel et al. (1971), for example, compared the $\dot{V}O_2$ requirements of gradual treadmill, cycle ergometer and step-device tests at seven different workloads. Even though the protocols of that study were very similar from one test mode to another,

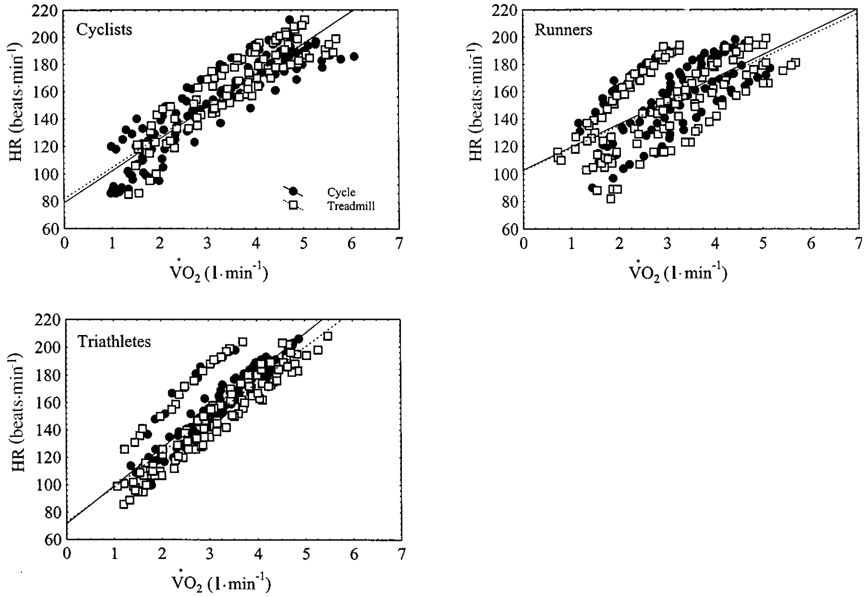


Fig. 1 Evolution of heart rate (HR) relative to absolute oxygen uptake ($\dot{V}O_2$) for the cycle ergometer (*closed circles*) and treadmill (*open squares*) tests (individual values for the cyclists, runners and triathletes)

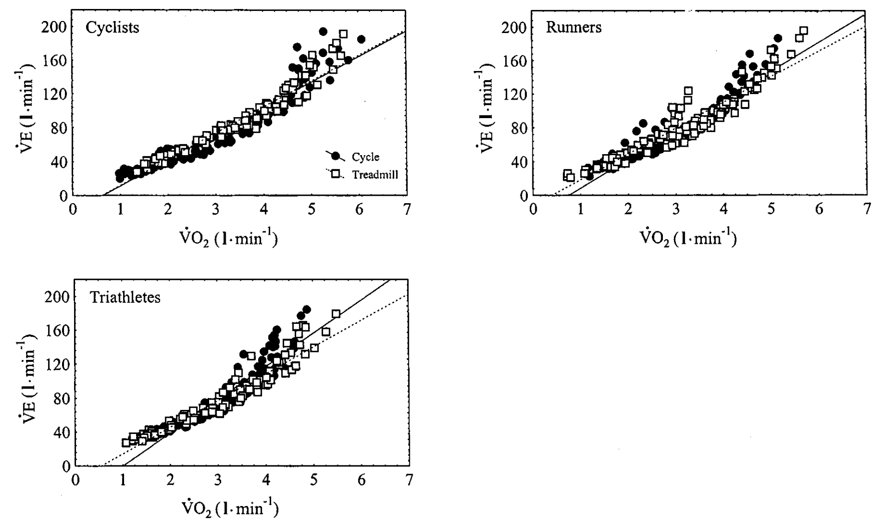


Fig. 2 Evolution of minute ventilation ($\dot{V}_E$) plotted against absolute $\dot{V}O_2$ for the cycle ergometer (*closed circles*) and treadmill (*open squares*) tests (individual values for the cyclists, runners and triathletes)

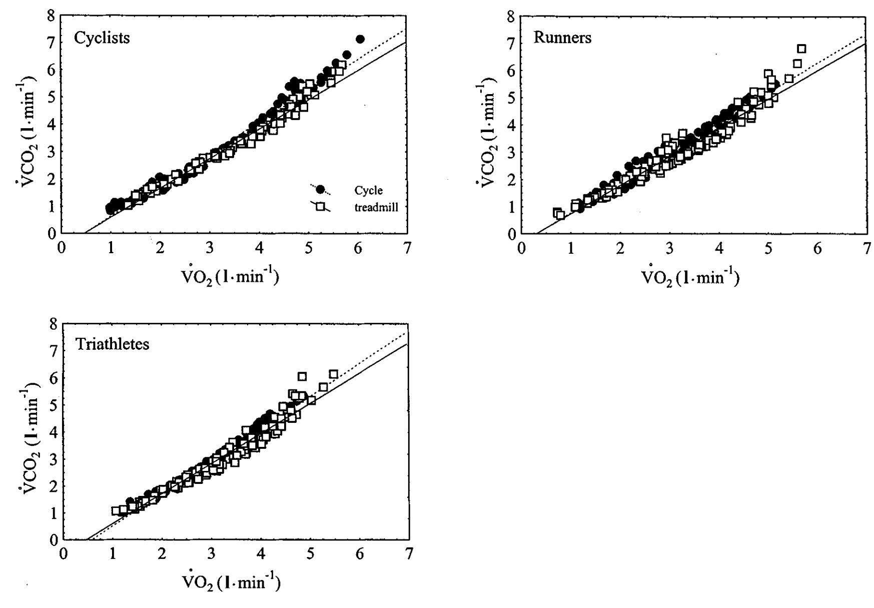
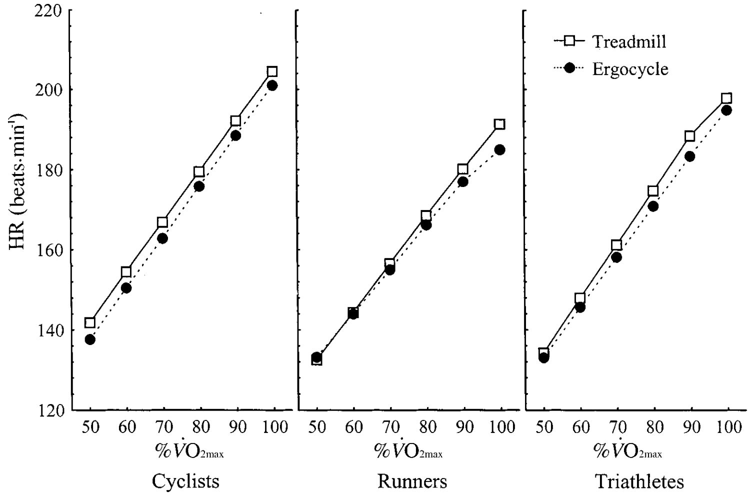


Fig. 3 Evolution of carbon dioxide output ($\dot{V}CO_2$) plotted against absolute maximal $\dot{V}O_2$ ($\dot{V}O_{2max}$) for the cycle ergometer (*closed circles*) and treadmill (*open squares*) tests (individual values for the cyclists, runners and triathletes)

Fig. 4 Mean HR plotted against fixed percentages of $\dot{V}O_{2max}$ for the cycle ergometer (*closed circles*) and treadmill (*open squares*) tests performed by cyclists (*left*), runners (*middle*) and triathletes (*right*)



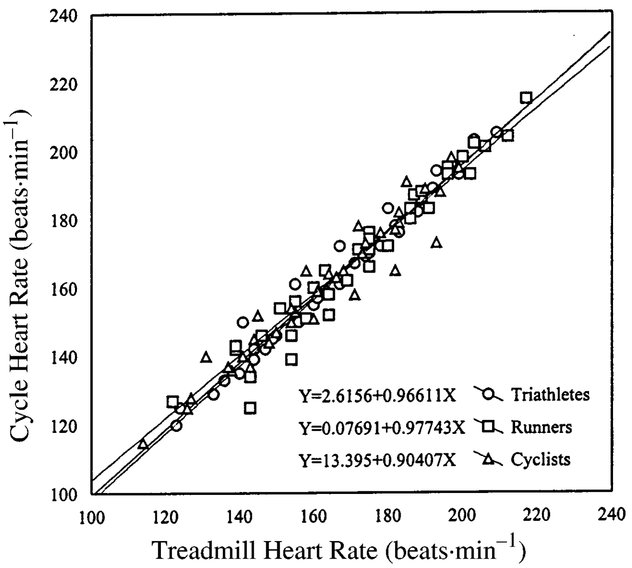


Fig. 5 Correlation between HR values attained during the cycle ergometer and treadmill tests at different percentages of $\dot{V}O_{2max}$ for the entire group (triathletes *circles*, runners *squares*, cyclists *triangles*)

the $\dot{V}O_2$ results, presented in $l \cdot min^{-1}$, showed small but significant differences between tests since: "...no single line could describe the metabolic responses to the work loads on the three instruments." These results, as well as many others, have revealed that adaptation in an exercise test appears to be specific to the mode of testing.

The tests used in the present protocol were neither designed to generate similar $\dot{V}O_2$ values at each stage, nor to give similar rates of increase between stages. The major means used to ensure that tests results would be comparable were based on attaining a roughly similar test duration, and on reporting results against fixed percentages of $\dot{V}O_{2max}$. The expression of work intensity in a relative form has definitive merits because it provides the possibility of comparing groups with very different characteristics. For example Turley and Wilmore (1997) used that procedure to compare the physiological stress induced by exercise tests in adults and children. Therefore, this procedure ensures that the results of both tests are not only comparable, but are also applicable to field situations in mimicking what athletes do in the field, because habitually they do not adhere to the same standardized work protocols in different exercise modes.

Test durations were not different between tests (Table 1), even though there was a 5-min difference for the runners that was caused by the presence of two female runners with a small body frame (42 and 57 kg) who could attain cycle ergometer maximal work loads of 200 and 250 W, respectively. Although the presence of these two female runners complicated the analysis of the data, their results have been retained because they are an expression of the biological variation that is likely to be encountered in the sports world.

The results of our investigation have shown that, as frequently reported by others, $\dot{V}O_{2max}$ was higher on the treadmill than on the cycle ergometer (Bouchard et al. 1979; Hermansen and Saltin 1969; Kohrt et al. 1987; Martinez et al. 1993; McArdle and Magel 1970; McConnell et al. 1984; Schneider et al. 1990). These differences were small for cyclists (2.8%), but higher for triathletes (6.1%) and runners (10.5%). These data thus confirmed that absolute $\dot{V}O_{2max}$ values are dependent upon the mode of exercise and the specific training of an athlete (McConnell 1988). Moreira-Da-Costa et al. (1984, 1989) also reported that $\dot{V}O_{2max}$ values were significantly different between testing modes for runners, but not for cyclists. Conversely, Miura et al. (1997), Medelli et al. (1993) and Zhou et al. (1997) did not find different values for $\dot{V}O_{2max}$ between tests with male triathletes, while Schneider and Pollack (1991) found similar results with female triathletes. One can postulate that these findings might be related to the training specificity that causes local adaptation in active muscles, which then may induce a specific enhancement of mechanical work efficiency. The small difference observed in the cyclists of the present study might be related to the fact that as a group, these athletes were older and had a far greater and more diverse training and racing experience than the other groups. These observations confirm that athletes with a substantial previous cycling experience as a form of exercise training exhibit cycle ergometer $\dot{V}O_{2max}$ values that are equal to or approach those attained on a treadmill (Pechar et al. 1974).

At maximal work rate, significant differences were observed in HR_{max} between tests for all groups, with higher values being attained on the treadmill. These results are in agreement with those of previous reports (Martinez et al. 1993; McArdle and Magel 1970; Medelli et al. 1993; Schneider and Pollack 1991; Zhou et al. 1997), but differ from others in which no significant differences are reported (Hermansen and Saltin 1969; Kohrt et al. 1987; Moreira-Da-Costa et al. 1989; Schneider et al. 1990). As in the present study, the former studies were performed with male and female athletes, while the latter studies included only male athletes. In the present study, without the female runners, the differences in HR_{max} between tests decreased to 3 beats · min^{-1} (190 beats · min^{-1} for the treadmill and 187 beats · min^{-1} for the cycle ergometer), and consequently reduced the mean HR_{max} for all groups. This might be an indication that in an exercise restricted to localized muscle groups such as cycling, the female runners of the present study were probably limited by their small muscle mass and/or by the specificity of movement patterns required on the cycle ergometer, while the two female triathletes (being taller and heavier in addition to being more familiar with the activity) were probably more efficient on the cycle ergometer.

Statistical analysis revealed that when expressed against percentages of $\dot{V}O_{2max}$, the runners' HRs were not significantly different between tests until 90% of $\dot{V}O_{2max}$, while the cyclists and triathletes exhibited distinct HR profiles throughout the tests, since, with the exception of triathletes at 50% of $\dot{V}O_{2max}$, significant differences were observed at each percentage of $\dot{V}O_{2max}$. These results might have been dependent upon the training period, however, because when athletes were tested in their competitive phase, Martinez et al. (1993) showed no HR differences between cycle ergometer and treadmill tests at work intensities expressed as percentages of $\dot{V}O_{2max}$. Moreover, unpublished data from our laboratory show that experienced triathletes obtain similar submaximal HRs when performing cycle ergometer and treadmill tests at the same percentage of $\dot{V}O_{2max}$ in the competitive phase of their training year, corroborating the results of McArdle and Magel (1970), who showed similar HRs in both tests with trained subjects. On the other hand, Hermansen and Saltin (1969) reported a different pattern; their subjects achieved higher HRs on the cycle ergometer than on the treadmill at the same metabolic rates. They assumed that a position effect was responsible, with a reduced venous return and a lower stroke volume occurring when the subjects were in the upright position. However, the trend for higher HRs on the cycle ergometer was reduced with training, since trained subjects demonstrated smaller differences (4 beats · min^{-1}) than untrained subjects (11 beats · min^{-1}).

The results of studies performed with triathletes are equivocal for $\dot{V}_{Emax}$. In some studies subjects achieved a higher $\dot{V}_{Emax}$ on the cycle ergometer than on the treadmill (Dengel et al. 1989; Kreider et al. 1988; Nagle et al. 1971; Schneider et al. 1990), while in other studies results were inconsistent because they used either untrained subjects or single-sport athletes (McArdle and Magel 1970; Pannier et al. 1980; Pechar et al. 1974). In the present study, runners displayed the highest treadmill $\dot{V}_{Emax}$ values; the cyclists achieved their $\dot{V}_{Emax}$ on the cycle ergometer, while the triathletes displayed similar values in both tests. The cyclists displayed the highest $\dot{V}_{Emax}$ values on both tests probably because as a group they were taller and heavier than the two other groups. The statistical analysis also revealed that the cyclists and runners exhibited different $\dot{V}_E$ values at each percentage of $\dot{V}O_{2max}$ tested, whereas the triathletes showed no difference at maximal values, but differences at sub-maximal work intensities. The higher $\dot{V}_E$ values observed in runners during treadmill running was a consequence of their greater mechanical efficiency on the treadmill (calculated at 10.0 km · h^{-1}). This translated into a longer duration of their run in spite of $\dot{V}O_{2max}$ values smaller than those observed in cyclists. As a motor activity, running is more complex than cycling such that a really good runner is able to minimize the energetically expensive vertical variations of his or her center of gravity, thus permitting a more efficient use of his or her aerobic power. Cyclists, on the other hand, displayed a higher $\dot{V}_{Emax}$ during the cycle ergometer test as they were more efficient on this instrument (gross mechanical efficiency calculated at 200 W), while being limited by a less efficient running technique. The importance of mechanical efficiency on the perception of physiological strain appears to be confirmed by the similar $\dot{V}_E$ values observed in triathletes. Since they devote about the same amount of time in each of the training modes studied, the triathletes probably had more similar mechanical efficiencies in both testing modes than did the other two groups.

Although all groups exhibited a higher $\dot{V}O_{2max}$ and HR_{max} on the treadmill than on the cycle ergometer, the triathletes exhibited a lower $\dot{V}O_{2max}$ in the treadmill test, and the runners exhibited the lowest HR for both tests than both of the other groups, HR values achieved on the treadmill were highly correlated to those attained on the cycle ergometer when expressed at a fixed percentage of $\dot{V}O_{2max}$ (Fig. 5). Our results were congruent with those of other studies. Similar observations have been reported by Hermansen and Saltin (1969) who found a high correlation between HRs attained on a cycle ergometer and those attained on a treadmill when expressed at absolute $\dot{V}O_{2max}$. Arts and Kuipers (1994) demonstrated that the relationship between power output, $\dot{V}O_{2max}$ and HR were linear for absolute values as well as for percentages of maximum power output, $\dot{V}O_{2max}$ and HR_{max}, and could be used interchangeably to monitor intensity bouts. On the other hand, Weltman et al. (1990) reported that HR data provide guidelines for exercise prescription for runners of similar ability for durations as short as 15–30 min. Moreover, Boulay et al. (1997) observed that HR was a more stable physiological variable than either $\dot{V}_E$ or blood lactate in an endurance performance test lasting 90 min, and revealed that establishing training intensities with HR results and the corresponding $\dot{V}O_2$ obtained from a common laboratory exercise test remains the most practical approach for controlling exercise intensity during a prolonged workout.

The results of the present study have shown that the HR differences generated by using the HR attained during a cycle ergometer test to predict the HR that would be attained while running were smaller than the habitual intra-individual variations observed while carrying out prolonged training activities. For example, at 70% of $\dot{V}O_{2max}$ these differences were 1 beat $\cdot$ min^{-1} for runners and 2 beats $\cdot$ min^{-1} for triathletes. At a higher training intensity (at $\dot{V}O_{2max}$) the differences reached 3 beats $\cdot$ min^{-1} for cyclists and triathletes and 6 beats $\cdot$ min^{-1} for runners. Therefore, to the athletes and coaches trying to monitor more precisely the density of training, these small statistical differences would appear to be rather non-significant and may very well justify the use of a single progressive test to provide information about training zones in endurance training activities.

Taken together, these results have demonstrated that the relationship between HR and $\dot{V}O_2$ expressed as a percentage of $\dot{V}O_{2max}$, gathered during cycle ergometer or treadmill tests, are interchangeable and can be used to monitor the intensity of activities performed using either mode of exercise. Although trained cyclists would probably prefer a cycle ergometer test and runners a treadmill test, these results are especially interesting for triathletes and other athletes who use a variety of training modes; those athletes may then be able to use only one mode of testing to obtain their training guidelines.

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