RESPONSES DURING EXERCISE AT 90% AND 100% OF THE RUNNING VELOCITY ASSOCIATED WITH

\( \dot{V}O_2_{\text{max}} \) (\( v\dot{VO}_2_{\text{max}} \))

THESIS

Presented to the Graduate Council of the University of North Texas in Partial Fulfillment of the Requirements

For the Degree of

MASTER OF SCIENCE

By

Shane E. Burt, B.A.
Denton, Texas
August 1995
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Six male long-distance runners participated in this study to evaluate the responses to exercise at 90% and 100% vVO$_2$max. Subjects participated in five maximal exercise tests: one incremental, three tests at 90% vVO$_2$max, and one test at 100% vVO$_2$max. The results of this study demonstrate that VO$_2$max can be elicited in a constant-velocity test at 90% vVO$_2$max. This suggests that there is a drift in VO$_2$ at this intensity. Secondly, stability of metabolic responses and the times to exhaustion at 90% of vVO$_2$max is low. Finally, responses to exercise at 90% and 100% of vVO$_2$max are not different. However, while obscured by intra-individual differences, the kinetics of the metabolic response seem faster in the higher intensity tests.
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CHAPTER I

INTRODUCTION

Several physiological variables are related to success in middle and long distance running. Among these variables are maximal aerobic power (\(\text{VO}_2\text{max}\)), anaerobic threshold, and running economy. The velocity associated with \(\text{VO}_2\text{max}\) (\(\text{vVO}_2\text{max}\)) is a measure which combines \(\text{VO}_2\text{max}\) and running economy. It has recently been suggested by Billat, Renoux, Pinoteau, Petit, and Koralsztein (1994b), Lacour, Magunacelaya, Chatard, and Barthélémy (1991), and Noakes, Myburgh, and Schall (1989), that this measure is useful in predicting running performance.

\(\text{vVO}_2\text{max}\) has been determined using different methods in different studies. For example, di Prampero, Atchou, Brückner, and Moia (1986) divided \(\text{VO}_2\text{max}\) by the oxygen cost of running at sub-maximal intensities (C) to calculate \(\text{vVO}_2\text{max}\). Lacour, Padilla-Maguacelaya, Barthélémy, and Dormois (1990) defined \(\text{vVO}_2\text{max}\) as \((\text{VO}_2\text{max} - \text{VO}_2\text{rest}) \cdot (C - \text{VO}_2\text{rest})^{-1}\). Billat (1994b) described \(\text{vVO}_2\text{max}\) as the slowest treadmill speed which elicited \(\text{VO}_2\text{max}\). Noakes et al. (1989) determined \(\text{vVO}_2\text{max}\) as the highest speed maintained for one minute during a progressive exercise test. And, lastly, Morgan, Baldini, Martin, and Kohrt (1989) computed \(\text{vVO}_2\text{max}\) by extrapolation from the submaximal steady state
\( \dot{V}O_2 \) relationship. \( v\dot{V}O_2 \max \) is a measure of aerobic fitness in athletes (Morgan, 1989) and is important in identifying the aerobic differences between various runners (Daniels, Scardina, Hayes, & Foley, 1984). It can also be used to monitor the effects of training in a group of runners (Billat et al., 1994b).

The time to exhaustion, or time limit (Tlim), for running at \( v\dot{V}O_2 \max \) has been shown to be a measure that is positively related to performance. For example, the Tlim at \( v\dot{V}O_2 \max \) is related to average pace in a 21.1 km race (Billat et al., 1994b). Measurement of Tlim at \( \dot{V}O_2 \max \) is a method of identifying physiological responses at this velocity. Tlim can also be used as a performance measure. Athletes can be tested throughout a competitive season to assess training and fitness levels.

\( \dot{V}O_2 \max \) is useful for the distance runner in that it theoretically describes the slowest speed which elicits maximal aerobic power (Billat, Bernard, Pinoteau, Petit, & Koralstein 1994a; Tanaka, Matsuura, Matsuzada, Hirakoba, Kumagai, Sun, & Asano, 1989). Therefore, it is possible that \( \dot{V}O_2 \max \) would be an optimal individualized training pace in order to improve \( \dot{V}O_2 \max \), because it is the intensity that can be sustained for the longest possible duration while eliciting \( \dot{V}O_2 \max \).

To use \( \dot{V}O_2 \max \) in repetition training, it has been suggested that the duration of repeats be individually
determined as a percentage of Tlim at $\bar{V}O_2 \text{max}$ (Anderson, 1994). However, while it is perhaps theoretically sound to use $\bar{V}O_2 \text{max}$ and Tlim at $\bar{V}O_2 \text{max}$ to prescribe training that is individualized in terms of volume and intensity, there are several questions yet to be answered. For example, it is not known if $\bar{V}O_2 \text{max}$ is indeed the lowest velocity that will elicit $V_0 \text{max}$; given that $V_0$ drifts upward during exercise above the anaerobic threshold, it seems possible that $\bar{V}O_2 \text{max}$ might be elicited during prolonged exercise at a submaximal (below $\bar{V}O_2 \text{max}$) velocity.

**Purpose**

The purpose of this investigation was three-fold. First, the goal was to determine if $V_0 \text{max}$ could be elicited during exhaustive exercise at an intensity below $\bar{V}O_2 \text{max}$, specifically, at 90% of $\bar{V}O_2 \text{max}$. The second purpose was to evaluate the stability of responses during exercise at submaximal velocities. The final purpose was to compare the responses to exercise at 90% and 100% of $\bar{V}O_2 \text{max}$.

**Null Hypotheses**

The null hypotheses of this study were (1) that the highest $V_0 \text{max}$ attained during exercise at 90% $\bar{V}O_2 \text{max}$ would not differ from the criterion measure for $V_0 \text{max}$ attained during an incremental test; (2) that cardiorespiratory-metabolic responses and $V_0$ kinetics during three tests at 90% $\bar{V}O_2 \text{max}$ would not differ; and (3) that maximal responses at 90% and 100% of $\bar{V}O_2 \text{max}$ would not differ.
CHAPTER II

REVIEW OF LITERATURE

In this chapter is a discussion of results of previous investigations pertaining to \( V\dot{O}_2 \text{max} \). Results of studies about the Tlim at these velocities is also discussed.

Methods of Determining \( V\dot{O}_2 \text{max} \)

**\( V\dot{O}_2 \text{max} \) is Treadmill Speed**

Billat et al., (1994b) determined \( V\dot{O}_2 \text{max} \) as the minimal speed that elicits \( V\dot{O}_2 \text{max} \). Eight sub-elite male runners participated. Using a progressive exercise protocol, treadmill speed was initially set at 12 km·h\(^{-1}\). Velocity was increased by 2 km·h\(^{-1}\) every three minutes until the subject reached 80% of his speed over a 3 km race. Thereafter, speed was increased by 1 km·h\(^{-1}\) until exhaustion. \( V\dot{O}_2 \text{max} \) was determined by a plateau in \( V\dot{O}_2 \) despite an increase in treadmill speed, and a respiratory exchange ratio (RER) above 1.1. \( V\dot{O}_2 \text{max} \) was the lowest speed which elicited a \( V\dot{O}_2 \) equal to \( V\dot{O}_2 \text{max} \).

In another study by Billat (1994a), \( V\dot{O}_2 \text{max} \) was defined as being \( V\dot{O}_2 \text{max} \) divided by running economy. However, the same progressive exercise test was used as described previously. This study used subjects who participated in the half-marathon at a national level in France. Thirty-eight male long distance runners participated in this study.
\( \dot{V}O_{2,\text{max}} \) is the Last Treadmill Speed Sustained for 1 min

Noakes et al. (1990) determined \( \dot{V}O_{2,\text{max}} \) as the highest velocity sustained for 1 min in an incremental test. Subjects were 20 marathon runners and 23 half-marathon runners. Initial treadmill speed was 10 km·h\(^{-1}\), with increments of 1 km·h\(^{-1}\) every minute until exhaustion. If the last stage was not sustained for 1 min, the treadmill velocity of the previous stage was taken as the \( \dot{V}O_{2,\text{max}} \).

\( \dot{V}O_{2,\text{max}} \) is Calculated from \( VO_{2,\text{max}} \) and Running Economy

Di Prampero (1986) determined \( \dot{V}O_{2,\text{max}} \) using the equation, \( \dot{V}O_{2,\text{max}} = VO_{2,\text{max}} \cdot C^{-1} \), where \( C \) is the energy cost of running, determined by the metabolic power divided by the speed of locomotion. The 36 male distance runners who participated in this study were marathon and half-marathon specialists. Testing took place one to four weeks after competition. Subjects ran on a treadmill for six minutes at four different speeds. 85\%, 100\%, 120\%, and 130\% of the average speed they sustained throughout a marathon or half-marathon race. The energy cost at each speed was calculated as \( O_2 \) uptake per m·min\(^{-1}\).

\( \dot{V}O_{2,\text{max}} \) is Calculated from \( VO_{2,\text{max}} \) and Running Economy with a Correction for Resting \( VO_2 \)

Lacour et al. (1991) calculated \( \dot{V}O_{2,\text{max}} \) using the equation \( (VO_2 - \text{rest}VO_2) \cdot (C - \dot{V}O_{2,\text{rest}})^{-1} \). Subjects ran for 4 minutes at each speed, and rested for 1 minute after each stage. The initial speed was set at 10.3 km·h\(^{-1}\) and was
increased by 1.54 km·h⁻¹ until exhaustion. Speeds at each stage were verified with stopwatch recordings of 15 treadmill belt revolutions. This study used 24 male and 8 female runners who competed in the 800 m. The value for resting $\text{VO}_2$, 5 ml·kg⁻¹·min⁻¹, established by Medbo, Mohn, Tabata, Bahr, Vaage, and Sejersted (1988), represents the average y-intercept of the linear $\text{VO}_2$:velocity relationship. $C$ was calculated as the mean of the two values for the oxygen cost of running obtained during the last two stages prior to attainment of $\text{VO}_2\text{max}$.

$v\text{VO}_2\text{max}$ is Determined by Extrapolation of the $\text{VO}_2$:Velocity Relationship

Morgan et al. (1989) used a regression equation in order to calculate $v\text{VO}_2\text{max}$, which they described as $\text{VO}_2\text{max}$ divided by running economy. Using 10 trained long distance runners, calculation of $\text{VO}_2\text{max}$ was performed using data collected during a treadmill test in which subjects ran at 0% slope at paces of 1 min·mile⁻¹ slower than their estimated 5 km pace for the first minute and 0.5 min·mile⁻¹ slower than their 5 km pace for the second minute. At the third minute, treadmill speed was increased to the estimated 5 km race pace and remained constant thereafter. After the first 2 min at this pace treadmill elevation was increased by 2% every 2 min until exhaustion. In order to verify that a plateau in $\text{VO}_2$ had been obtained subjects performed a 4 min supramaximal test. Over the next 2 to 4 weeks, subjects
performed three running economy tests. The tests began with a 5-min warmup at 3.57 m·s⁻¹, followed by four 6-min running bouts at 3.83, 4.13, 4.47, and 4.88 m·s⁻¹. There was a 5-min rest period between each treadmill speed in which stopwatch recordings of 40 belt revolutions were taken. 

\( v\tilde{V}_{O_2,\text{max}} \) was calculated with linear regression of mean submaximal \( V_{O_2} \) against the four submaximal running speeds; \( v\tilde{V}_{O_2,\text{max}} \) was the predicted velocity at \( V_{O_2,\text{max}} \). The authors noted that athletes who had similar \( V_{O_2,\text{max}} \) values had large differences in running economy which could possibly explain the variance in running performance.

**\( v\tilde{V}_{O_2,\text{max}} \) and Performance**

Billat et al. (1994a) and Billat et al. (1994b) demonstrated that \( v\tilde{V}_{O_2,\text{max}} \) was positively related to pace in a 21.1 km race (\( r=0.73, p<0.05 \)) and (\( r=0.72, p<0.05 \)), respectively.

di Prampero et al. (1986) have demonstrated that the \( v\tilde{V}_{O_2,\text{max}} \) accounts for 70% of the individual variability in performance. The calculated velocities were found to be linearly correlated with the average speed sustained by their 36 subjects throughout a marathon or half-marathon (\( r^2=0.72 \)). They noted that \( v\tilde{V}_{O_2,\text{max}} \) is a good descriptor of performance because the runners' metabolic characteristics are defined by the numerator and the running economy is described by the denominator. An increase in running performance would be a result of an increase of the
fractional use of oxygen and/or \( \dot{V}O_2\max \) and/or a decrease in the oxygen cost of running.

\( \dot{V}O_2\max \) has been found to be related to performance in a variety of track and field distances greater than 800 m. Lacour et al. (1990) found that \( \dot{V}O_2\max \) was strongly related to races sustained over 1500 m \((r=0.62, p<0.01)\) and 5000 m \((r=0.86, p<0.001)\). In a later study, Lacour et al. (1991) found that \( \dot{V}O_2\max \) was highly correlated with velocity sustained over 1500 m \((r=0.90, p<0.01)\).

A significant relationship has been reported between \( \dot{V}O_2\max \) and 10 km run time \((r=-0.87, p<0.01)\). Athletes with similar \( \dot{V}O_2\max \) values could sustain \( \dot{V}O_2\max \) longer if they had a greater running economy (Morgan et al., 1989). The researchers concluded that measurement of \( \dot{V}O_2\max \) is useful in determining training status and as a predictor of running performance in middle and long distance runners.

Responses to Exercise at \( \dot{V}O_2\max \)

**Attainment of \( \dot{V}O_2\max \)**

Although, incremental and constant velocity tests have been used to measure \( \dot{V}O_2\max \), little research has assessed if there are differences between the values obtained by the two methods. However, the consensus is that \( \dot{V}O_2\max \) can be obtained using either method.

LaVoie and Mercer (1987) have found that \( \dot{V}O_2\max \) values obtained using an incremental test were significantly higher than the values obtained using a constant-load test.
found that the constant-load tests had lower values for heart rate and ventilation, and higher values for RER. They concluded that local muscular fatigue in the subjects' legs was responsible for the lower \( \dot{VO}_2 \text{max} \). The subjects were five women who exercised to exhaustion on a cycle ergometer. One incremental test was performed followed by a constant-load exercise test a week later.

Stamford (1976) tested ten male students using five maximal treadmill tests. The subjects performed a random combination of: a progressive, step increment, continuous test; a progressive, step increment, discontinuous test; and a constant-load test. All correlation coefficients were significant and had a high degree of relationship between tests \((r=0.89 \text{ to } 0.93, \ p<0.01)\).

Katz, Snell, and Stray-Gunderson (1989) tested 20 male and 4 female trained runners using a incremental treadmill protocol and a constant-velocity protocol. Mean \( \dot{VO}_2 \text{max} \) was not significantly different \((58.2\pm5.8 \text{ and } 58.4\pm6.6 \text{ ml \cdot kg}^{-1} \cdot \text{min}^{-1}, \ \text{respectively})\) and values were significantly correlated \((r=0.89, \ p<0.01)\).

Billat, Renoux, Pinoteau, Petit, and Koralsztein (1994d) found that \( \dot{VO}_2 \text{max} \) was the same for incremental and constant velocity tests. Only the mean \( \dot{VO}_2 \text{max} \) for the incremental test was provided \((69.4\pm3.7 \text{ ml \cdot kg}^{-1} \cdot \text{min}^{-1})\). It
was reported that values from the two tests were significantly correlated.

**VO\textsubscript{2} Kinetics**

The kinetics of the VO\textsubscript{2} response to constant load exercise may, most simply, be described by a mono-exponential model, although more complicated models have been proposed (Whipp, 1994; Barstow, 1994). The mono-exponential model is given as $\dot{V}O_2(t) = \dot{V}O_2\text{rest} + (\dot{V}O_2\text{max} - \dot{V}O_2\text{rest}) \cdot (1 - e^{-t/\tau})$. $\tau$, the time constant of the response, which describes the rate of the response (i.e., the time for 63% of the ultimate increase) independent of $\dot{V}O_2\text{max}$, is about 30 seconds (Péronnet and Thibault, 1989). It may be influenced by several factors, such as initial or final intensity, mode of exercise, state of training, or time of day. At intensities close to but above the lactate threshold, there is a delay in VO\textsubscript{2} attainment of a steady-state. At 100 to 200 s into exercise, there is a second (delayed) rise in VO\textsubscript{2}. This steady rise in VO\textsubscript{2} has been hypothesized to be caused by an increase in blood lactate (Poole, 1995) and an increase in recruitment of Type IIb muscle fibers (Willis & Jackman, 1995).

Billat et al. (1995) have reported that during exercise at $\dot{V}O_2\text{max}$, $\dot{V}O_2\text{max}$ is achieved within 97 s: this would suggest that $\tau$ was about 20 s at this intensity. It would also mean that $\dot{V}O_2\text{max}$ was sustained for about 297 s ($T_{\text{lim}}$ was 394 s). On the other hand, it has been found that
\( \dot{V}O_2 \text{max} \) is not attained until 234 s into exercise at \( v \dot{V}O_2 \text{max} \) (Hill and Rowell, personal communication, April 1995). In that study, Tlim was 290 s, so \( \dot{V}O_2 \text{max} \) was sustained for only 56 s.

**Tlim and Performance**

Billat et al. (1994b) found that those athletes who could sustain exercise at \( v \dot{V}O_2 \text{max} \) for a longer duration were able to obtain a higher lactate concentration later on in a progressive exercise test. The Tlim at \( v \dot{V}O_2 \text{max} \) was found to be significantly related to lactate threshold expressed as a percentage of \( \dot{V}O_2 \text{max} \) \( (r=0.745, p<0.03) \). It was found that those runners who performed longer at \( v \dot{V}O_2 \text{max} \) were able to obtain the highest maximal aerobic power outputs.

**Reliability of Tlim at \( v \dot{V}O_2 \text{max} \)**

Mean values for Tlim at \( v \dot{V}O_2 \text{max} \) have ranged from 378 ± 121 s (Billat, 1994a) to 404 ± 101 s and 402 ± 113 s (Billat et al. 1994b). But the reliability of Tlim at \( v \dot{V}O_2 \text{max} \) has been directly addressed in only one study (Billat et al., 1994b). After determination of \( v \dot{V}O_2 \text{max} \), subjects performed two exhaustive tests at this velocity. The tests were separated by one week. There were no significant differences between test-retest values for Tlim at \( v \dot{V}O_2 \text{max} \). Mean Tlim were 404 ± 101 vs 402 ± 113 and the times in the two tests were correlated \( (r=0.86, p<0.05) \). However, there was a wide within-subject variability in test-retest values \( (\text{coefficient of variation} = 25\%) \).
In a recent report (McLellan, Cheung, & Jacobs, 1995) it was suggested that Tlim at about 80% of \( \dot{V}O_2 \text{max} \) was subject to considerable intra-individual variation (CV=17%). The authors concluded that the Tlim at less than 100% of \( \dot{V}O_2 \text{max} \) are variable because exercise tests are longer in duration and, in addition to energy demand and \( O_2 \) utilization, familiarization with testing procedures and day to day variations in motivation, diet and hydration may influence the results. When comparing other modes of testing Tlim (time-trials, incremental tests, and \( \dot{V}O_2 \text{max} \)), it was found that there was less variability in Tlim at \( \dot{V}O_2 \text{max} \) than in Tlim for given percentages of \( \dot{V}O_2 \text{max} \).

**Summary**

The question of \( \dot{V}O_2 \text{max} \) being attained in a constant velocity test has been addressed in only a few studies. The consensus is that values for \( \dot{V}O_2 \text{max} \) are the same when using either a incremental or constant velocity test. Theoretically \( \dot{V}O_2 \text{max} \) is the minimal speed which elicits \( \dot{V}O_2 \text{max} \). However, it is possible that \( \dot{V}O_2 \text{max} \) might be elicited at lower velocities. The first purpose of this study was to determine if \( \dot{V}O_2 \text{max} \) could be elicited during exhaustive exercise at 90% of \( \dot{V}O_2 \text{max} \). The second purpose was to evaluate the stability of responses during exercise at 90% of \( \dot{V}O_2 \text{max} \). The final purpose was to compare the responses to constant-velocity exercise at 90% and 100% \( \dot{V}O_2 \text{max} \).
CHAPTER III

METHODS AND MATERIALS

The procedures employed to determine $\dot{V}O_2\text{max}$ and responses to all-out exercise at $\dot{V}O_2\text{max}$ are explained in this chapter. Subject characteristics, the process of recording the metabolic responses during testing, methods in determining treadmill speeds, and statistical methods employed for analysis of data are other topics of discussion in this section.

Overview

$\dot{V}O_2\text{max}$ was calculated as the treadmill speed at which $V_2\text{max}$ was elicited in an incremental treadmill test. Each subject participated in three all-out efforts at 90% $\dot{V}O_2\text{max}$ to determine (1) if $V_2\text{max}$ could be elicited at this velocity and (2) to evaluate the stability of TLim and other responses at this velocity. All tests were administered at the same time of day for each subject with at least 24 hours separating each test to provide complete rest. A fourth constant-velocity test was then performed at 100% of $\dot{V}O_2\text{max}$ in order to compare Tlim and the physiological responses to the incremental test and 90% of $\dot{V}O_2\text{max}$.

Subject Characteristics
Six male middle and long distance runners participated in this study. Subjects' descriptive characteristics are presented in Table 1, with individual data listed in Appendix A. Written informed consent (Appendix B) was obtained in accordance with the policy statements of the American College of Sports Medicine (ACSM) for the protection of human subjects (ACSM, 1991). The study was approved by the Institutional Review Board of the University of North Texas.

Table 1. Mean (±SD) Subject Characteristics

<table>
<thead>
<tr>
<th>Age (yr)</th>
<th>Weight (kg)</th>
<th>Height (cm)</th>
</tr>
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<tbody>
<tr>
<td>24 ± 4</td>
<td>70.0 ± 6.2</td>
<td>178.5 ± 6.5</td>
</tr>
</tbody>
</table>

Data Collection Procedures

**Calculation of VO₂ max**

All subjects performed one incremental test in order to directly determine VO₂ max and vVO₂ max. Incremental tests were performed until exhaustion at a 0% slope on a treadmill. The initial speed was set at 7.0 mph (3.30 m·s⁻¹) for 4 min followed by another 4 min at 8.0 mph (3.77 m·s⁻¹). All subsequent stages were 2 min in duration with the velocities increasing by 0.5 mph (0.24 m·s⁻¹). All treadmill speeds were verified by stopwatch recordings of 20 belt revolutions.
Expired gases were collected continuously during all tests with the use of a CPX metabolic cart (Medical Graphics Inc, St. Paul, MN). Calibration of the pneumotach was performed using a calibrated 3 liter syringe. Prior to each test, O₂ and CO₂ analyzers were calibrated according to the manufacturer’s instruction using gases of known concentration. Oxygen uptake and other cardiorespiratory measures were obtained on a breath by breath basis. Breath by breath data were reduced to 15-s averages from which rolling 30-s averages (first breath and subsequent breaths over 30-s followed by second breath over 30-s and so on) were calculated. VO₂max was determined as the highest 30-s average. Similarly, the highest 30-s average for Vₚ was taken as V̇ₚmax and the highest 30-s average for RER was recorded as the maximal RER. The highest 30-s values in any given test are referred to as max.

Calculation of vVO₂max

vVO₂max was determined by the methodology of Billat et al. 1994b, as the speed at which VO₂max was achieved. Data recorded from the incremental treadmill tests were evaluated as described above to determine VO₂max, and the treadmill velocity at which VO₂max was attained was recorded as vVO₂max.

TLim and Other Responses at vVO₂max

Subjects performed three tests at 90% vVO₂max and one test at 100% of vVO₂max, each on a separate day. Each test
began with a warmup at 7 mph (3.30 m·s−1) for 5 min, followed by a 3-min rest period. In this rest period, treadmill speed (v\(\text{VO}_{2\text{max}}\)) was set and verified by counting 20 treadmill belt revolutions. As with the incremental test, expired gases were analyzed on a breath by breath basis, 15-s means were calculated, and 30-s rolling averages were recorded. \(\text{VO}_{2}\), \(\dot{V}_{\text{E}}\), and RER were measured, and the highest of these values were taken as \(\text{VO}_{2\text{max}}\), \(\dot{V}_{\text{Emax}}\), and maximal RER, respectively.

**Percentages of Time To and Time At \(\text{VO}_{2\text{max}}\)**

Print-outs of all tests were visually inspected for the time to and the time at 95% and 100% of \(\text{VO}_{2\text{max}}\). The time to \(\text{VO}_{2\text{max}}\) was determined as the time it took to reach the first 15-s period which elicited \(\text{VO}_{2\text{max}}\). Time to 95% of \(\text{VO}_{2\text{max}}\) was determined in the same way. Time at 95% of \(\text{VO}_{2\text{max}}\) was calculated as the difference between TLim and the time to 95% of \(\text{VO}_{2\text{max}}\). Similarly, time at 100% of \(\text{VO}_{2\text{max}}\) was calculated as the time in which 100% of \(\text{VO}_{2\text{max}}\) was achieved until the test was terminated. In each case, "\(\text{VO}_{2\text{max}}\)" refers to the \(\text{VO}_{2\text{max}}\) achieved in the particular test.

**\(\text{VO}_{2}\) Kinetics**

The breath by breath metabolic data collected during the first 2 min of exercise at 90% \(v\text{VO}_{2\text{max}}\) and 100% \(v\text{VO}_{2\text{max}}\) were reduced to rolling eight-breath averages. These data were fit to a mono-exponential model, \(\text{VO}_{2}(t) = \text{VO}_{2\text{rest}} + (\text{VO}_{2\text{max}} -\text{VO}_{2\text{rest}}) \cdot (1 - e^{-t/T})\) using a nonlinear regression
procedures on SPSS (Chicago, IL, USA) to derive values for the time constant (τ) and expected $\dot{V}O_2\text{max}$. The program also generates a standard error of the estimate (SEE) for each parameter and an $R^2$ value that describes the overall fit of the data to the model.

The time from the onset of exercise until 95% and 100% of $\dot{V}O_2\text{max}$ were expected to be achieved, based on the kinetics in the first 2 min, were calculated assuming that the maximal value for $\dot{V}O_2$ would be attained at $t=5\tau$. The time from the onset of exercise until 95% of $\dot{V}O_2\text{max}$ was predicted to be achieved was calculated with $t=2.4\tau$. The time spent at $\dot{V}O_2\text{max}$, or above 95% of $\dot{V}O_2\text{max}$, was calculated by subtracting the time to achieve that value from $T\text{lim}$.

Statistical Procedures

A one-way repeated measures ANOVA was used to evaluate responses during the three efforts at 90% $\dot{V}\dot{V}O_2\text{max}$. Follow-up Tukey post hoc tests and correlations were used, as appropriate, to further evaluate results. Repeated measures ANOVA were also used to evaluate responses to 90% and 100% $\dot{V}\dot{V}O_2\text{max}$ and responses across all five treadmill tests. All results are presented as means ± SD. Statistical significance was set at the 0.05 level.
CHAPTER IV

RESULTS

The primary purpose of this study was to determine if exercise at 90% \( \mathit{\dot{V}O}_2\max \) could elicit \( \mathit{VO}_2\max \). The second purpose was to evaluate the stability of responses during exercise at 90% \( \mathit{\dot{V}O}_2\max \) over three trials. The final purpose was to compare responses to exercise at 90% \( \mathit{\dot{V}O}_2\max \) and 100% \( \mathit{\dot{V}O}_2\max \). The results of this study are presented in this chapter.

Responses to Incremental and Constant-Velocity Tests

Table 2 presents responses to incremental tests and constant-velocity tests at 90% and 100% of \( \mathit{\dot{V}O}_2\max \). Mean values and the results of the repeated measures ANOVA across the five trials are included in the table. Mean values for \( \mathit{\dot{V}O}_2\max \) in the constant-velocity tests (including the three tests at 90% \( \mathit{\dot{V}O}_2\max \)) were not different (\( F_{4,19}=0.66, \ p=0.63 \)) from the criterion measure for \( \mathit{VO}_2\max \) determined in the incremental test.

Similarly, no differences were found across trials in \( \dot{V}_e \max \) (\( F_{4,15}=0.91, \ p=0.48 \)) or in RER\( \max \) (\( F_{4,15}=2.12, \ p=0.12 \)).
Table 2. Responses to Incremental and Constant-Velocity Tests

<table>
<thead>
<tr>
<th>TEST</th>
<th>90-1</th>
<th>90-2</th>
<th>90-3</th>
<th>100</th>
<th>Incremental</th>
<th>ANOVA</th>
</tr>
</thead>
<tbody>
<tr>
<td>( \dot{V}O_2 ) max</td>
<td>4750 ± 891</td>
<td>4593 ± 550</td>
<td>4455 ± 536</td>
<td>4571 ± 502</td>
<td>4491 ± 761</td>
<td>( F_{4,19}=0.66 )</td>
</tr>
<tr>
<td>( V_e ) max</td>
<td>159.4 ± 17</td>
<td>157.2 ± 24</td>
<td>154.9 ± 21</td>
<td>164.7 ± 12.9</td>
<td>166.8 ± 27</td>
<td>( F_{4,19}=0.91 )</td>
</tr>
<tr>
<td>RER max</td>
<td>1.18 ± 0.1</td>
<td>1.23 ± 0.1</td>
<td>1.31 ± 0.2</td>
<td>1.33 ± 0.1</td>
<td>1.27 ± 0.1</td>
<td>( F_{4,19}=2.21 )</td>
</tr>
</tbody>
</table>

\( \dot{V}O_2 \) max (ml·min\(^{-1}\))

\( V_e \) max (ml·min\(^{-1}\))
Stability of Responses at 90% \( \dot{V}O_2 \)max

Mean values for responses at 90% \( \dot{V}O_2 \)max are presented in Table 3 along with the results of repeated measures ANOVA and post hoc Tukey tests.

**Velocity**

The actual mean treadmill velocities for the three tests at 90% \( \dot{V}O_2 \)max were 291±17, 291±17, and 292±17 m·min\(^{-1}\). The means were not significantly different.

**TLim**

The mean values for TLim at 90% \( \dot{V}O_2 \)max were 675±171 s, 710±199 s, and 657±235 s. There were no significant differences between these TLim \( (F_{2,10}=0.29, \ p=0.75) \).

**\( \dot{V}O_2 \)max**

The means for \( \dot{V}O_2 \)max in the three tests were 4750±891, 4593±550, and 4455±536 ml·kg\(^{-1}\)·min\(^{-1}\). No significant differences were found across the three tests \( (F_{2,10}=0.69, \ p=0.53) \).

**Time To and Time At Percentages of \( \dot{V}O_2 \)max**

Table 3 presents the mean values for the time to attain 95% or 100% of \( \dot{V}O_2 \)max and the time that 95% and 100% of \( \dot{V}O_2 \)max was sustained. These values were calculated based on the \( \dot{V}O_2 \)max achieved in the particular constant velocity test.

**\( \tau \) and Predicted \( \dot{V}O_2 \)max**

The kinetic responses derived from 2 min of data are presented in Table 3. Included are the mean values for the time constant (\( \tau \)), the SEE of \( \tau \), predicted \( \dot{V}O_2 \)max, the SEE of
$\text{\textit{VO}_2\text{max}}$, and $R^2$. There were no differences across the three tests in any of the kinetics variables.

Responses to Exercise at 90% and 100% of $v\text{\textit{VO}_2\text{max}}$

Responses to exercise during the tests at 90% $v\text{\textit{VO}_2\text{max}}$, and 100% $v\text{\textit{VO}_2\text{max}}$ as well as the results of ANOVA and Tukey post hoc tests are presented in Table 4.

$\text{\textit{TLim}}$

The mean $\text{\textit{TLim}}$ at 100% $v\text{\textit{VO}_2\text{max}}$ was $330\pm84$ s. There were significant differences in $\text{\textit{TLim}}$ in the four tests at 90% $v\text{\textit{VO}_2\text{max}}$ and 100% $v\text{\textit{VO}_2\text{max}}$ ($F_{3,15}=14.16$, $p<0.01$). Results of Tukey post hoc tests revealed differences between $\text{\textit{TLim}}$ in the three tests at 90% of $v\text{\textit{VO}_2\text{max}}$ compared to $\text{\textit{TLim}}$ in the test at 100% $v\text{\textit{VO}_2\text{max}}$.

$\text{\textit{VO}_2\text{max}}$

The mean $\text{\textit{VO}_2\text{max}}$ in the test at 100% $v\text{\textit{VO}_2\text{max}}$ was $4571\pm502$ ml·kg$^{-1}$·min$^{-1}$. This was not statistically different from the $\text{\textit{VO}_2\text{max}}$ recorded in the tests at 90% $v\text{\textit{VO}_2\text{max}}$ ($F_{3,15}=0.54$, $p=0.65$).

Time To and Time At 95% and 100% of $\text{\textit{VO}_2\text{max}}$

Table 4 provides the means of the times to achieve 95% and 100% of $\text{\textit{VO}_2\text{max}}$ and the times that 95% and 100% $\text{\textit{VO}_2\text{max}}$ was sustained. Following the determination of $\text{\textit{VO}_2\text{max}}$ in each test, time to $\text{\textit{VO}_2\text{max}}$ (or 95% of $\text{\textit{VO}_2\text{max}}$) was defined as the time span between the onset of the treadmill test and the middle of the 15-s period when the $\text{\textit{VO}_2\text{max}}$ (or 95%) was
first achieved. Time at 95% or 100% of VO$_2$max is defined as the TLim minus the time to achieve that percentage.

1 and Predicted VO2max

The kinetics responses derived from 2 min of data are presented in Table 4. Included are the mean values for the time constant ($\tau$), the SEE $\tau$, predicted VO$_2$max, the SEE of VO$_2$max, and $R^2$. 
Table 3. Responses at 90% \( \dot{\text{VO}}_2 \text{max} \)

<table>
<thead>
<tr>
<th>TEST</th>
<th>90-1</th>
<th>90-2</th>
<th>90-3</th>
<th>ANOVA</th>
<th>Pearson r</th>
</tr>
</thead>
<tbody>
<tr>
<td>Velocity (m·min(^{-1}))</td>
<td>291 ±17</td>
<td>291 ±17</td>
<td>292 ±17</td>
<td>( F_{2,10}=0.04, , p=0.96 )</td>
<td>1-2 2-3 1-3</td>
</tr>
<tr>
<td>TLim (s)</td>
<td>675 ±171</td>
<td>710 ±199</td>
<td>675 ±235</td>
<td>( F_{2,10}=0.29, , p=0.75 )</td>
<td>.86  .31  .65</td>
</tr>
<tr>
<td>( \dot{\text{VO}}_2 \text{max} ) (ml·min(^{-1}))</td>
<td>4750 ±891</td>
<td>4593 ±550</td>
<td>4455 ±536</td>
<td>( F_{2,10}=0.69, , p=0.53 )</td>
<td>.41  .85* .71</td>
</tr>
<tr>
<td>( \dot{V}_L \text{max} ) (ml·min(^{-1}))</td>
<td>159.4 ±17</td>
<td>157.2 ±24</td>
<td>154.9 ±21</td>
<td>( F_{2,10}=0.37, , p=0.70 )</td>
<td></td>
</tr>
<tr>
<td>RERmax</td>
<td>1.18 ±0.02</td>
<td>1.23 ±0.1</td>
<td>1.31 ±0.2</td>
<td>( F_{2,10}=1.56, , p=0.26 )</td>
<td></td>
</tr>
<tr>
<td>TT95_CV (s)</td>
<td>271 ±155</td>
<td>275 ±157</td>
<td>355 ±173</td>
<td>( F_{2,10}=0.56, , p=0.59 )</td>
<td>.55  -.33  .03</td>
</tr>
<tr>
<td>TT100_CV (s)</td>
<td>509 ±184</td>
<td>526 ±204</td>
<td>568 ±194</td>
<td>( F_{2,10}=0.23, , p=0.80 )</td>
<td>-0.04 .35 .82*</td>
</tr>
<tr>
<td>TA95_CV (s)</td>
<td>404 ±228</td>
<td>435 ±246</td>
<td>302 ±184</td>
<td>( F_{2,10}=1.14, , p=0.36 )</td>
<td>.59  .56  .75</td>
</tr>
<tr>
<td>TA100_CV</td>
<td>166 ±165</td>
<td>184 ±285</td>
<td>89 ±110</td>
<td>F&lt;sub&gt;2.10&lt;/sub&gt;=0.36, p=0.71</td>
<td>-.25</td>
</tr>
<tr>
<td>------------</td>
<td>-----------</td>
<td>-----------</td>
<td>--------</td>
<td>-------------------------------</td>
<td>------</td>
</tr>
<tr>
<td>τ</td>
<td>35 ±7</td>
<td>33 ±7</td>
<td>34 ±7</td>
<td>F&lt;sub&gt;2.10&lt;/sub&gt;=0.25, p=0.78</td>
<td>-.11</td>
</tr>
<tr>
<td>SEE</td>
<td>2 ±1</td>
<td>2 ±1</td>
<td>2 ±1</td>
<td>F&lt;sub&gt;2.10&lt;/sub&gt;=0.04, p=0.96</td>
<td></td>
</tr>
<tr>
<td>'VO&lt;sub&gt;2max&lt;/sub&gt;</td>
<td>4240 ±520</td>
<td>4185 ±381</td>
<td>4178 ±522</td>
<td>F&lt;sub&gt;2.10&lt;/sub&gt;=0.05, p=0.95</td>
<td>.34</td>
</tr>
<tr>
<td>'SEE</td>
<td>66 ±22</td>
<td>60 ±28</td>
<td>59 ±30</td>
<td>F&lt;sub&gt;2.10&lt;/sub&gt;=0.10, p=0.90</td>
<td></td>
</tr>
<tr>
<td>R²</td>
<td>0.94 ±0.03</td>
<td>0.93 ±0.04</td>
<td>0.94 ±0.04</td>
<td>F&lt;sub&gt;2.10&lt;/sub&gt;=0.15, p=0.86</td>
<td></td>
</tr>
</tbody>
</table>

'VO<sub>2max</sub>= predicted VO<sub>2max</sub> (ml·min<sup>-1</sup>)

'SEE= standard error of predicted VO<sub>2max</sub>

* p<0.05
Table 4. Responses to Constant-Velocity Tests at 90% and 100% \( \dot{V}O_2 \text{max} \).

<table>
<thead>
<tr>
<th>Exercise Test</th>
<th>90-1</th>
<th>90-2</th>
<th>90-3</th>
<th>100</th>
<th>ANOVA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Velocity (m·min(^{-1}))</td>
<td>291 ±17</td>
<td>291 ±17</td>
<td>292 ±17</td>
<td>317.8 ±27.0</td>
<td></td>
</tr>
<tr>
<td>TLim (s)</td>
<td>675 ±171(^a)</td>
<td>710 ±199(^a)</td>
<td>675 ±235(^a)</td>
<td>329.8 ±84(^b)</td>
<td>( F_{3,15}=14.16, p&lt;0.01 )</td>
</tr>
<tr>
<td>( \dot{V}O_2 \text{max} ) (ml·min(^{-1}))</td>
<td>4750 ±891</td>
<td>4593 ±550</td>
<td>4455 ±536</td>
<td>4571 ±502</td>
<td>( F_{3,15}=0.54, p=0.66 )</td>
</tr>
<tr>
<td>( V_e \text{max} ) (ml·min(^{-1}))</td>
<td>159.4 ±17</td>
<td>157.2 ±24</td>
<td>154.9 ±21</td>
<td>164.7 ±12.9</td>
<td>( F_{3,15}=1.14, p=0.36 )</td>
</tr>
<tr>
<td>RER\text{max}</td>
<td>1.18 ±0.02</td>
<td>1.23 ±0.07</td>
<td>1.31 ±0.20</td>
<td>1.33 ±0.06</td>
<td>( F_{3,15}=2.21, p=0.13 )</td>
</tr>
<tr>
<td>TT95_CV (s)</td>
<td>271 ±155</td>
<td>275 ±157</td>
<td>355 ±173</td>
<td>177.5 ±68.7</td>
<td>( F_{3,15}=1.84, p=0.18 )</td>
</tr>
<tr>
<td>TT100_CV (s)</td>
<td>509 ±184(^a)</td>
<td>526 ±204(^a)</td>
<td>568 ±194(^a)</td>
<td>310 ±89(^b)</td>
<td>( F_{3,15}=4.28, p=0.02 )</td>
</tr>
<tr>
<td>TA95_CV (s)</td>
<td>404 ±228(^a)</td>
<td>436 ±246(^a)</td>
<td>302 ±184(^ab)</td>
<td>152 ±61(^b)</td>
<td>( F_{3,15}=4.63, p=0.02 )</td>
</tr>
<tr>
<td></td>
<td>TA100_CV</td>
<td>TA95_CV</td>
<td>TA100_CV</td>
<td>95% VO_2 max</td>
<td>100% VO_2 max</td>
</tr>
<tr>
<td>---------------</td>
<td>-----------</td>
<td>-----------</td>
<td>-----------</td>
<td>--------------</td>
<td>---------------</td>
</tr>
<tr>
<td>(s)</td>
<td>166 ±165</td>
<td>184 ±285</td>
<td>89 ±110</td>
<td>20 ±18</td>
<td>F&lt;sub&gt;3.15&lt;/sub&gt;=1.12, p=0.37</td>
</tr>
<tr>
<td>(s)</td>
<td>35 ±7</td>
<td>33 ±6</td>
<td>34 ±7</td>
<td>38 ±17</td>
<td>F&lt;sub&gt;2.10&lt;/sub&gt;=0.26, p=0.85</td>
</tr>
<tr>
<td>SEenity</td>
<td>1.83 ±1</td>
<td>1.91 ±1</td>
<td>1.73 ±1</td>
<td>2.96 ±4</td>
<td>F&lt;sub&gt;2.10&lt;/sub&gt;=0.37, p=0.78</td>
</tr>
<tr>
<td>'VO_2 max</td>
<td>4240 ±520</td>
<td>4185 ±381</td>
<td>4178 ±522</td>
<td>4559 ±751</td>
<td>F&lt;sub&gt;2.10&lt;/sub&gt;=1.35, p=0.30</td>
</tr>
<tr>
<td>'SEE</td>
<td>66.4 ±22</td>
<td>60.4 ±28</td>
<td>59.2 ±30</td>
<td>117.1 ±161</td>
<td>F&lt;sub&gt;2.10&lt;/sub&gt;=0.60, p=0.62</td>
</tr>
<tr>
<td>R²</td>
<td>0.94 ±0.03</td>
<td>0.93 ±0.04</td>
<td>0.94 ±0.04</td>
<td>0.94 ±0.05</td>
<td>F&lt;sub&gt;2.10&lt;/sub&gt;=0.08, p=0.97</td>
</tr>
</tbody>
</table>

TT95_CV=Time to 95% of constant velocity VO_2 max
TT100_CV=Time to 100% of constant velocity VO_2 max
TA95_CV=Time at 95% of constant velocity VO_2 max
TA100_CV=Time at 100% of constant velocity VO_2 max
'VO_2 max'= predicted VO_2 max (ml·min⁻¹)
'SEE'= standard error of VO_2 max'

Values with similar subscripts did not differ (Tukey, p>0.05)
CHAPTER V

DISCUSSION

The purpose of this study was three-fold. First, the goal was to determine if $V\dot{O}_2\text{max}$ could be elicited during exhaustive exercise at an intensity below $v\dot{V}O_2\text{max}$, namely 90% of $v\dot{V}O_2\text{max}$. The second purpose was to evaluate the stability of responses at these submaximal velocities. And the third aim was to compare responses to exercise at 90% $v\dot{V}O_2\text{max}$ and 100% $v\dot{V}O_2\text{max}$. Subjects' participated in one incremental treadmill test in order to determine $v\dot{V}O_2\text{max}$ and cardiorespiratory-metabolic responses to a maximal incremental test. Next, subjects' participated in three all-out efforts at 90% of $v\dot{V}O_2\text{max}$ and one final test at 100% $v\dot{V}O_2\text{max}$ in order to determine the stability of responses at 90% $v\dot{V}O_2\text{max}$ and to allow comparison of responses to incremental exercise and constant-velocity exercise at these two intensities.

The results of the present study demonstrated that $V\dot{O}_2\text{max}$ can be achieved in the constant-velocity tests at 90% or 100% of $v\dot{V}O_2\text{max}$ as defined by the criterion measure for $V\dot{O}_2\text{max}$ in the incremental test. This is important because it demonstrates that $V\dot{O}_2\text{max}$ can be elicited at an intensity below the $v\dot{V}O_2\text{max}$ that Billat et al. (1994a), Billat et al. (1994b), Billat et al. (1994c) and Billat et al. (1994d)
have described as the lowest velocity that could elicit \( V_{O_2\text{max}} \). These results demonstrate that exercise above the anaerobic threshold sustained for more than 180 s may be characterized by an \( O_2 \) drift, as described by Whipp (1994), Poole (1994) and Barstow (1994). Thus, the achievement of \( V_{O_2\text{max}} \) at this intensity and possibly at a lower intensity.

The finding that exercise at 100% \( vV_{O_2\text{max}} \) elicits \( V_{O_2\text{max}} \) is consistent with most previous research (Billat et al. 1994d; Katz et al. 1989; Stamford, 1976). The results of this study are different from those LaVoie and Mercer (1987). However, there were only five subjects and a cycle ergometer was use. They concluded that due to local muscular fatigue \( V_{O_2\text{max}} \) was not achieved.

The results of the present study have demonstrated that many responses to exercise at 90% of \( vV_{O_2\text{max}} \) are not very stable. Although, there were no significant differences in the mean responses in the three tests at this velocity, there was considerable intra-individual variability across the tests.

Previous studies have evaluated reproducibility of TLim at 100% \( vV_{O_2\text{max}} \) (Billat et al., 1994b) and 80% of \( vV_{O_2\text{max}} \) (McLellan, 1995). While Billat et al. (1994b) reported that TLim values were reproducible, there was a high intra-individual variability reported. In fact, Billat et al. (1994b) concluded that TLim at \( vV_{O_2\text{max}} \) "is probably not sensitive for prescribing and monitoring the training
program of an individual athlete". High variability was also found by McLellan et al. (1995) at 80% of \( \dot{V}O_2 \text{max} \). These authors concluded that exercise that is longer in duration tends to be more variable because of day to day variation in motivation, hydration and diet.

The values obtained in this study for the respective times to and times at 95% and 100% of \( \dot{V}O_2 \text{max} \) demonstrated poor stability. While it can be concluded that it takes roughly 8 min to reach \( \dot{V}O_2 \text{max} \) at 90% of \( \dot{V}O_2 \text{max} \), and that \( \dot{V}O_2 \text{max} \) is sustained for about 1.5 min to 3 min in duration, there is large inter- and intra-individual variability.

Similarly, values for \( \tau \) and predicted \( \dot{V}O_2 \text{max} \) derived in this study were not stable across the three trials at 90% \( \dot{V}O_2 \text{max} \). However, the values for \( \tau \) are similar to those reported by Péronnet and Thibault (1989), Whipp (1994), Poole (1994) and Barstow (1994) have described an \( O_2 \) drift during exercise at intensities above the anaerobic threshold, and have suggested that \( \dot{V}O_2 \text{max} \) might be achieved if exercise is sustained long enough. Results of this study suggest that there was an \( O_2 \) drift, with \( \dot{V}O_2 \) increasing from 90% of \( \dot{V}O_2 \text{max} \) to 100% of \( \dot{V}O_2 \text{max} \) during exercise at 90% of \( \dot{V}O_2 \text{max} \).

Responses to 90% and 100% of \( \dot{V}O_2 \text{max} \)

**TLim**

The TLim at 100% of \( \dot{V}O_2 \text{max} \) was significantly shorter than that observed in the tests at 90% \( \dot{V}O_2 \text{max} \). The mean
TLim presented in this study is typical of values observed by Billat et al. (1994a) 378 ± 121 s and Billat et al. (1994b) 404 ± 101 s and 402 ± 113 s.

\( \dot{V}O_2_{\text{max}} \)

The values for \( \dot{V}O_2_{\text{max}} \) obtained in this study during exercise at 90% and 100% of \( \dot{V}V_0_{2\text{max}} \) were the same. Other metabolic responses such as \( \dot{V}p_{\text{max}} \) and RERmax were also the same. This demonstrates that the tests were "maximal" in nature in that both could elicit \( \dot{V}O_2_{\text{max}} \).

Kinetics data across the 3 tests at 90% \( \dot{V}V_0_{2\text{max}} \) and the one test at 100% \( \dot{V}V_0_{2\text{max}} \) demonstrated considerable inter- and intra-individual variability. It appeared that the kinetics of the response were faster in the test at 100% \( \dot{V}V_0_{2\text{max}} \); and it appeared (as might be expected) that the time 95% or 100% of \( \dot{V}O_2_{\text{max}} \) could be sustained was shorter in the test at 100% \( \dot{V}V_0_{2\text{max}} \). However, these findings were not always supported by the statistical tests (see Table 4). In addition, \( \tau \) for the test at 100% \( \dot{V}V_0_{2\text{max}} \) was actually longer (not significant) than \( \tau \) in the lower intensity tests; this was unexpected, and was inconsistent with the apparently faster response at 100% \( \dot{V}V_0_{2\text{max}} \). However, it is noted that the value for \( \tau \) at 100% \( \dot{V}V_0_{2\text{max}} \) was associated with an extremely high SEE.
CHAPTER VI

SUMMARY AND CONCLUSIONS

Summary

The purpose of this study was to determine if $\dot{V}O_2$max could be elicited during exhaustive exercise at an intensity below $v\dot{V}O_2$max, specifically, at 90% of $v\dot{V}O_2$max. The second purpose was to evaluate responses during exercise at submaximal velocities. The final purpose was to compare the responses to exercise at 90% and 100% of $v\dot{V}O_2$max.

Conclusion

In conclusion, the results of this study demonstrate that $V_O_2$max can be elicited in a constant-velocity test at 90% $v\dot{V}O_2$max. This suggests that there is a drift in $\dot{V}O_2$ at this intensity. Secondly, responses at 90% of $v\dot{V}O_2$max has demonstrated very poor stability. Finally maximal responses to exercise at 90% and 100% of $v\dot{V}O_2$max are not different. However, while obscured by intra-individual difference, the kinetics of the metabolic response seem faster in the higher intensity tests.

Future Recommendations

Several recommendations can be made for future research. A larger sample size would account for the subject variability in the responses at $v\dot{V}O_2$max. It would be interesting to examine various performance levels of
long-distance runners at $\text{VO}_2\text{max}$ and the various percentages at which the velocities could be sustained. An attempt should be made to fit data from 90% $\text{VO}_2\text{max}$ to a bi-exponential model to determine if the $O_2$ drift can be described mathematically. Finally, there may be value in comparing the responses to exercise at an intensity defined as a percentage of $\text{VO}_2\text{max}$ when this velocity has been determined using the various different methodologies available.
APPENDIX A

SUBJECT CHARACTERISTICS
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<th>Subject</th>
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APPENDIX B

SUBJECT CONSENT FORM
1. I hereby volunteer to participate as a subject in the study entitled "Time limit at maximal aerobic velocity." I understand that the purpose of this study is to evaluate responses to exhaustive treadmill running. I understand that I will be tested in the Exercise Physiology Laboratory at the University of North Texas on 5 separate days and that each test requires an all-out effort. I will be expected to follow guidelines about eating and drinking during the study. These guidelines required that I abstain from drinking alcoholic beverages for 12 hours prior to each test and that I restrict my caffeine intake for 4 hours prior to each test. It is recommended that I not eat 2 to 3 hours prior to any testing.

I hereby authorize David W. Hill and/or assistants as may be selected by him to perform on me the following procedures, on different days.

A: Pre-testing:
(a) to measure my height, weight, resting heart rate and blood pressure, and skinfold thicknesses;

(b) to obtain a resting 12-lead electrocardiogram (EKG);

B: Testing:

(c) to have me wear a nose-clip and breathe through a mouthpiece and run on a treadmill at high speeds, and to have me continue to run until I cannot maintain the treadmill speed or until I want to stop for whatever reason, in order to assess my maximal oxygen capacity. (a total of five times: one incremental test, in which treadmill speed is increased every two minutes and four tests at a constant treadmill speed. I understand that these are all-out tests, and that each may last from about two to twenty minutes;

(d) to obtain from me a 40 microliter blood sample (about 3 drops of blood) by pricking my finger tip with a sterile disposable lancet;

2. The procedures outlined in paragraph 1 [(a) through (d) above] have been explained to me by David W> Hill.

3. I understand that the procedures described in paragraph 1 (above) involve the following risks and discomforts: temporary muscle pain and soreness is expected as a result of the all-out exercise. There is a risk of pain, infection, or
fainting as a result of the finger prick to obtain the blood sample. There is a possibility of abnormal changes in my heart beat of blood pressure, or even of a heart attack during the tests. I understand that my heart rate will be monitored during testing, and that I can terminate any test at any time at my discretion. However, I also understand that there will not be a physician present during testing.

4. I have been advised that the following benefits will be derived from my participation in this study: aside from the educational benefit of learning about exercise testing or about my fitness level, there are no direct benefits to me.

5. I understand that David W. Hill and/or appropriate assistants as may be selected by him will answer any inquiries that I may have at any time concerning these procedures or investigations.

6. I understand that all data concerning myself will be kept confidential and available upon my written request. I further understand that in the event of publication, no association will be made between the reported data and myself.

7. I understand that there is no monetary compensation for my participation in this study.
8. I understand that in the event of physical injury directly resulting from participation, compensation cannot be provided. Medical treatment will be available at the University Health Center and the laboratory has an outside telephone line to the City of Denton emergency services.

9. I understand that I may terminate participation in this study at any time without prejudice to future care or any possible reimbursement of expenses, compensation, employment status, and that owing to the scientific nature of the study, the investigator may terminate the procedures and/or investigations at any time.

10. I understand that I may contact the chairperson of the Kinesiology Department's Committee on the Use of Human Subjects in Research, Dr. Allen Jackson (Room 210-R, 817-565-2651), on any matters concerning my participation in this study or if I feel that there is infringement on my rights.

Subject Signature: ________________________________

Witness: _______________________________________

Date: _________________________________________
APPENDIX C

SUBJECTS INDIVIDUAL DATA
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Sub. = subject number
Test1 = incremental test
VO2max = maximal oxygen uptake
Vemax = maximal ventilation
RERmax = maximal respiratory exchange ratio
T20_I = time for 20 treadmill belt revolutions
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Sub=subject

Test 2, 3, & 4 = 90% of \( v \text{VO}_{2\max} \)

Test 5 = 100% of \( v \text{VO}_{2\max} \)

VCV = the velocity of constant velocity test

TA95max = time at 95% of VO2max

TA100max = time at 100% of VO2max

TT95Pmax = time to 95% of predicted VO2max

TT100Pmax = time to 100% of predicted VO2max

TA95mx = time at 95% of predicted VO2max

TA100mx = time at 100% of predicted VO2max
REFERENCES


Billat, V., Renoux, J. C., Pinoteau, J., Petit, B., & Koralsztein, J. P. (in press). Times to exhaustion at 90, 100, & 105% of velocity at VO₂max (maximal aerobic speed) and critical speed in elite long distance runners. Archives of International Physiology, Biochemistry, and Biophysics.


