ABSTRACT

PANNING, J.K. Accuracy of exercise prescription methods compared to the ventilatory threshold. MS in Adult Fitness/Cardiac Rehabilitation, December 2002, 21pp. (C. Foster)

Many exercise professionals use non-invasive methods to determine exercise prescription. These methods have the risk of prescribing exercise intensities that are below and above the ventilatory threshold (VT). This study compared the ACSM recommended exercise prescription percentages to variables (HR, VO_2) at VT. Twenty healthy volunteers (n = 20) performed a maximal exercise test to determine VT, peak VO_2, HRmax. The variables at VT were compared to the percentages (40, 60, 80% VO_2peak, 55, 70, 90% peak HR, and 40, 85% HRR) that were widely used to prescribe exercise. There was a statistically significant difference ($p < .05$) between the variables at VT and numerous recommended percentages; however, there were no significant correlations between the percentages and variables at VT. The authors concluded that intensities of 60% VO_2peak, and 75% HRmax were associated with intensities that are equivalent to the VT.

ACCURACY OF EXERCISE PRESCRIPTION METHODS COMPARED TO THE VENTILATORY THRESHOLD

A MANUSCRIPT STYLE THESIS PRESENTED

TO

THE GRADUATE FACULTY

UNIVERSITY OF WISCONSIN-LA CROSSE

IN PARTIAL FULFILLMENT

OF THE REQUIREMENTS OF THE

MASTER OF SCIENCE DEGREE

BY

JILL K PANNING

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THESIS FINAL ORAL DEFENSE FORM

Candidate Jill K Panning

We recommend acceptance of this thesis in partial fulfillment of this candidate's requirements for the degree:

Master of Science in Adult Fitness/Cardiac Rehabilitation

The candidate has successfully completed the thesis final oral defense.

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Signature of Thesis Chairperson — Department — Date

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Signature of Committee Member — Department — Date

PT 5/22/02

Signature of Committee Member — Department — Date

This thesis is approved by the College of Health, Physical Education, Recreation, and Teacher Education.

9-25-02

Associate Dean, College of HPERTE — Date

9-25-02

Director of University Graduate Studies — Date

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

APPENDIX PAGE

INTRODUCTION

Exercise professionals often have had difficulty prescribing exercise for many populations. This is due to in part to the wide range of exercise intensities derived from the accepted methods of exercise prescription. For example, an individual with a max heart rate (HR) of 180 and a resting HR of 60 beats per minute (bpm), would have an exercise prescription with a range of heart rates at 132 and 156 at 60 and 80% of their max HR reserve (HRR)[1]. Similarly, using percent of max metabolic equivalents (METS) as the basis for an exercise prescription, an individual with an exercise capacity of 10 METS would have an exercise prescription ranging from 6 to 8 METS[1]. This problem is magnified if predicted rather than measured max HR is used or if the use of handrail support leads to overestimation of exercise capacity. The use of the Borg[2] Rating of Perceived Exertion (RPE) scale may help to narrow the range of prescribed intensities. Recent evidence, however, suggests that the range of prescribed intensity relative to an idealized exercise training intensity, such as the ventilatory threshold (VT), may still be too wide.

VT is widely regarded as an important measurement factor in an exercise test. Past research has indicated that exercise prescriptions based on intensities above the VT may be dangerous in patients with ischemia[3]. A recent study tested the accuracy of exercise prescription methods compared to VT in patients with left ventricular systolic dysfunction[4]. This study, however, used an inappropriate exercise protocol (Bruce treadmill protocol) in patients with left ventricular dysfunction, making detection of VT sub-optimal. The proposed study would replicate this research in a healthy population with an appropriate exercise protocol.

METHODS

Subjects

Twenty healthy subjects (10 male, 10 female) between the ages of 18-50 volunteered to participate in this study. All subjects were regular exercisers and were assumed to have no health problems. Each subject received an informed consent form prior to testing (see Appendix A). The University of Wisconsin-La Crosse Institutional Review Board for the Protection of Human Subjects (IRB) approved the study. All testing was performed in the Human Performance Laboratory at the University of Wisconsin-La Crosse.

Protocol

Each subject performed a graded exercise test on a treadmill using a modified Balke protocol (see Appendix B). Respiratory gas exchange was measured continuously throughout the test, and VT was determined using the V slope method[5]. HR was assessed using radio telemetry, and RPE was assessed using the Borg category ratio scale[2] (see Appendix C). Both were recorded at the end of each stage. Blood pressures were also taken at the end of each stage using a standard cuff and sphygmomanometer.

Instrumentation

Each subject performed the VO_2max test on a motorized treadmill (Quinton Instrument Company, Seattle, WA) using the Q-Plex Metabolic Analyzer (Quinton Corporation, Bothell, WA). Male and female subjects remained at rest for the first two minutes of the test. After the initial two minute rest, the males began at 3.5 mph, 0% grade and females began at 3.0 mph, 0% grade with the grade increasing by 2% at the end of each two-minute stage until the subject could no longer continue. Prior to the test, the gas analyzer was calibrated with a 3.0 L syringe and known gas concentrations. A Polar Vantage Heart Rate Monitor (Polar CIC Inc., Port Washington, NY) was used to measure HR.

Statistical Analysis

From the results obtained during the treadmill test, the HR at representative percentages (70% and 85%) of the max HR and (60% and 80%) of the max HRR was compared to the HR at the VT^1 using multiple linear regression comparisons and a Repeated Measures ANOVA with Tukey post-hoc test. Similarly, the VO_2 at representative percentages (40, 60, and 80%) of the peak VO_2 and (50% and 85%) of the VO_2 reserve was compared to the VO_2 at the VT^1.

RESULTS

The descriptive statistics of the subjects are reported in Table 1. Based on the percentages of age-gender predicted VO_2peak, all of the subjects were relatively fit. The mean values (± standard deviation) for the outcome variables are listed in Tables 2 and 3.

Figures 1-12 compare the individual variables at VT to the variables represented using the recommended percentages from the ACSM[1] exercise prescription guidelines. Figures 1 and 3 ($r = .64$) indicate that 40 and 80% VO_2peak are below and above the ideal exercise training intensity for VO_2. Figure 2 ($r = .64$) represents a suitable VO_2 exercise intensity at least relative to the VO_2 at VT. Figures 4 and 6 ($r = .60$, $r = .64$) represent the relationship of VO_2 at VT to VO_2 at 40% and 85% VO_2Reserve as recommended by the ACSM[1]. Figure 5 ($r = .56$) represents a more appropriate intensity within the recommended percentages for VO_2.

Figures 7-9 ($r = .63$, $r = .62$) compare HR at VT to HR at 55, 75, and 90% peak. As Figures 7 and 9 indicate, they are above and below the appropriate exercise intensity for % HRmax. Figure 8 ($r = .64$) represents the relationship between HR at 75% peak to HR at VT. This intensity was chosen as a marker in between the recommended intensity range from the ACSM[1]. The HR at 75% peak is closely related to the appropriate intensity, and it is within the recommended percentages of 55 and 90% for % HRmax from the ACSM[1]. Figures 10 and 12 ($r = .62$, $r = .64$) represent the recommended ACSM[1] percentage range of 40 to 85% HRR. Figure 11 ($r = .71$) is 60% HRR and is within the 40 to 85% HRR range to demonstrate a middle intensity. As Figures 10 and 11 ($r = .62$, $r = .71$) show, 40% and 60% HRR appear to be a good representation of VT. Figure 12 ($r = .64$), however, is above the appropriate intensity. Therefore, there were no significant correlations between the variables at VT to the outcome variables represented at the ACSM recommended intensity percentages.

A Repeated Measures ANOVA with Tukey post hoc test was then performed to see if there were any significant differences between the ACSM recommended percentages of intensity to the variables at VT. There were significant differences ($p<.05$) between VO_2 at 40% peak and at 40% VO_2R compared to VO_2 at VT. There was also a significant difference between 40% peak and 40% VO_2R. VO_2 at 60% peak compared to VO_2 at VT was not statistically significant ($p>.05$). However, VO_2 at VT compared to 80% peak and 85% VO_2R were statistically significant ($p<.05$). VO_2 at 80% peak and 85% VO_2R also had a significant difference between them.

HR at 55% HRmax (mean value 98±9) was significantly lower than HR at VT (mean value 134±20). 75% HRmax (mean value 134±12) was not significant compared to HR at VT (mean value 134±20). HR at 90% HRmax (mean value 160±15) was significantly higher than HR at VT (mean value 133.8±20).

HR at 40% HRR (mean value 125±14) was significantly lower compared to HR at VT (mean value 134±20). HR at 60% HRR was significantly higher compared to HR at VT (mean value 134±20). HR at 85% HRR was also significantly higher compared to HR at VT (mean value 134±20).

Table 1. Descriptive physical characteristics of subjects

Variable	Men (n = 10)	Women (n = 10)
Age (yrs)	27.4 ± 11.8	21.1 ± 3.2
Height (cm)	178.6 ± 6.2	168.5 ± 12.3
Weight (kg)	83.9 ±13.5	61.3 ± 6.8
VO_2peak ($ml*kg^{-1}*min^{-1}$)	42.8 ± 6.1	38.6 ± 3.8
% Predicted VO_2peak	105.7 ± 16.8	123.3 ± 27.7
VO_2 at VT ($ml*kg^{-1}*min^{-1}$)	25.0 ± 7.6	26.5 ± 5.2
% VO_2peak @ VT	57.5 ± 10.6	68.7 ± 11.6
HRpeak ($b*min^{-1}$)	179.4 ± 17.3	177.1 ± 15.8
HR at VT ($b*min^{-1}$)	126.9 ± 18.3	140.7 ± 20.8
% HRpeak @ VT	70.6 ± 6.4	79.8 ± 8.8
% HRR @ VT	51.2 ± 11.8	65.8 ± 14.8

Table 2. Relative VO_2 Responses

Variable	Men (n = 10)	Women (n = 10)	Total (n = 20)
VO_2 @ VT ($ml*kg^{-1}*min^{-1}$)	25.0 ± 7.6	26.5 ± 5.2	25.8 ± 6.4
VO_2 @ 40% peak ($ml*kg^{-1}*min^{-1}$)	17.1 ± 2.4	15.4 ± 1.5	16.3 ± 2.2
VO_2 @ 60% peak ($ml*kg^{-1}*min^{-1}$)	25.6 ± 3.7	23.0 ± 2.4	24.3 ± 3.3
VO_2 @ 80% peak ($ml*kg^{-1}*min^{-1}$)	34.1 ± 4.9	30.6 ± 3.2	32.4 ± 4.4
VO_2 @ 40% Reserve ($ml*kg^{-1}*min^{-1}$)	20.5 ± 2.4	18.6 ± 2.0	19.55 ± 2.4
VO2 @ 85% Reserve ($ml*kg^{-1}*min^{-1}$)	37.2 ± 5.2	33.6 ± 3.3	35.4 ± 4.6

*Mean ± Standard Deviation

Table 3. Relative HR Responses

Variable	Men (n = 10)	Women (n = 10)	Total (n = 20)
HR @ VT ($b*min^{-1}$)	126.9 ± 16.3	140.7 ± 20.8	133.8 ± 20.3
HR @ 55% peak HR ($b*min^{-1}$)	98.7 ± 9.4	97.3 ± 8.9	98.0 ± 8.9
HR @ 90% peak HR ($b*min^{-1}$)	161.4 ± 15.6	159.3 ± 14.2	160.4 ± 14.6
HR @ 40% HRR ($b*min^{-1}$)	123.7 ± 12.9	125.3 ± 16.0	124.5 ± 14.2
HR @ 85% HRR ($b*min^{-1}$)	165.4 ± 15.8	164.1 ± 15.3	164.8 ± 15.1

*Mean ± Standard Deviation

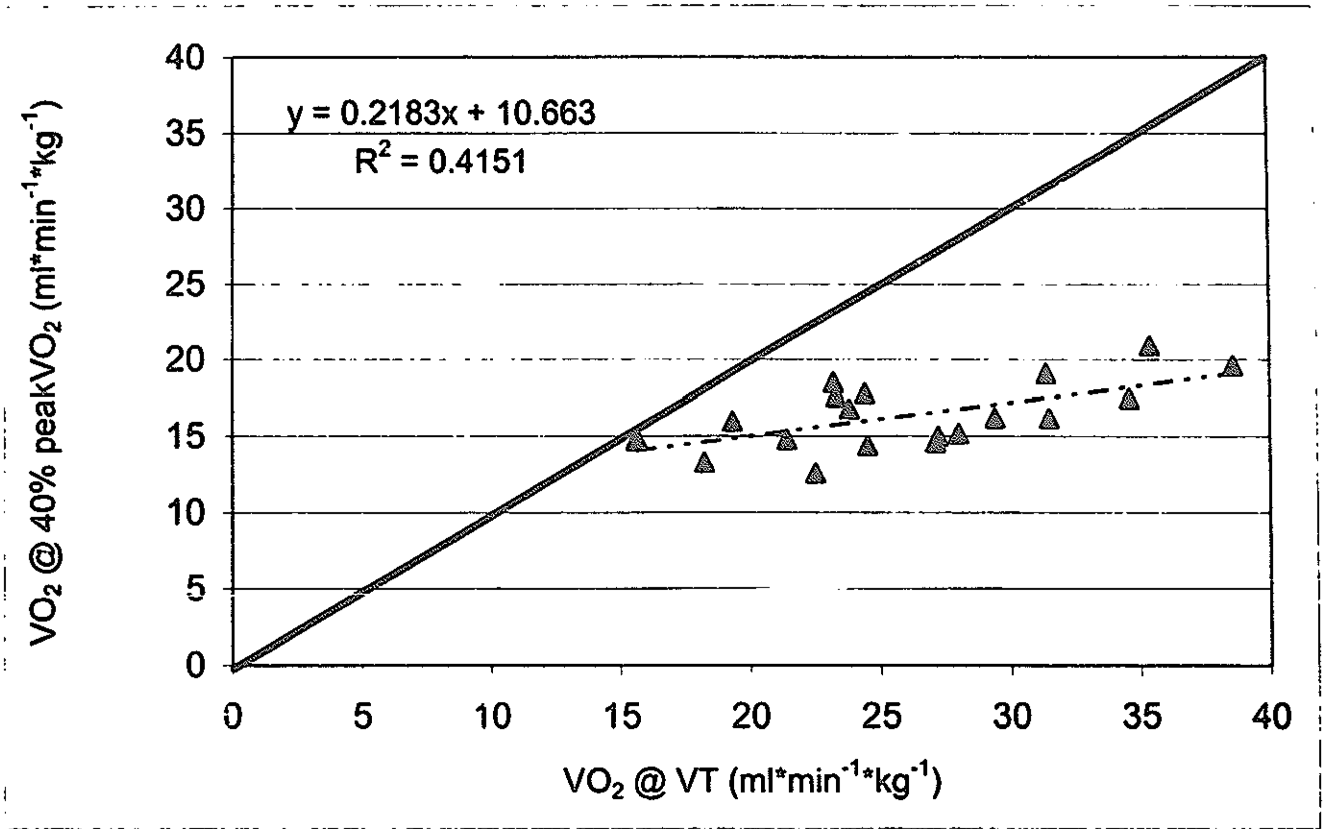

Figure 1. Relationship between oxygen consumption at 40% peak VO_2 versus oxygen consumption at VT. Note that 40% is relatively lower than ideal intensity represented by darkened line of identity.

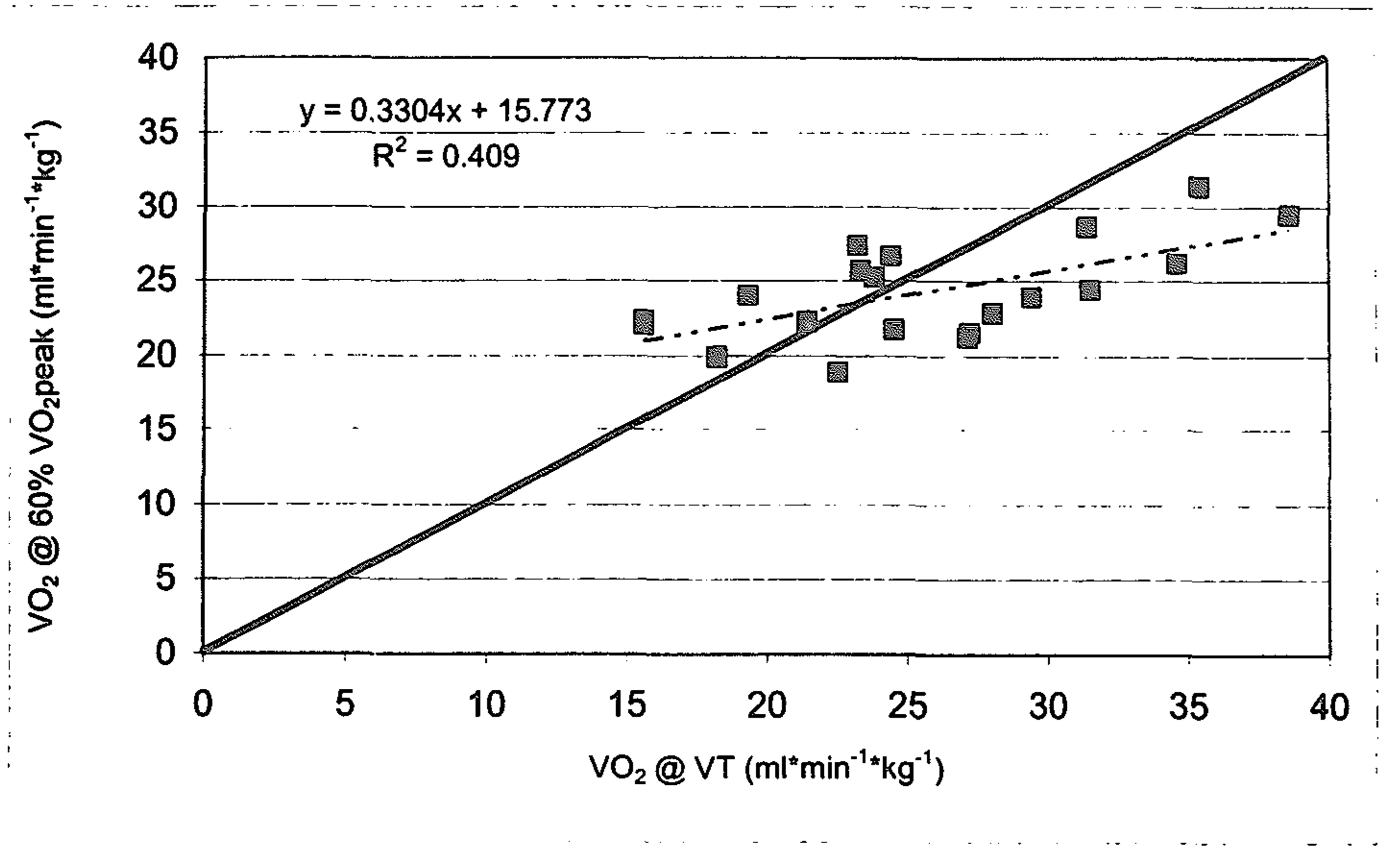

Figure 2. Relationship between oxygen consumption at 60% peak VO_2 versus oxygen consumption at VT. Note that 60% is relatively close to appropriate exercise intensity represented by dark black line of identity.

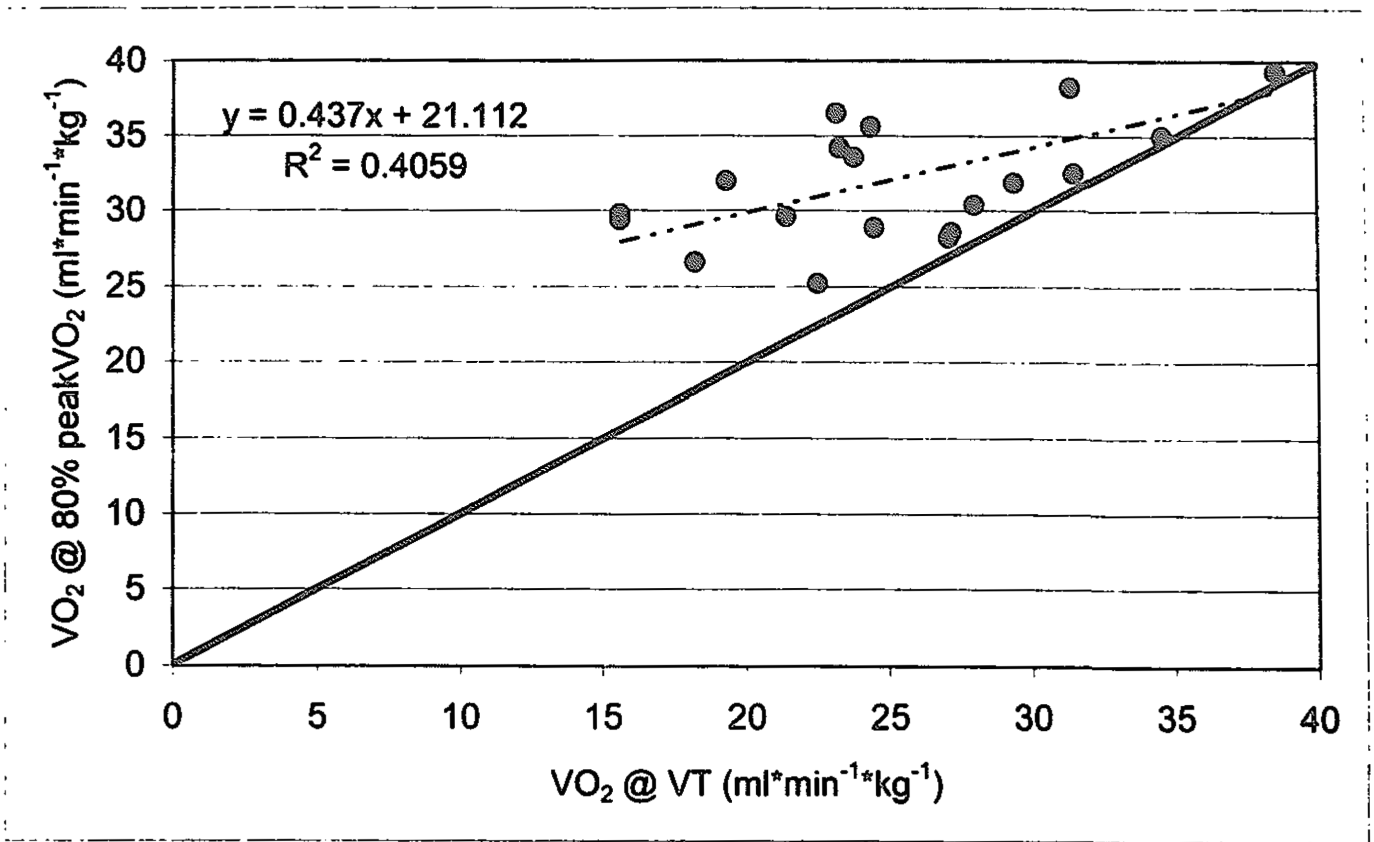

Figure 3. Relationship between oxygen consumption at 80% peak VO_2 versus oxygen consumption at VT. Note that at 80% peak, exercise intensity is relatively higher than what would be considered appropriate intensity.

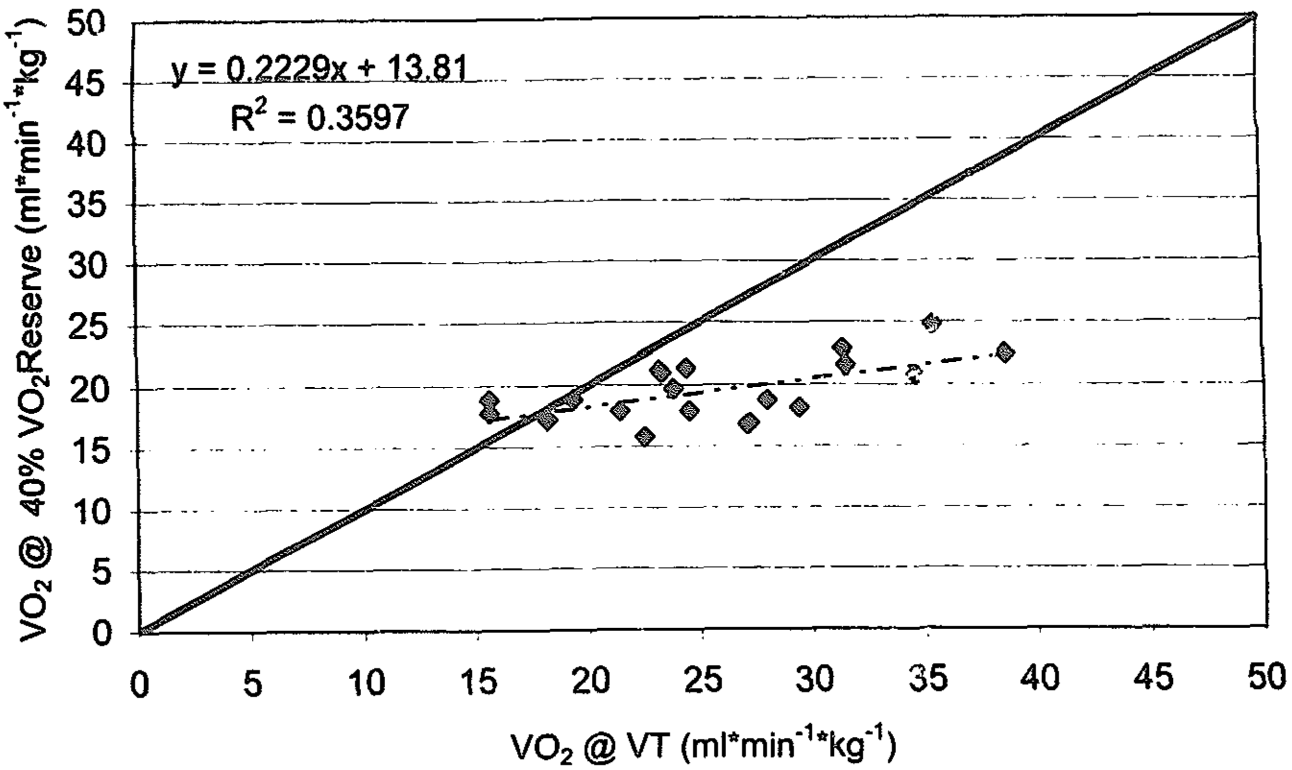

Figure 4. Relationship between oxygen consumption at 40% VO_2Reserve versus oxygen consumption at VT. Note that at 40% VO_2Reserve, intensity is near accuracy but still is lower than desired.

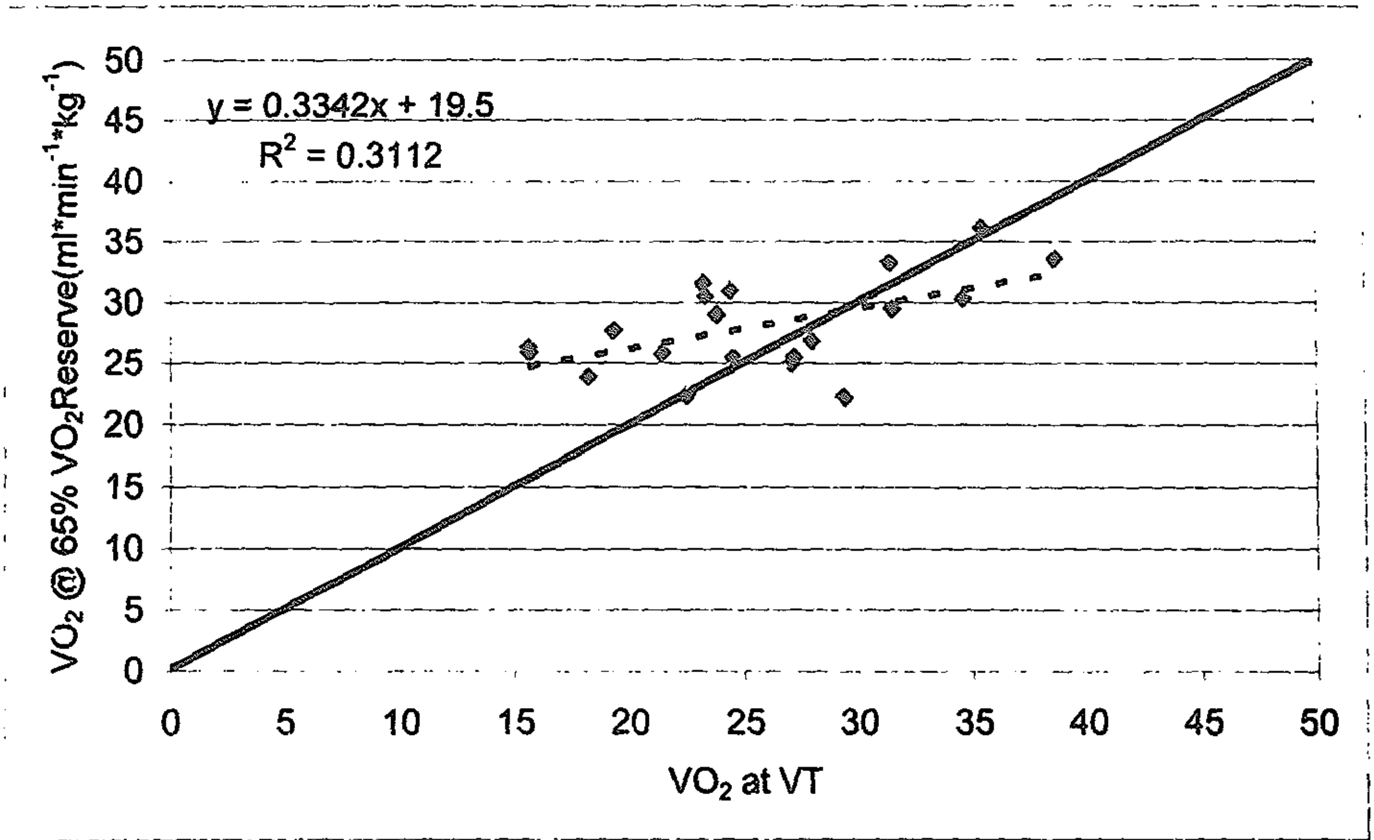

Figure 5. Relationship between oxygen consumption at 65% VO_2Reserve versus oxygen consumption at VT. Note that 65% VO_2Reserve intensity is appropriate.

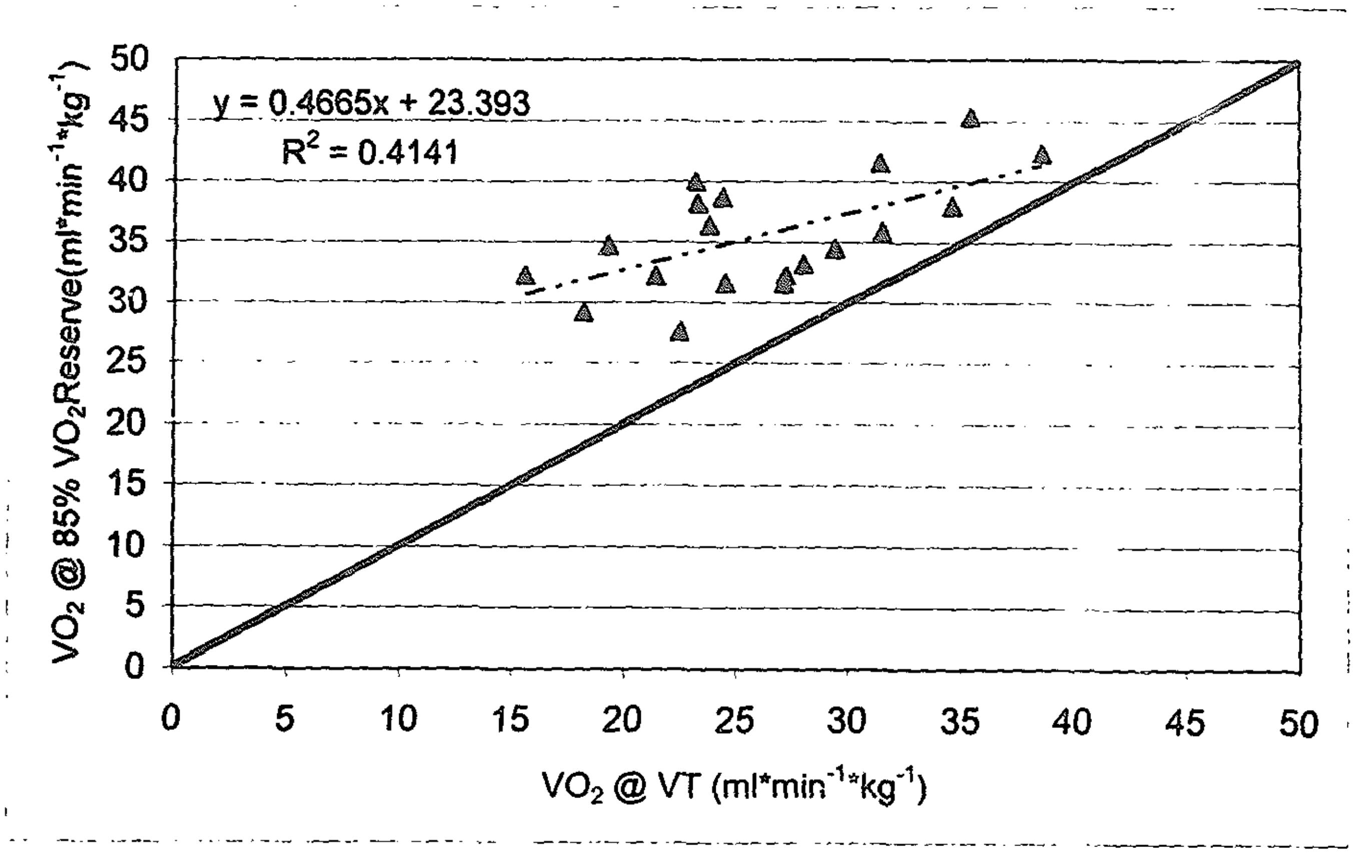

Figure 6. Relationship between oxygen consumption at 85% VO_2Reserve versus oxygen consumption at VT. Note that 85% VO_2Reserve is relatively higher than is desired for appropriate exercise intensity.

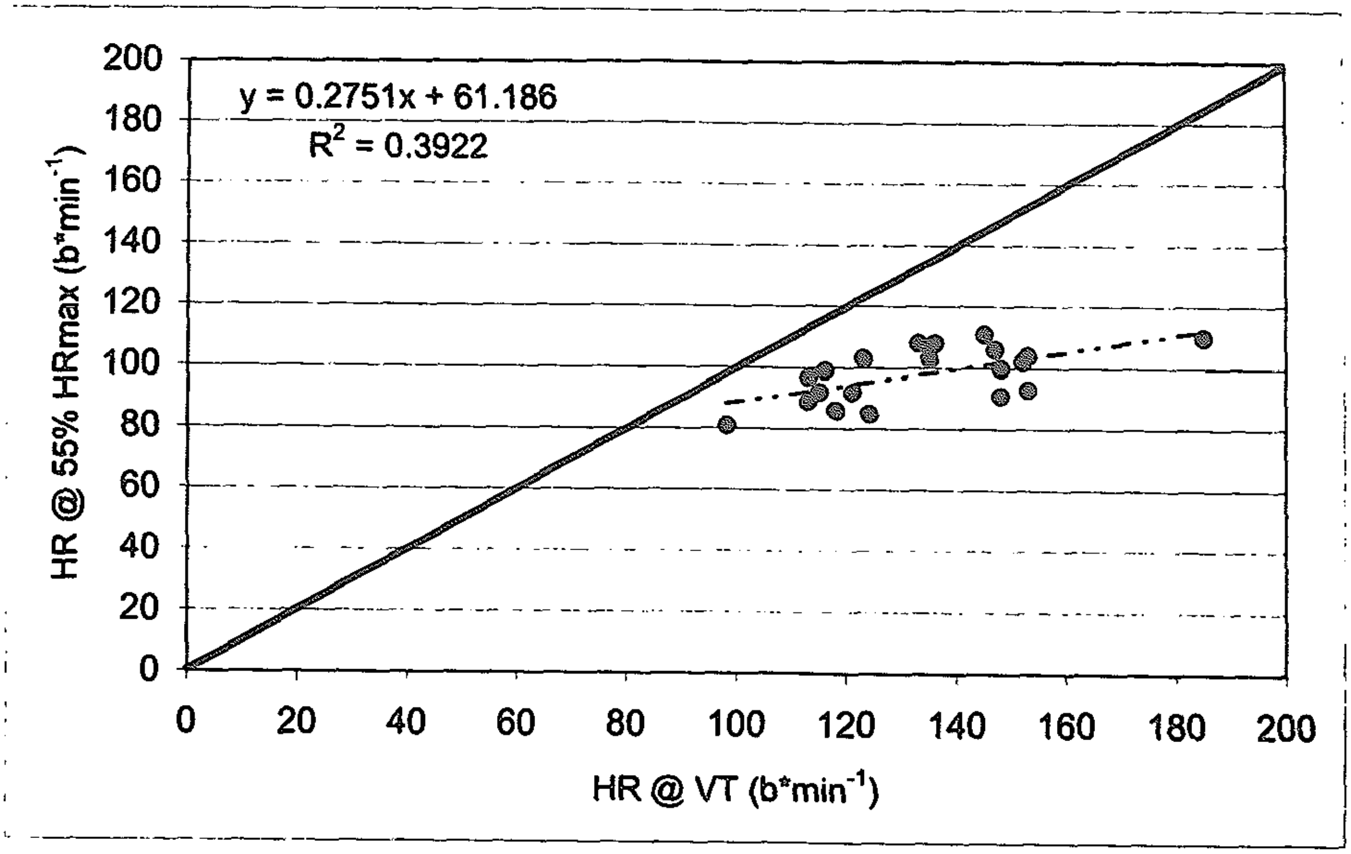

Figure 7. Relationship between heart rate at 55% HRmax versus HR at VT. Note that HR at 55%peak is relatively lower than wanted exercise intensity.

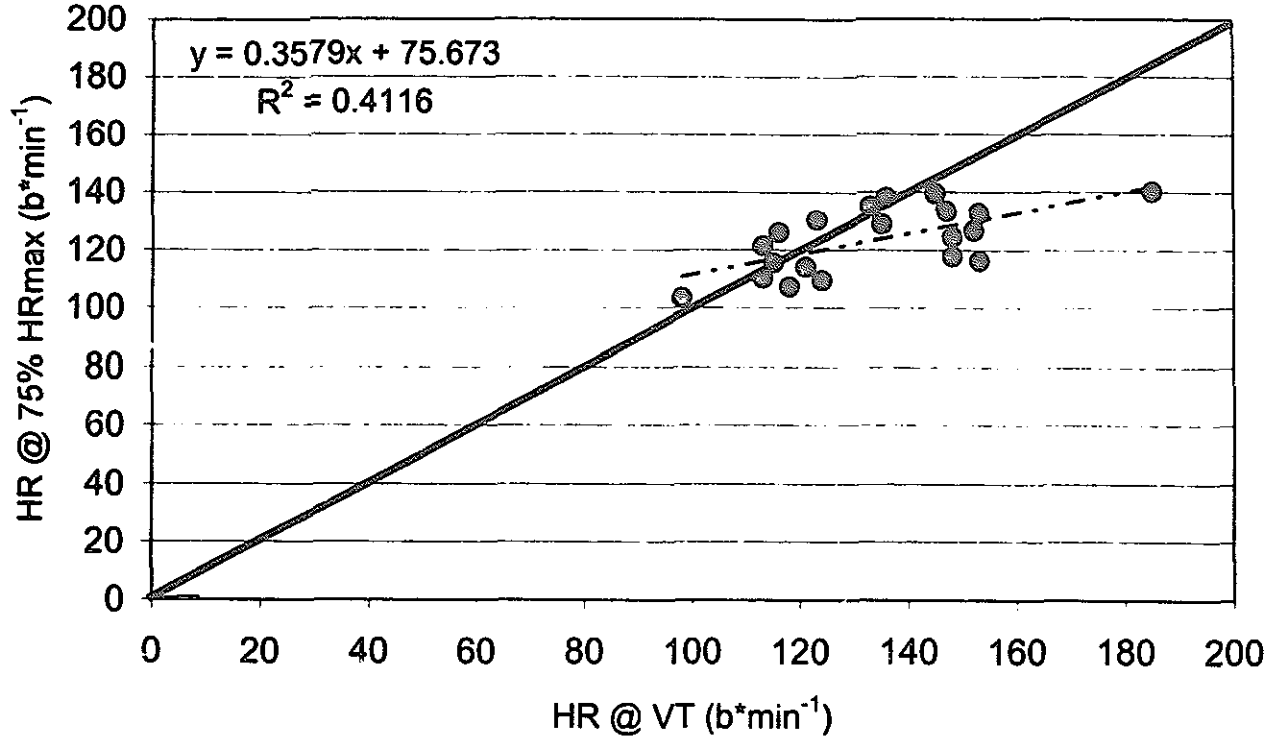

Figure 8. Relationship between heart rate at 75% HRmax versus HR at VT. Note that HR at 75%peak is fairly close to an intensity at VT.

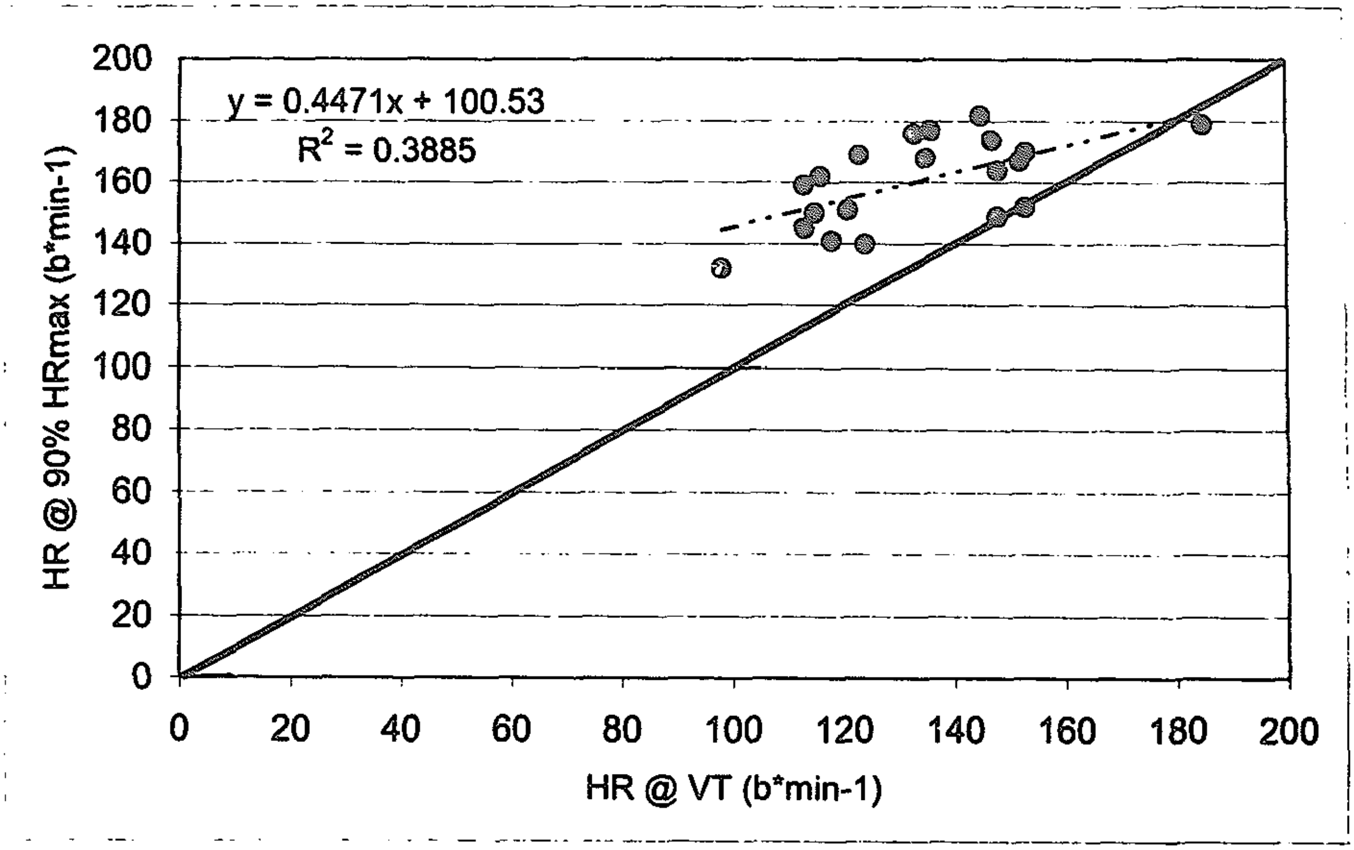

Figure 9. Relationship between heart rate at 90% HRmax versus heart rate at VT. Note that heart rate at 90%peak is higher than desired exercise intensity.

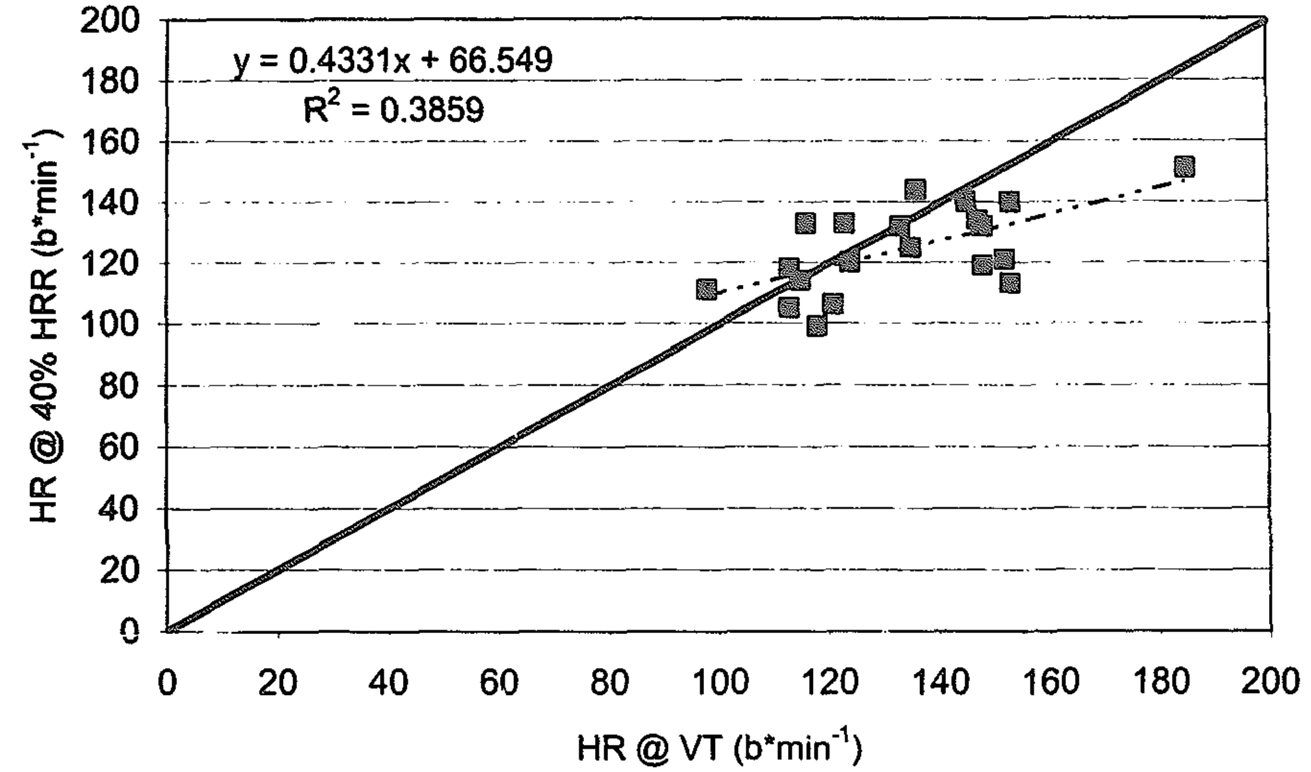

Figure 10. Relationship between heart rate at 40% HRR versus heart rate at VT. Note that 40%HRR is an appropriate intensity for exercise.

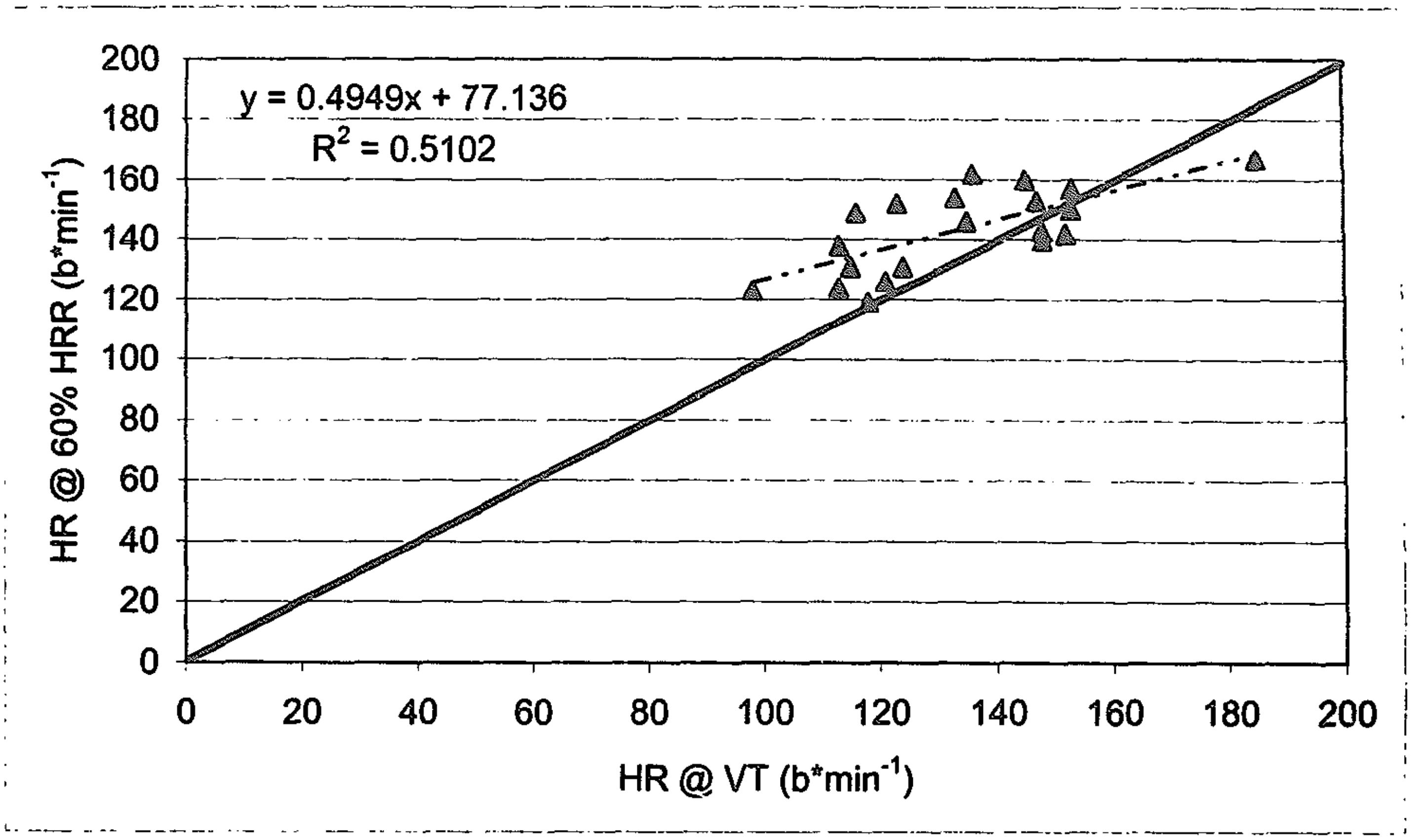

Figure 11. Relationship between heart rate at 60% HRR versus heart rate at VT. Note that 60%HRR is close to VT.

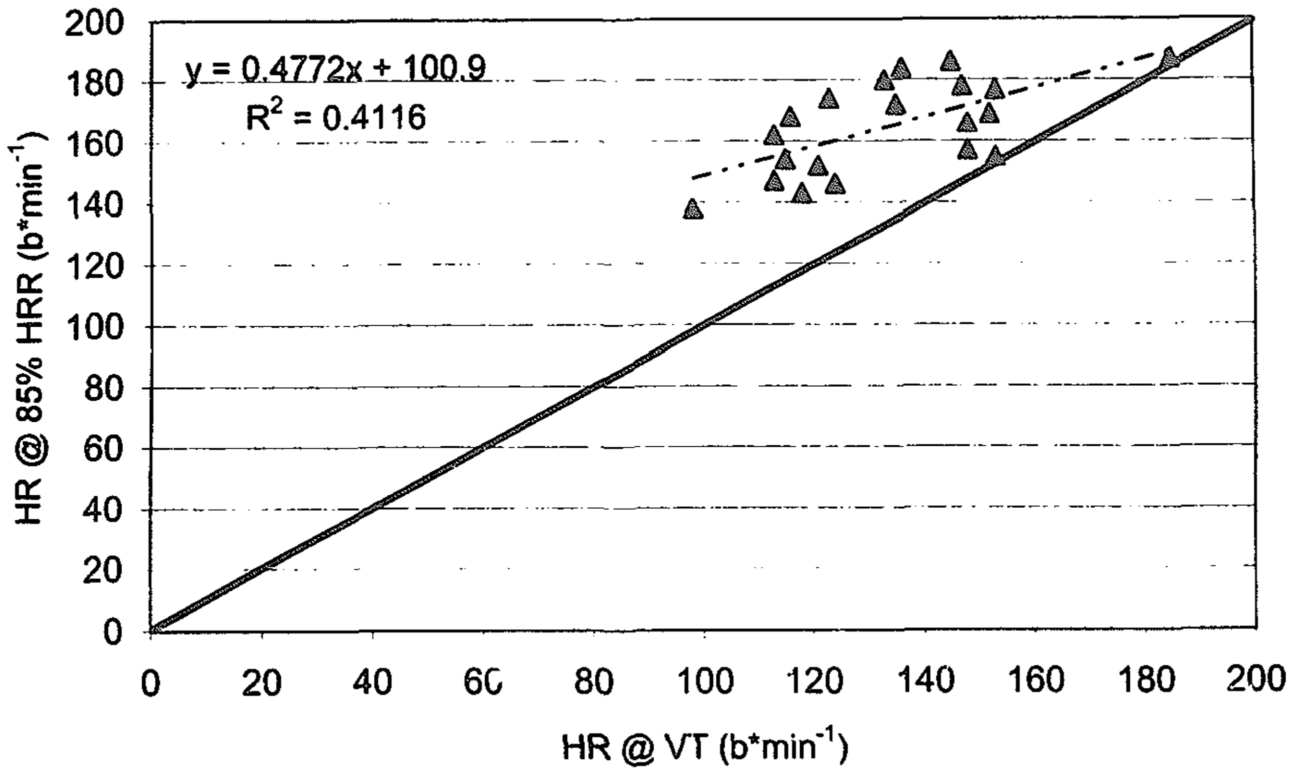

Figure 12. Relationship between heart rate at 85% HRR versus heart rate at VT. Note that 85% HRR is relatively higher exercise intensity than what is desired.

DISCUSSION

The purpose of this study was to compare the recommended ACSM intensity percentages[1] to the variables (HR, VO_2) at VT to determine an appropriate exercise training intensity. The ACSM recommends percentages that have such a wide range that the room for error in exercise intensity prescription is quite significant[1]. The varying range of percentages has proven to be one of the biggest challenges in determining an appropriate exercise prescription for a variety of populations.

Training at VT has been shown to have a significant beneficial effect. A study done by Hoffman[6] found that training at VT increased performance by 36% and resulted in a significant increase in VO_2peak values in distance runners. Current research has also been studying the effects of training at VT and has been finding positive results[6,7,8,9].

A previous study done by Strzelczyk et al[4] attempted to narrow the recommended percentages to a point that would be appropriate for patients with left ventricular systolic dysfunction (LVSD). This study expanded on their research to help determine an appropriate intensity for a healthy population. As the results indicate, there were significant differences between the lower (40% HRR, 55% HRmax, 40% VO_2peak) and higher intensities (90% HRmax, 60% HRR, 85% HRR, 80% VO_2peak, 85% VO_2R) recommended by the ACSM[1] compared to the values at VT. This finding suggests that intensities prescribed at 60% VO_2peak or 75% HRmax are closely related to intensities at VT, which has been suggested to be an appropriate training intensity according to recent research. Strzelczyk et al[4] found that intensities at 60, 70, and 80% HRR were highly correlated with a training intensity at VT, which is consistent with our findings. Moreover, a study done by Meyer et al[3] found that exercising at an intensity around VT preceded the ischemic threshold. This suggests that at an intensity of 60% peakVO_2 would also be appropriate for many heart patients who have such a threshold. Training at an intensity beyond VT has been shown to produce negative physiological effects, which could be detrimental to certain populations. Wasserman[10] found that exercising above the anaerobic threshold results in the development of metabolic acidosis, reduced exercise endurance, slowed steady state VO_2 kinetics, and progressive tachypnea as a result of the disproportionate ventilation.

One of the limitations of this study is the need for a graded exercise test to prescribe an appropriate intensity. As mentioned before, cost and time constraints prove to be a problem when using a graded exercise test to determine intensity. However, the Talk Test has been proven to be an appropriate field-test that is easy to do and been shown to be associated with an intensity around VT. A study done by Dehart[12] found that the point at which an individual is no longer speaking comfortably during exercise was consistent with values beyond VT. In addition, this study was done with a healthy population. Gaskill[7] studied a sedentary population and found that those that trained at an intensity above VT were found to have improved their VO_2 at VT more than those who trained below VT. Moreover, Strzelczyk[4] found that an intensity of 70% HRR would be appropriate with patients with left ventricular systolic dysfunction. This is similar to our findings that 60% HRR would be consistent with training at VT.

The findings of this study suggest that training at an intensity of 60% VO_2peak, or 75% HRmax, which are within the recommended ACSM[1] percentages are consistent with an intensity at VT and have been shown to be an appropriate training intensity for most healthy adults.

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APPENDIX A

INFORMED CONSENT

University of Wisconsin- La Crosse

The Accuracy of Exercise Prescription Methods
Compared toVentilatory Threshold
Informed Consent

I, ______________________________, consent to participate in this study, which tests the accuracy of exercise prescription methods of healthy individuals compared to the ventilatory threshold. The purpose of this study is to determine if recommended methods are giving exercise prescription target heart rates that are higher than patients' ventilatory threshold, the point at which ventilation abruptly increases with workload. I consent to presentation and publication of the study results as long as no personal identification can be made.

I have been informed that testing will take place in the Human Performance Laboratory Room in Mitchell Hall on the campus of University of Wisconsin- La Crosse. I will be required to complete one testing session that is approximately two hours in length. The testing will include a graded exercise test on a motor-driven treadmill, a breath-by-breath gas analysis test, heart rate and blood pressure measurements, and rating of perceived exertion. The test will begin on a level grade, which can easily be accomplished and will advance in stages depending on my fitness level. I have been informed that either I or the investigator may stop the test at any time because of signs of fatigue, abnormal heart rate or blood pressure responses.

I have been informed that potential risks include the possibility of certain abnormal changes occurring during the test. They include atypical blood pressure and heart rate responses, fainting, disorders in heartbeat, and in rare instances, heart attack, stroke or death. The risk of serious complications during exercise testing in healthy individuals, such as myself, is approximately 6/10,000 tests. Every effort is made to minimize these risks by evaluating my health questionnaire prior to participation. Emergency equipment and trained personnel are available to deal with any unusual situations that might occur.

I have been informed that in the unlikely event that any injury or illness occurs as a result of this research, the Board of Regents of the University of Wisconsin System, and the University of Wisconsin-La Crosse, their officers, agents and employees, do not automatically provide reimbursement for medical care or other compensation. Payment for treatment of any injury or illness must be provided by me or my third-party payer, such as my health insurer or Medicare. If any injury or illness occurs in the course of research or for more information please [illegible] Jill K. Panning (608) 785-8765 or (715) 284-3026. I have been informed that I am not waiving my rights that I may have for injury resulting from negligence of any person or the institution. I understand that it is my responsibility to report any past history, unusual feelings, injuries or discomfort promptly to the researcher, Jill K. Panning.

I have been informed that the results of this exercise test will help in determining what types of physical activities are right for me and may assist me in the evaluation of cardiovascular disease that is not recognized. There will be no cost to me for these tests.

I have been informed of the purpose, procedures, and risks of this study and understand there will be a two-hour commitment during the period of time from December 2001 to April 2002. I have been informed that I can stop the test at any time if I so desire.

At any time, questions can be addressed to the researcher, Jill K. Panning at (608) 785-8675 or (715) 284-3026 and/or Dr. Carl Foster in his office at (608) 785-8687.

Questions regarding the protection of human subjects can be addressed to Dr. Dan Duquette, chairperson of the University of Wisconsin-La Crosse Institutional Review Board for the Protection of Human Subjects at (608) 785-8124.

_______________________________________ _____________

Signature of Participant Date

_______________________________________ _____________

Signature of Researcher Date

APPENDIX B

TREADMILL PROTOCOLS

Treadmill Protocols

Modified Balke Protocol-Men

Stage (2 min)	Speed (m*s)	Grade
I	0.0	0.0%
II	3.5	0.0%
III	3.5	2.5%
IV	3.5	5.0%
V	3.5	7.5%
VI	3.5	10.0%
VII	3.5	12.5%
VIII	3.5	15.0%
IX	3.5	17.5%
X	3.5	20.0%
XI	3.5	22.5%
XII	3.5	25.0%
XIII	3.5	27.5%

Modified Balke Protocol- Women

Stage (2 min)	Speed (m*s)	Grade
I	0.0	0.0%
II	3.0	0.0%
III	3.0	2.5%
IV	3.0	5.0%
V	3.0	7.5%
VI	3.0	10.0%
VII	3.0	12.5%
VIII	3.0	15.0%
IX	3.0	17.5%
X	3.0	20.0%
XI	3.0	22.5%
XII	3.0	25.0%
XIII	3.0	27.5%

APPENDIX C

RATING OF PERCEIVED EXERTION

Borg's Rating of Perceived Exertion

0.0	No Effort (Standing at Rest)
0.5	Very, Very Easy
1.0	Very Easy
2.0	Easy
3.0	Moderate
4.0	Somewhat Hard
5.0	Hard
6.0	
7.0	Very Hard
8.0	
9.0	Very, Very Hard (Nearly Maximal)
10.0	Maximal

APPENDIX D

REVIEW OF LITERATURE

REVIEW OF LITERATURE

Introduction

Exercise prescription has proven to be a lasting challenge for exercise professionals. This is mainly due to the difficulty in estimating appropriate exercise intensity, particularly for certain populations such as cardiac or sedentary. There are a wide variety of methods used today to determine exercise intensity including: anaerobic threshold, lactate threshold, ventilatory threshold (VT), percentage of maximal heart rate (% HRmax), rating of perceived exertion (RPE), percentage of maximal oxygen consumption (% VO_2max), Karvonen/heart rate reserve (HRR), and percentage of max metabolic equivalents (% maxMETS). Of these, most fitness programs and wellness facilities use the % HRmax and Karvonen/HRR methods to determine exercise prescription because they are non-invasive and easy to use. However, using these formulas increases the risk of underestimating or overestimating a person's exercise capacity because it uses a predicted maximal HR and not actual. By using physical markers of exercise such as VT or lactate threshold, exercise intensity can be better pinpointed. This study evaluates the accuracy of exercise prescription methods compared to ventilatory threshold.

Ventilatory Threshold

Ventilatory threshold (VT) has been defined as the point at which "the rate of pulmonary minute ventilation that increases non-linearly with workload".[1] However, there are various definitions of VT, which is due in part because of the confusion as to why VT occurs. VT has been known to be an important physiological determinant of performance[2], and it has been associated as an important link in determining anaerobic threshold by a non-invasive method.[3] In addition, ventilatory markers, such as VT, have been regarded as usually easier to detect.[4] The most common and simplified way to determine VT is the V-slope method as described by Schneider, Phillips, and Stoffolano.[5] This method is based on a concept produced by Beaver, Wasserman, and Whipp[6] in which they plotted the carbon dioxide (CO_2) production against the oxygen uptake during incremental exercise. Davis et al[3] found that VT had good test-retest reproducibility with incremental exercise.

Current research has focused the physiological changes that occur with training at VT. A study done by Hoffman[7] found that training at VT produced beneficial results in endurance performance and suggested that VT may be an appropriate alternative to using blood lactate markers. Furthermore, a meta-analysis done by Londeree[8] concluded that training at an intensity of VT produced the most significant training effect. However, training at intensities beyond VT has been shown to produce negative physiological effects. Wasserman[9] found that training beyond VT causes an acid-base disturbance, which causes in the increase in ventilation to try to correct for pH acidity. Another study done with patients with heart disease showed that incremental exercise increased venous lactate levels and produced a rapid increase in ventilation to a point where the patient had to stop due to fatigue.[10] Thus, VT has been shown to be an excellent physiological marker of exercise intensity.

Anaerobic Threshold

Anaerobic threshold (AT) is the loosely given term for the blood lactate and ventilatory markers (including VT) that occur with prolonged exercise.[4] However there are many terms given for the same phenomena, and the same terms given for different phenomena. Wasserman[9] defined AT as the point at which oxygen supply does not meet demand in the working muscle. This imbalance causes an increase in lactic acid, which is buffered by bicarbonate, and ultimately causes increases in CO_2 output and blood pH.[11] Similar to VT, training at AT has been shown to significantly increase VO_2 max and endurance performance, and AT has been shown by various researchers as an accurate method of predicting performance.[11]

VO_2max

Maximal oxygen consumption (VO_2max) has typically been viewed as the gold standard when determining exercise intensity and functional capacity. It is defined as the maximal amount of O_2 that the body can uptake, transport and utilize for bodily functions. While VO_2max has a beneficial value of looking at normal function, the maximal value achieved is typically not a true max possibly due to the limitations of peak cardiac output. In addition, performing VO_2max tests for exercise prescription is very cost-ineffective in the field. Therefore, the American College of Sports Medicine (ACSM) came up with formula that can estimate VO_2max to determine exercise intensity.[12] However, anytime an exercise prescription is based on an estimated value, there is a high risk in either over-estimating or under-estimating the appropriate intensity.

This study compares the estimated exercise intensities based on the ACSM formula to actual VO_2max values.

VO_2Reserve

The % VO_2Reserve (% VO_{2R}) method is based on the same idea as the HRR method. % VO_{2R} is defined as "a percentage of the difference between the maximal and resting values".[13] Swain[14] discovered that the HRR method[15] is not equivalent to % VO_2max as originally thought, but is equivalent to the % VO_{2R} method. This discrepancy shows that using % VO_2max method for exercise intensity in relation to the HRR method for low-fitness and elderly populations can provide significant differences in intensities and could be detrimental.[13] This study compares two ACSM recommended percentages of VO_{2R} to the VO_2 at VT.

HRmax

Heart rate (HR) has long been an easy, non-invasive measurement that can be used in exercise prescription, and it has a relatively linear relationship to VO_2max. For those reasons, many professionals in the field often use HR as a marker of intensity during exercise. The problem with this is that there is a lot of individual variance of intensities at a certain HR including the decrease of HRmax with age. To determine a true HRmax, a maximal effort in a graded exercise test is usually required. As mentioned before, graded exercise tests can be time consuming and cost ineffective. Therefore, the ACSM recommends using the formula (220-age) to determine an estimated HRmax.[12]

This formula then can be used to determine exercise intensity by multiplying it times a range of percentages (55/65-90%) also recommended by the ACSM.[12] However, these percentages have such a wide variance that it is very likely to produce an exercise intensity that is not appropriate for the individual. A study done by Weltman et al[16] found that based on the % HRmax formula, most of the sedentary women they studied would be exercising at intensities beyond their lactate threshold, which could produce negative physiological effects.[16] Despite this, the % HRmax formula is still widely accepted and used to prescribe exercise intensities non-invasively.

HRR

Another method recommended by the ACSM is the heart rate reserve (HRR) formula, also known as the Karvonen formula.[15] This formula uses the difference between the resting HR and the maximal HR times the recommended intensity percentage (ranging from 40-85%) and adds into account the resting HR to determine exercise prescription.[12] As mentioned previously, HRR corresponds fairly equally to percentages of VO_2R.

RPE

The rating of perceived exertion (RPE) scale was developed by Borg.[17] It is commonly used in exercise prescription and testing today as a subjective measure of intensity. The individual uses the 15 point scale (6-20) to subjectively rate their perceived exertion throughout their entire body. Borg[18] also made a modified version that consists of a 10 point category ratio scale that is used in similar fashion. There have been many studies that have shown the positive relationship of RPE to other physiological markers. Purvis and Cureton[19] found that a RPE of "somewhat hard" was associated with the AT. Moreover, they found a strong correlation between RPE and HR, VO_2, and ventilation.[19] Another study done by Swaine et al[20] suggested that a self selected intensity of "moderate" on the RPE scale during exercise was associated with the AT. The results of these studies demonstrate that RPE is related to other physiologic markers used for intensity.

CONCLUSION

In summary, determining an appropriate exercise prescription for a wide variety of populations has been a challenge for exercise professionals in the past. This is mainly due to the difficulty in determining the correct intensity using the variety of methods described previously. The majority of these methods have a great risk for over-estimating or under-estimating due to the wide range of intensities. By using a known physiological marker, such as VT, hopefully, such problems can be avoided and the appropriate intensity will be easily determined.

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