UNIVERSITY OF WISCONSIN-LA CROSSE
Graduate Studies

DETERMINATION OF MAXIMAL LACTATE STEADY STATE
USING THE TALK TEST

A Manuscript Style Thesis Submitted in Partial Fulfillment of the Requirements for the Degree of Master of Science in Clinical Exercise Physiology

Justine M. Lueck

College of Science and Health

December, 2011
DETERMINATION OF MAXIMAL LACTATE STEADY STATE USING THE TALK TEST

By Justine M. Lueck

We recommend acceptance of this thesis in partial fulfillment of the candidate's requirements for the degree of Master of Science in Clinical Exercise Physiology.

The candidate has completed the oral defense of the thesis.

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Date
Lueck, JM. Determination of maximal lactate steady state using the talk test. MS in Clinical Exercise Physiology, December 2011, 42 pp, (C. Foster)

Because of the relationship between training intensity and blood lactate accumulation, maximal lactate steady state (MLSS) can be a valuable tool to determine appropriate exercise intensity. The Talk Test has also been shown to be a valuable tool for exercise intensity in a variety of populations. This study was done to evaluate whether the Talk Test can be used to define MLSS. Fourteen well trained subjects completed 2 maximal tests to determine the stages for the subsequent tests, which included: the stage the subject was unsure whether speech was comfortable (EQ), the last stage the subject could speak comfortably (LP), and the stage before the LP (LP-1). Following the determination of these speeds, each subject completed 30 minute steady state runs at each of the Talk Test identified intensities with measurement of blood lactate at 0, 10, 20, and 30 minutes to define whether MLSS is related to Talk Test intensity. Significant differences were found in heart rate, RPE, Talk Test score, and blood lactate concentration for Talk Test conditions. Bonferroni corrected T-Tests demonstrated further differences at Talk Test conditions and time values. Changes in blood lactate concentration were <1.0mmol*min⁻¹ for each subject at the LP-1 condition, and for 12 of the 14 subjects in the LP and EQ conditions. This demonstrated that MLSS was not reached on average by the subjects, even at the EQ Talk Test condition. In this population of highly trained individuals, most subjects were still below the intensity MLSS even when exercising at the EQ Talk Test intensity.
ACKNOWLEDGEMENTS

First and foremost, I’d like to thank Dr. Carl Foster for being my thesis advisor. Without your guidance and support, I would not have gotten past the question stage of this project. Thank you for everything you have helped with at each stage of this thesis. I feel more independent and confident after working with you.

Secondly, I’d like to thank my committee members, Glenn Wright and Mark Gibson. Your time and effort in this project was something I’m very grateful for. I’d also like to thank my subjects because without your hard work, this project wouldn’t have been what it was. You were great people to work with, and I wish you well on your future running endeavors.

Thank you especially to my family. Without your patience, and never ending support, I don’t think I would have made it through this year. Mom and Dad, thank you for believing in me and helping me believe in myself, and also for reminding me everyday what perseverance means.

Finally, thank you to my classmates and other faculty members. We have done so much this year and I’m truly thankful to have been able to work with you. Your friendship, support, and consideration were invaluable.

I feel extremely blessed to have had these people assisting me and supporting me throughout this process, because without them, it wouldn’t have been possible.
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INTRODUCTION

Endurance athletes are typically instructed to train at an intensity defined in terms of percentage of maximal heart rate (HR), heart rate reserve, VO₂ max, or VO₂ reserve (1). These values, while effective in creating training plans for athletes, may be costly and time consuming to define. They may also require maximal testing in a controlled laboratory setting. More recently, training recommendations have been defined with reference to the lactate or ventilatory threshold (2, 3, 16, 17). Prescribing intensity in absolute measures (speed and grade) is a simpler and more practical approach for coaches and athletes. Intensity distribution is also a major component of training for both individual and team sport athletes (16, 17). When an athlete trains at an intensity that is too high, they risk overtraining, injury, or fatigue which may result in poor performance. Alternatively, if the intensity is too low, the athlete might not elicit a great enough stimulus to improve performance.

Recently it has been shown that endurance athletes (runners, skiers, rowers, cyclists) tend to train in various zones of intensity (low, moderate, high) in a polarized distribution which is designed to create balance in their training, improving performance while minimizing the risk of overtraining (17). Seiler (17) suggests that a polarized distribution with an intensity distribution of 75-80% of training sessions spent in zone 1 (low intensity, below the ventilatory threshold), 5% of sessions in zone 2 (moderate intensity, between the ventilatory threshold and respiratory compensation threshold), and 15-20% in zone 3 (high intensity, above respiratory compensation threshold) is likely
optimal. This training distribution is in contrast with a threshold training distribution
where the majority of training is spent at intensities near the maximal lactate steady state
(MLSS). Seiler (16) and Esteve-Lanao (9), in separate studies, have shown a positive
relationship between spending the majority of training at a low intensity (below
ventilatory threshold) and improved performance in high intensity (above ventilatory
threshold and respiratory compensation threshold) events in endurance sports (skiing and
running).

The Talk Test has been shown to be a valid and practical surrogate of the
ventilatory threshold during submaximal exercise (6, 10, 11, 12, 13). We have found the
use of the Talk Test to be a safe, beneficial tool for exercise prescription in a variety of
populations including athletes (15), healthy individuals (6, 10, 11, 12, 13), patients with
heart disease (18), and patients who develop exertional ischemia (6). It has been shown
that during stages which the subject can “pass” the Talk Test (e.g. speak comfortably
during exercise), they are below their ventilatory threshold (VT). The first stage where
they are unsure whether they can speak comfortably (equivocal) is very near the VT, and
the first stage where they definitely cannot speak comfortably (negative) is when they are
at or above the respiratory compensation threshold (RCT) (7). Jeans et al. (12) and Foster
et al. (11) demonstrated in two different studies that during the last stage the subject can
speak comfortably (last positive, LP) as well as in the stage before the LP (LP-1) the
subject reaches a steady state relative to Rating of Perceived Exertion (RPE), heart rate,
percent of heart rate max, and Talk Test results. There was a progressive increase in all
the measures at the equivocal stage and no steady state was demonstrated. Thus, the Talk
Test may be used in a wide range of individuals and does not require a maximal exercise test, making it an ideal tool for training prescription for athletes and coaches.

In addition to percentage of HR max and VO\textsubscript{2} max, blood lactate has been used as a marker of exercise intensity (2, 3, 4, 14). Maximal lactate steady state (MLSS) is the highest intensity at which the blood lactate concentration remains elevated but stable during exercise. Beneke and von Duvillard (2) defined it as the equilibrium between lactate production and lactate elimination, and Philp (14) describes it as the highest running speed or power output at which blood lactate concentration (LA) remains stable (change of less than 1 mmol\textsuperscript{-1}l\textsuperscript{-1}) between 10 and 30 minutes of constant load exercise. It has been demonstrated that training at MLSS can be used to elicit positive submaximal and maximal changes in aerobic capacity (4). Because of the relationship between training intensity and lactate accumulation, MLSS can be a valuable tool to determine appropriate exercise intensity.

Jeans et al. (12) demonstrated that a steady state occurs in heart rate and RPE at the LP and LP-1 stages of the Talk Test. However, Jeans did not demonstrate whether lactate, which is a more definitive marker of metabolic conditions, was in steady state during exercise bouts defined by Talk Test variables. By repeating a similar protocol in well trained individuals, this study is designed to determine whether MLSS can be defined using the Talk Test. This could produce a simplified marker of training intensity making the Talk Test useful for athletes and coaches to make effective training plans and produce optimal performance results.
METHODS

Subjects

The subjects included 14 healthy well-trained individuals. On average they trained 5 hours or more each week. Five of the subjects were collegiate cross country runners at the University of Wisconsin-La Crosse, and six of the subjects had completed one or more marathons. All subjects provided written informed consent, and the Institutional Review Board for the Protection of Human Subjects at University of Wisconsin-La Crosse approved the protocol. Demographic characteristics of the subjects are presented in Table 1.

Table 1. Demographic Characteristics of subjects (mean ± standard deviation)

<table>
<thead>
<tr>
<th></th>
<th>Males (n=9)</th>
<th>Females (n=5)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (years)</td>
<td>25.2±9.8</td>
<td>29±9.1</td>
</tr>
<tr>
<td>Height (m)</td>
<td>1.8±0.4</td>
<td>1.7±0.1</td>
</tr>
<tr>
<td>Body Mass (kg)</td>
<td>60.9±3.4</td>
<td>74.8±9.4</td>
</tr>
<tr>
<td>VO2max (ml<em>kg</em>min)</td>
<td>67.1±9.0</td>
<td>50.7±2.8</td>
</tr>
<tr>
<td>HRmax (bpm)</td>
<td>193.2±8.7</td>
<td>187.2±10.9</td>
</tr>
</tbody>
</table>

Procedures

We followed an experimental protocol of an earlier study in our laboratory (12) to perform the procedures of this study. Each subject performed 5 treadmill running tests with at least 48 hours between tests. The first test for each subject was a maximal exercise test to fatigue using respiratory gas exchange via open circuit spirometry. The analyzers and volume turbine were calibrated with reference gases and room air and a 3L
syringe, respectively. Gas analysis data was integrated over 30 seconds. The grade of the treadmill remained constant at 1% for the duration of the test, and the subject performed a three minute warm up at a walking pace. The speed of the treadmill was then increased by 0.5 mph every minute until the subject could not continue. During the last 30 seconds of each stage the subject’s heart rate and RPE were recorded. The second test was a maximal exercise test using the Talk Test. The grade of the treadmill remained constant at 1% for the entire duration of the test, and the subject performed a three minute warm up at a walking pace. The speed of the treadmill was then increased by 0.5 mph every two minutes until the subject could not continue. During the last 30 seconds of each stage the subject’s heart rate and RPE, and Talk Test score were recorded. The Talk Test consisted of the subject reciting the Pledge of Allegiance. After completion of the Pledge the subject was asked, “can you speak comfortably?” They could answer yes (+), unsure or equivocal (+/-), or no (-) which were recorded as 1, 2, and 3 respectively. The speed at which they could last speak comfortably (last positive, LP), the speed where they were unsure if comfortable speech was possible (equivocal, EQ), and the speed where speech was definitely not comfortable were recorded (negative, NEG). The Category Ratio RPE Scale (0-10) was used to measure the RPE (5). A radiotelemeter recorded heart rate (Polar USA E600).

The next three tests were 30 minute runs completed at various intensities defined relative to Talk Test responses. The subjects had a warm up period of five minutes before beginning the protocol. The test began with the treadmill at the established speed for the specific stage which then stayed constant the remainder of the run. The tests, which were performed in randomized order, were the equivocal stage (EQ), the last positive stage
(LP), and the stage before the last positive stage (LP-1). Every five minutes heart rate, RPE, and the Talk Test score were recorded. Blood lactate was measured after the warm up and at 10, 20, and 30 minutes of the run using dry chemistry (Lactate Plus-Nova Biomedical).

**Statistical Analysis**

Repeated measures ANOVA was performed on heart rate, RPE, Talk Test scores, and blood lactate concentration. Bonferroni post hoc t-tests were performed as justified by ANOVA. Statistical significance was accepted at p ≤ 0.05. Data is presented as mean ± standard deviation.
RESULTS

Mean values for subject speed and responses for the incremental Talk Test maximal exercise test are shown in Table 2. The mean values for subject speed and responses for the steady state runs are shown in Table 3.

Table 2. Responses of Subjects during the Incremental Talk Test (mean ± standard deviation)

<table>
<thead>
<tr>
<th></th>
<th>Speed (mph)</th>
<th>HR</th>
<th>RPE</th>
</tr>
</thead>
<tbody>
<tr>
<td>LP</td>
<td>7.4±1.71</td>
<td>157.4±11.61</td>
<td>3.9±0.78</td>
</tr>
<tr>
<td>EQ</td>
<td>7.9±1.71</td>
<td>162.6±13.05</td>
<td>4.5±0.91</td>
</tr>
<tr>
<td>NEG</td>
<td>9.0±1.69</td>
<td>176.7±9.79</td>
<td>6.6±1.10</td>
</tr>
<tr>
<td>Max</td>
<td>9.6±1.46</td>
<td>185.1±9.34</td>
<td>10±1.50</td>
</tr>
</tbody>
</table>

Table 3. Responses of Subjects during Steady State Runs (mean ± standard deviation)

<table>
<thead>
<tr>
<th></th>
<th>10 min</th>
<th>20 min</th>
<th>30 min</th>
</tr>
</thead>
<tbody>
<tr>
<td>Speed LP-1</td>
<td>6.89±1.71</td>
<td>6.89±1.71</td>
<td>6.89±1.71</td>
</tr>
<tr>
<td>Speed LP</td>
<td>7.39±1.71</td>
<td>7.39±1.71</td>
<td>7.39±1.71</td>
</tr>
<tr>
<td>Speed EQ</td>
<td>7.89±1.71</td>
<td>7.89±1.71</td>
<td>7.89±1.71</td>
</tr>
<tr>
<td>HR LP-1</td>
<td>147.5±11.48</td>
<td>151.9±13.67</td>
<td>154.1±14.89</td>
</tr>
<tr>
<td>HR LP</td>
<td>156.6±14.71</td>
<td>161.4±15.74</td>
<td>164.0±16.17</td>
</tr>
<tr>
<td>HR EQ</td>
<td>165.4±12.75</td>
<td>169.8±14.05</td>
<td>173.6±12.94</td>
</tr>
<tr>
<td>RPE LP-1</td>
<td>2.4±0.76</td>
<td>2.8±0.77</td>
<td>2.9±0.93</td>
</tr>
<tr>
<td>RPE LP</td>
<td>3.0±0.84</td>
<td>3.6±1.29</td>
<td>4.1±2.05</td>
</tr>
<tr>
<td>RPE EQ</td>
<td>4.1±0.81</td>
<td>4.86±1.03</td>
<td>5.7±1.89</td>
</tr>
<tr>
<td>TT LP-1</td>
<td>1.0±0</td>
<td>1.0±0</td>
<td>1.0±0</td>
</tr>
<tr>
<td>TT LP</td>
<td>1.0±0</td>
<td>1.3±0.61</td>
<td>1.4±0.76</td>
</tr>
<tr>
<td>TT EQ</td>
<td>1.6±0.63</td>
<td>2.1±0.77</td>
<td>2.3±0.73</td>
</tr>
<tr>
<td>LA LP-1</td>
<td>1.7±0.88</td>
<td>1.7±0.86</td>
<td>1.6±0.97</td>
</tr>
<tr>
<td>LA LP</td>
<td>2.4±2.27</td>
<td>2.8±2.24</td>
<td>3.2±4.05</td>
</tr>
<tr>
<td>LA EQ</td>
<td>3.2±2.38</td>
<td>3.6±2.92</td>
<td>3.9±3.60</td>
</tr>
<tr>
<td>Δ LA LP-1</td>
<td>-0.11±0.59</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Δ LA LP</td>
<td>0.78±1.84</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Δ LA EQ</td>
<td>0.71±1.46</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
There was a significant difference in heart rate for the Talk Tests conditions and for time. There was no significant interaction between Talk Test conditions and time. Significant differences were found at 10 minutes between LP-1 and LP, LP-1 and EQ, and no significance was seen between LP and EQ. At 20 and 30 minutes, significance was seen between each Talk Test condition (p < 0.01).

Figure 1. Mean Responses for Heart Rate during Steady State Runs
There were significant differences in RPE for the Talk Test conditions, for time, and for the interaction between Talk Test condition and time. At 10, 20, and 30 minutes, there was no significant difference between LP-1 and LP and there were significant differences between LP-1 and EQ as well as LP and EQ (p < 0.01).

![Graph showing mean responses for RPE during steady state runs](image)

Figure 2. Mean Responses for RPE during Steady State Runs
Significant differences were seen in the Talk Test scores for Talk Test condition, for time, and for the interaction between Talk Test condition and time. Bonferroni corrected t-tests were performed, and at 10, 20, and 30 minutes. No significant difference was observed in Talk Test score between LP-1 and LP. There was a significant difference at 10, 20, and 30 minutes between LP-1 and EQ as well as LP and EQ (p<0.001), where EQ was always greater than LP-1 and LP.

Figure 3. Mean Responses for Talk Test Score during Steady State Runs
Significant differences were seen in the blood lactate concentrations between Talk Test conditions. There were no significant differences between time and the interaction between Talk Test conditions and time. Bonferroni corrected t-test showed no significant differences between Talk Test conditions at 10, 20, and 30 minutes. In the LP-1 condition, all subjects had blood lactate concentrations that increased $<1.0 \text{ mmol} \cdot \text{l}^{-1}$. In the LP and EQ condition, only 3 subjects had blood lactate concentration that increased $>1.0 \text{ mmol} \cdot \text{l}^{-1}$. Thus, in general, MLSS intensity had not been achieved, even at the EQ velocity.

Figure 4. Mean Responses for Blood Lactate Concentration during Steady State Runs
There was no significant difference in change in blood lactate concentration from 10-30 minutes (p>0.05). At LP-1 the change in lactate was -.1143 mmol*l⁻¹. At LP the change in lactate was .7786 mmol*l⁻¹. At EQ the change in lactate was .7143 mmol*l⁻¹. These values indicate that MLSS had not been reached in each Talk Test condition.

![Figure 5. Mean Change in Blood Lactate Concentration during Steady State Runs](image)

Figure 5. Mean Change in Blood Lactate Concentration during Steady State Runs
DISCUSSION

The Talk Test has been shown to be a useful tool for exercise prescription in a wide variety of populations including athletes because of the relationship to the ventilatory threshold. There is also a significant relationship between ventilatory threshold and lactate threshold making blood lactate concentration values another valid tool for exercise prescription. Maximal lactate steady state (MLSS) is the highest velocity at which blood lactate concentration does not change more than 1.0 mmol/l during steady state exercise (2). Other studies have shown steady state conditions in heart rate, RPE, and Talk Test to occur at the LP Talk Test condition (12), as well as a training effect to occur at the velocity of MLSS (4). This study sought to determine if a significant relationship exists between the Talk Test and maximal lactate steady state. We previously hypothesized that MLSS would occur at the LP Talk Test condition in relation to the steady state that has already been demonstrated in heart rate, RPE, and Talk Test scores at the LP Talk Test condition, whereas at EQ there was an upward drift in these factors (12).

Significant differences were found in heart rate, RPE, Talk Test scores, and blood lactate concentration for Talk Test conditions. Bonferroni corrected T-Tests demonstrated further differences at Talk test conditions and time values as shown in Figures 1-4. Changes in blood lactate concentration were <1.0mmol*l^-1 for each subject at the LP-1 condition, as well as in the LP and EQ conditions as seen in Figure 5. This demonstrates that MLSS was not reached on average by the subjects, even at the EQ Talk Test condition.
Because MLSS was reached by 12 of the 14 subjects at the EQ Talk Test condition, it would be of interest to replicate the study and have subjects run at the EQ + 1 condition in order to find the highest velocity that MLSS can be reached. The well-trained nature of the subjects showed that MLSS can be achieved at relatively high velocities and may only be exceeded at Talk Test conditions above the equivocal stage.

This study showed that well trained athletes may use the Talk Test as a measure of intensity in their training, as shown in other studies from our laboratory. MLSS can be a valid measure of intensity as well, but may occur at higher velocities in athletes that are competitive and well trained runners. The Talk Test can be useful for determining training zones in which a polarized training distribution is followed in many endurance athletes because of the relationship to heart rate, blood lactate concentration, and ventilatory threshold. Finding more simple measures of training intensity can benefit athletes and coaches in determining the speed or workload of a workout.
REFERENCES


APPENDIX A

INFORMED CONSENT
Protocol Title: Determination of Maximal Lactate Steady State using the Talk Test

Principal Investigator:
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La Crosse, WI 54601
(507)450-3956

Emergency Contact:
Dr. Carl Foster
133 Mitchell Hall
University of Wisconsin-La Crosse
(608)785-8687

Purpose and Procedure
- The purpose of this study is to use the Talk Test to determine the maximal lactate steady state in order to use it as a tool for exercise prescription.
- My participation will involve six running tests, two being maximal effort tests. The other four tests will be 30 minute runs at varying speed and intensity in random order.
- The total time requirement is six hours over a three-week period.
- Testing will take place in room 225 Mitchell Hall, UW-L.
- During all tests, I will wear a heart monitor, strapped around my chest, to monitor my heart rate.
- During one of the maximal effort tests, I will wear a snorkel-like device to analyze my breathing.
- Blood will be taken from my fingertip every ten minutes during testing to measure blood lactate concentration.

Potential Risks
- I may experience finger and muscle soreness, possible discomfort while wearing the snorkel-like device, and substantial fatigue from running.
- Individuals trained in CPR, Advanced Cardiac Life Support and First Aid will be in the laboratory, and the test will be terminated if complications occur.
- The risk of serious or life-threatening complications, for healthy individuals, like myself, is near zero.

Rights & Confidentiality
- My participation is voluntary.
- I can withdraw from the study at any time for any reason without penalty.
- The results of this study may be published in scientific literature or presented at professional meetings using group data only.
- All information will kept confidential through the use of number codes. My data will not be linked with personally identifiable information.
Possible benefits (for use if there are any direct benefits to the participant)

- I and other athletes may benefit by having a simple valid tool for exercise prescription of training intensity.

Questions regarding study procedures may be directed to Justine Lueck (507-450-3956), the principal investigator, or the study advisor Dr. Carl Foster, Department of Exercise and Sport Science, UW-L (608-785-8687). Questions regarding the protection of human subjects may be addressed to the UW-La Crosse Institutional Review Board for the Protection of Human Subjects, (608-785-8124 or irb@uwlax.edu)

Participant ___________________________ Date ___________

Researcher ___________________________ Date ___________
APPENDIX B

DATA RECORDING SHEETS
<table>
<thead>
<tr>
<th>TIME (minutes)</th>
<th>SPEED (mph)</th>
<th>HEART RATE</th>
<th>RPE</th>
<th>TALK TEST</th>
</tr>
</thead>
<tbody>
<tr>
<td>rest</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0-2</td>
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APPENDIX C

REVIEW OF LITERATURE
Training

Fitness participants are typically instructed to train at an intensity defined in terms of percentage of maximal heart rate (HR) or VO\textsubscript{2} max (1). The American College of Sports Medicine (ACSM) defines appropriate intensity of exercise as moderate to vigorous (40-85% VO\textsubscript{2}R or HRR, 64-94% HR\textsubscript{max}) (1). These values, while effective in creating efficient training plans for athletes, may be costly and time consuming to determine, requiring maximal testing in a controlled laboratory setting to determine. Further, the rather broad range of recommended intensities may be so large that meaningful individual recommendations are hard to develop. Prescribing intensity in absolute measures (speed and grade, pace) is a more ideal approach for coaches and athletes.

Intensity distribution is a major component of training for both individual and team sports. There is a necessary balance that needs to be achieved for optimal performance results. When an athlete trains at an intensity that is too high, they run the risk of overtraining, injury, and fatigue, which may result in poor performance. Alternatively, if the training intensity is too low, the athlete may not elicit a great enough training effect to improve performance. It has been found that elite endurance athletes tend to train in various zones of intensity (low, moderate, high) in a polarized distribution which creates balance in their training, minimizing the risk of overtraining and improving performance (17).
More recently training recommendations have been defined with reference to the 25enti1ator and lactate thresholds (2, 17). The 3-zone intensity model, according to Esteve-Lanao (9), is defined by reference heart rates in relation to the 25enti1ator threshold and respiratory compensation threshold. Zone 1 (light intensity) is below the 25enti1ator threshold; zone 2 (moderate intensity) is between the 25enti1ator threshold and respiratory compensation threshold; and zone 3 (high intensity) is above the respiratory compensation threshold. These training zones can also be described in terms of blood lactate concentration, a low lactate zone, a lactate accommodation zone (where blood lactate is elevated but production and removal rate re-establish equilibrium), and a lactate accumulation zone (where the blood lactate production exceeds maximum clearance rates, and muscle fatigue occurs rapidly) (16).

Seiler (17) illustrates the concept of the “80-20 rule” of intensity distribution which is seen in athletes’ training patterns in different endurance sports with different event durations. Approximately 80% of training sessions are performed at intensities under the 25enti1ator threshold, or with a blood lactate concentration <2mM (zone 1). The remaining 20% of training is distributed between training at or near the lactate threshold (zone 2) and training at 90-100% of VO2max (zone 3). Variation is seen in the distribution of the latter 20% of training sessions between sports and athletes (17).

Seiler (16) also describes a polarized distribution as being the optimal intensity distribution where 75-80% of training sessions are spent in zone 1, 5% of sessions in zone 2, and 15-20% of sessions in zone 3. This training distribution is in contrast with the threshold training distribution where most of the training sessions are spent at intensities at or very near the lactate threshold. There has been evidence that elite endurance athletes
(rowers, runners, skiers, cyclists) tend to use the polarized distribution approach, with the majority of their training sessions in zone 1 and very few sessions are spent in zone 2 or at threshold intensity (16).

Esteve-Lanao et al. (9) tracked the training of competitive runners over a six month period and found that the runners spent 71% of training sessions in zone 1, 21% of training sessions in zone 2, and 8% of training sessions in zone 3. Their findings also showed a correlation between the amount of time spent in zone 1 and improved times in competition (short race-4.175 km, long race-10.130 km). These competitive events were typically contested at zone 3 intensity (30 minutes at >85% VO\textsubscript{2} max). They suggested that the small amount of high intensity training sessions in the runners was consistent with the likelihood of down-regulation of their sympathetic nervous system if they were to do high intensity exercise in large volumes, e.g. catecholamine depletion and insensitivity to catecholamines (9).

Esteve-Lanao et al. (8) conducted another study in subelite endurance runners over a five month period in order to compare the effect of two training programs using blood lactate concentration and heart rates as measures of exercise intensity. The programs did not differ in overall training load or high intensity exercise sessions, but had different distributions of low intensity and moderate intensity exercise sessions. The first group (Z1) spent most of their total training in zone 1 (below VT) whereas the second group (Z2) spent most of their total training in zone 2 (between VT and RCT). The final training distribution of Z1 was approximately 80% spent in zone 1, 10% in zone 2, and 10% in zone 3; and Z2 was approximately 65% spent in zone 1, 25% in zone 2, and 10% in zone 3. The Z1 group showed significantly greater performance enhancement.
over the five month period than the Z2 group which supports previous studies findings of the relationship between low intensity training and improved performance. They stated that large volumes of training sessions in zone 2 may contribute to fatigue and down-regulation of the sympathetic nervous system and fail to stimulate further adaptations in cardiorespiratory fitness. They also mention that the proper training combination includes more low intensity training and less moderate intensity training to improve performance contrary to previous thought as well as the importance of balance within training sessions for athletes.

Billat et al. (4) studied the physical and training characteristics of top-class marathon runners from France and Portugal. She found, among other significant results about physical and training characteristics, that the training distribution between high-level and top-class marathoners of both genders follows an identical pattern. The majority of their training is done at velocities either well above or well below their marathon or half marathon pace (close to the lactate threshold velocity) with very little done at their marathon or half marathon pace. This is in accordance to the polarized training distribution found in other elite and well-trained endurance athletes. Interestingly, it violates the supposed rule of training specificity.

This polarized distribution model and positive relationship between amount of training time spent in zone 1 and performance in events in zone 3 has been shown in many well-trained to elite athletes in endurance sports in recent years. Seiler and Kjerland (16) used elite junior cross country skiers to show a similar training distribution. 75% of training was in zone 1, 5-10% was in zone 2, and 15-20% was spent in zone 3. In a review article by Seiler (17) about the role of intensity and duration in endurance
training, he also mentions this distribution seen in the training of nationally and
internationally competitive runners, rowers, cross country skiers, and cyclists competing
in events ranging from four minutes to two hours.

**Maximal Lactate Steady State**

Because of the relationship between training intensity and lactate threshold
values, maximal lactate steady state can be a useful intensity marker for determining
appropriate exercise intensity. In terms of blood lactate concentration and lactate
threshold, maximal lactate steady state (MLSS) has been utilized for training intensity
recommendations. Beneke and von Duvillard (3) define MLSS as the equilibrium
between lactate production and elimination. In a later study, Beneke (2) refers to the fact
that MLSS can be used to detect the highest workload that can be maintained over time
without continual blood lactate accumulation and is the highest workload during which
blood lactate concentration increases by no more than 1.0 mmol *l⁻¹ during the final 20
minutes of an exercise test. Philp (14) describes MLSS as the highest running speed or
power output at which blood lactate concentration remains stable between 10 and 30
minutes of constant load exercise. In a study by Beneke and von Duvillard (3) it was
shown that MLSS and the speed and power output at which MLSS occurs varies between
sports (rowing, cycling, and speed skating) and the level of MLSS may be related to the
sport specific muscle mass as well as the level of sport specific strain of the dominant
muscles.

It has been demonstrated that training at MLSS can be used to elicit positive
submaximal and maximal changes in aerobic capacity (5,14). Billat et al. (5) used nine
well trained male runners over a six week period to study the effect of training at the speed at which MLSS occurs (MLSSv) on the time-to-exhaustion at MLSSv. After determining MLSS and MLSSv, the runners were given a training plan that included sessions at MLSSv. It was found that including training at MLSSv increased VO_{2}max, vVO_{2} max, and MLSSv significantly. There was also a tenfold increase on the time-to-exhaustion at MLSSv after training which was not related to the increase in MLSSv or VO_{2} max which demonstrates a significant improvement in endurance, and ability to sustain a high intensity for longer period of time.

Philp et al. (14) did an eight week exercise intervention study and separated subjects into two groups: continuous running at an intensity corresponding to the vMLSS (CONT) and intermittent running at 0.5 km/h above and below the vMLSS (INT). Though it was hypothesized that the INT group would have greater improvements in running speed at MLSS, significant improvements were made in both groups (CONT increased 8%, INT increased 5%), and there was increased running speed at lactate threshold and VO_{2} max along with the MLSS running speed. They concluded that in order to improve MLSS it is best to train specifically at vMLSS. Using MLSS has been shown to be a useful marker of exercise intensity thus giving athletes another tool to determine optimal training intensity distribution.

**Talk Test**

The Talk Test may be used as a technique to determine exercise intensity which does not require a maximal exercise test making it an ideal tool for training prescription for athletes and coaches. It has been found in our laboratory that the use of the Talk Test
for exercise prescription in a variety of populations (athletes, healthy individuals, patients
with heart disease, and patients who develop exertional ischemia) is a safe, beneficial
method (6,7,10,11,12,13,15,18).

Dehart-Beverley et al. (7) found that the Talk Test is a practical surrogate to the
ventilatory threshold in exercise in healthy individuals where subjects performed two
maximal exercise tests, one using gas analysis to determine VT and the other to
determine comfortable speech. When the results were compared it was found that that the
last stage which the subject can pass the Talk Test and speak comfortably during exercise
(last positive, +) they are below their ventilatory threshold. The first stage where they are
unsure whether they can speak comfortably (equivocal, +/-) is very near the VT, and the
first stage where they cannot speak comfortably (negative, -), they are above the VT.

Recalde et al. (15) studied this effect in well trained individuals. It was found that
when an individual can still speak comfortably they are consistently below the VT. The
first stage when the individual is unsure of whether comfortable speech is possible
(equivocal) is very close to the VT. The first stage that the individual cannot speak
comfortably (negative), they are at an intensity corresponding to the respiratory
compensation threshold and beyond the VT. In well trained individuals, the equivocal
and negative Talk Test scores may occur at very high intensities and speeds.

Foster et al. (10) demonstrated that the Talk Test is sensitive enough to track
changes in ventilatory threshold (VT) due to exercise intervention (increase in VT) or
blood donation (decrease in VT). It is also able to determine changes in exercise intensity
where comfortable speech was difficult at intensities greater than VT and regained when
intensities are below VT as well as respond to the changes in intensity within a short period of time (2-4 minutes). Persinger et al. (13) evaluated the consistency of the Talk Test in different modes of exercise. Close similarities of the ventilatory threshold were seen between treadmill and cycle ergometer tests using the Talk Test when the data was expressed in term of the metabolic sustainability of the exercise. They also demonstrated that the last positive or equivocal scores of the Talk Test (where speech is comfortable or unsure) is comparable to the ACSM’s suggested exercise intensity guidelines, and the negative score (where speech is no longer comfortable) is beyond the suggested guidelines for appropriate exercise intensity. The results of Dehart-Beverley et al.’s study in healthy individuals confirm Persinger et al.’s findings that the last positive and equivocal stages of the Talk Test are within ACSM suggested exercise intensity guidelines (7, 13).

Jeans et al. (12) and Foster et al. (11) determined in two different studies using healthy regular exercisers and healthy sedentary individuals respectively, that at the last stage the subject can speak comfortably during exercise (last positive, LP) as well as in the stage before the LP (LP-1) the subject reaches a steady state of RPE, heart rate, % of heart rate max, and Talk Test results. There is a considerable increase in all the measures at the equivocal stage and no steady state was demonstrated. Using these results it was concluded that the exercise intensity in untrained individuals, in order to speak comfortably during the 20 minute exercise bout, the absolute exercise intensity must be decreased from that during which comfortable speech is last observed (last positive) during the incremental exercise test. While steady state responses were observed and within the ACSM guidelines for exercise intensity, the subjective intensity (RPE and
Talk Test) was excessive in most subjects unless the intensity was decreased by approximately 10-12% (1 exercise stage) below the LP stage (11).

In Jeans et al.'s study (12), the primary finding was that in well-trained individuals the amount of down-regulation of the absolute intensity compared to incremental exercise was less than in sedentary individuals as seen in Foster et al.'s (11) study. The subjects were able to stay in steady state exercise intensity while running at the LP stage (below VT), most likely because of their well-trained status. Even with this result, it is appropriate, in order to provide a margin of error, to recommend training at the LP-1 stage. Another valuable indication of exercise intensity, blood lactate concentration, was not tested for steady state response using the Talk Test method, therefore the purpose of the current study is to attempt to determine the maximal lactate steady state using the Talk Test making exercise prescription simpler for coaches and athletes.
REFERENCES


