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BLOOD LACTATE THRESHOLD DETERMINATION IN ELITE CROSS-COUNTRY SKIERS ON A SKI TREADMILL

by

Ryan M. Stark

A thesis
presented to the University of Ottawa
in fulfillment of the
thesis requirement for the degree of
Master of Science
in
Kinanthropology

DEDICATION

I am dedicating this thesis to my grandfather Merwin Elwood (Pappy) McCulloch who taught me the meaning of patience.

ACKNOWLEDGEMENTS

I would like to take this opportunity to express thanks to the many people who helped me see this work through to completion.

To my advisor Dr. Alfred Reed, I extend a sincere thanks for the support, interest and friendship. His persistence and sharp eye for details made for a memorable learning experience. Thanks Al.

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My deepest appreciation and love go to my parents Sheila and Cliff for providing me with the opportunity to further my education and for showing me that there are no limits.

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ABSTRACT

The purpose of this study was to identify the concentration of lactate in the blood at which the first statistically significant increase had occurred during progressive incremental exercise by elite cross-country skiers on a ski treadmill. Thirty seven highly trained endurance athletes (seventeen women and twenty men) completed a total of 101 progressive incremental exercise tests to exhaustion. Mixed venous finger-tip blood samples were taken during the last minute of each three minute stage as were $\dot{V}O_2$'s and heart rates. Lactate threshold (LT) was defined as that workload which elicited a blood lactate concentration of 4.0 mMol/l. The first statistically significant increases in blood lactate concentration occurred across stages LT-2 and LT-1, whose mean blood lactate values were 2.51 mMol/l and 3.01 mMol/l respectively. The critical difference required to achieve significance was an increase of 0.50 mMol/l between two consecutive workloads. Statistical significance occurred over a range of blood lactate concentrations from 2.51 mMol/l to 5.53 mMol/l.

The findings of the present study show a distinct compartmentalization effect during progressive intensity changes elicited through graded exercise testing and strongly support the sub-threshold, threshold, supra-threshold

model. It was also shown that the LT is a transition zone which occurs across a range of blood lactate concentrations.

CONTENTS

TABLES

FIGURES

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Chapter 1
INTRODUCTION

Measurement of the physiological parameters associated with athletic endurance performance is a widely accepted practice. Although the measurement spectrum is extensive, Astrand and Rodahl (1986) have identified exercise intensity and duration as important considerations in determining performance capabilities. New methods, techniques and equipment are continuously being sought so as to more accurately assess the intensity of effort.

Traditionally, the use of oxygen consumption and heart rate as indices of intensity has predominated in events requiring oxidatively derived energy as a primary fuel source. However, recent advances in the physiology of exercise testing have promoted the measurement of lactate in the blood as an indicator of performance intensity (Jones and Ehrsam, 1982).

Brooks (1985) has shown lactate accumulation in blood during a progressive incremental exercise test to be a linear function of the rate of oxygen consumption up to approximately 60% of maximal oxygen consumption values. However, as the workload is gradually increased, there is a stage where the oxidative energy supply alone is no longer sufficient to

meet the metabolic demands of the body. It is at this point that further stimulation of glycolytic metabolism, and a subsequent increase in lactic acid production result in the accumulation of blood lactate (Green et al., 1983). The workload or rate of oxygen consumption (VO_2) at which lactate accumulation in the blood rises exponentially has been referred to as "lactate inflection point" (LIP) or "lactate threshold" (LT) (Brooks, 1985; Brooks and Fahey, 1984).

Karlsson and Jacobs (1982) proposed an absolute value of 4 mM/l in peripheral blood lactate during gradual increases in workloads as the criteria for the establishment of their "aerobic-anaerobic threshold" in ergonomic testing. The threshold value of 4 mM/l resulted from the observation that endurance trained athletes could tolerate workloads for longer periods of time below that level and that higher workloads normally resulted in a continual increase in blood lactate concentration. This absolute threshold of 4 mM/l was termed the "Onset of Blood Lactate Accumulation" (OBLA).

Farrel and his co-workers (1979) defined the "Onset of Plasma Lactate Accumulation" (OPLA) as the exercise intensity which induced a 1.0 mMol/l rise in plasma lactate above that obtained from 40% to 60% of maximal oxygen consumption, while Hurley et al. (1984) defined lactate threshold as an absolute value of 2.5 mM/l after 10 minutes of exercise.

Further still, Stegmann, Kinderman and Schnabel (1981), have defined what they call "Individual Anaerobic Threshold" (IAT) by a complex

mathematical model. IAT values reported ranged from 1.4 mM/l to 7.5 mM/l depending upon an individual's lactate kinetics.

In order to ascertain changes in blood lactate, $\dot{V}O_2$, and heart rate parameters related to endurance performance, conventional bicycle ergometer and treadmill tests consisting of incremental workload protocols are frequently implemented. Withers et al. (1981) noted the specificity of endurance indices as related to ergometry. They stated that trained cyclists had higher lactate thresholds than did marathon runners when measured on a bicycle ergometer although maximal oxygen consumption values were not significantly different. The converse was true when the same group of athletes were measured on a treadmill test. This specificity of physiological measurement is further supported by Cerretelli et al. (1979) who found that endurance training increased the rate of adjustment of oxygen uptake and lactate production at the onset of exercise specifically in the trained muscles. Therefore, event specific equipment and protocols would seem necessary if an individual's true physiological performance characteristics are to be accurately measured.

1.1 Rationale

Endurance exercise is generally performed at a fractional level of the maximal oxygen consumption ($\dot{V}O_2max$) (Farrel et al., 1979; Hagberg and Coyle, 1979). Evidence presented by Farrel et al. (1979) has shown minimal

blood lactate concentration at workloads up to 80% of $\dot{V}O_2max$. A slight increase in workload above a critical limit was reported to result in an exponential increase in blood lactate concentration. This lactate threshold has been shown to be important for endurance athletes (Brooks, 1985; Hurley et al., 1982). Tanaka and Matsuura (1984) have also shown lactate threshold to be of particular importance to long distance event performers. Their work with marathon runners gave evidence that superiority in marathon running may be characterized by a limited accumulation of blood lactate while performing at high work loads. Similarly, Yoshida et al. (1987) concluded that the lactate threshold is "the best index of aerobic capacity and endurance running performance." In this instance, the use of the the term "aerobic capacity" was synonymous with $\dot{V}O_2max$.

The findings of Wasserman (1987) support the significance of the lactate threshold. He found the lactate threshold to be an "important functional demarcation" since the physiological responses to exercise are different above and below the lactate threshold. Above the lactate threshold, in addition to the systemic metabolic acidosis, Wasserman (1987) stated that exercise endurance is reduced, $\dot{V}O_2$ kinetics are changed so that a steady state is delayed, minute ventilation increases disproportionately to the metabolic requirement and there is progressive tachypnea. The summary of these responses is the greater the increase in lactate, the less the endurance time (Wasserman, 1984).

However, controversy exists as to the true nature of the lactate response curve with graded exercise and the concentration of lactate in peripheral blood at which the threshold phenomenon occurs for endurance trained athletes.

There is a lack of agreement in the scientific community as to the measurement of the lactate threshold. One of the possible causes of lack of agreement is the use of non-specific protocols/ergometers.

There exists a need to establish a method to determine lactate threshold during sport specific athletic testing. If it can be shown that endurance trained athletes elicit a lactate threshold response at a fixed blood lactate level then this absolute blood lactate concentration may be used to identify training intensities and other physiological parameters associated with the lactate threshold workload.

1.2 Statement of the Problem

The purpose of this study is to identify the concentration of blood lactate at which the first statistically significant increase has occurred during progressive incremental exercise by cross-country skiers on a ski treadmill. The relationship between the responses of blood lactate, oxygen consumption and heart rate during the above exercise will also be examined.

1.3 Experimental Hypothesis

It was hypothesized that the first statistically significant increases in blood lactate concentration would occur at an OBLA of 4 mM/l and that significant relationships would exist between blood lactate, oxygen consumption and heart rate at an exercise intensity corresponding with the onset of blood lactate accumulation.

1.4 Limitations

The subjects in this study are all members of the Canadian National Cross-Country Ski Team and as such, conclusions can only be inferred to a group of similarly trained endurance athletes.

Although there are many indices of exercise intensity only blood lactate concentration, oxygen consumption and heart rate will be studied.

The progressive incremental exercise protocol used for testing is a multi-stage protocol designed specifically for use with a central fulcrum ski

treadmill. Thus comparisons may not necessarily be drawn with standard exercise ergometers even though exercise progression similarities probably exist.

1.5 Operational Definitions

LIP: Lactate Inflection Point. The point of delineation on the blood lactate curve (Brooks and Fahey, 1984).

$\dot{V}O_2$: The rate of oxygen consumption expressed relatively as ml of O_2 per Kg of body tissue per minute (ml/kg/min) or absolutely in litres of O_2 per minute (l/min).

$\dot{V}CO_2$: The rate of carbon dioxide production expressed relatively as ml of CO_2 per Kg of body tissue per minute (ml/kg/min) or absolutely in litres of CO_2 per minute (l/min).

$\dot{V}_E$: The volume of expired gases usually expressed in litres/minute (l/min).

LT: Lactate Threshold. the workload or $\dot{V}O_2$ at which lactate accumulation in the blood rises exponentially (Brooks, 1984).

$LT_{2.5}$: The lactate threshold associated with an absolute blood lactate level of 2.5 mM/l (Farrel et al., 1979).

F_ECO_2: The expired fraction of carbon dioxide (Astrand and Rodahl, 1986).

F_EO_2: The expired fraction of oxygen (Astrand and Rodahl, 1986).

OBLA: An absolute blood lactate concentration of 4.0 mM/l (Karlsson and Jacobs, 1982).

OPLA: An absolute plasma lactate concentration of 4.0 mMol/l (Farrel et al., 1979).

IAT: "The work rate of $\dot{V}O_2$ at which the maximal rate of lactate elimination from blood is in equilibrium with the rate of diffusion into the blood determined during a stepwise incremental exercise test" (Stegmann et al., 1981).

$\dot{V}O_2max$: The maximal rate of oxygen consumption expressed relatively as ml of O_2 per KG of body tissue per minute (ml/kg/min) or absolutely in litres of O_2 per minute (l/min).

Workload: The net effect on the subject of the changes of velocity and angle of the moving belt of the ski treadmill.

1.6 Symbols and Abbreviations

ADP: Adenosine Diphosphate

ATP: Adenosine Triphosphate

CoA: Coenzyme A

ETC: Electron Transport Chain

FAD: Flavin Adenine Dinucleotide

FFA: Free Fatty Acid

GDP: Guanine Diphosphate

LDH: Lactate Dehydrogenase

NAD: Nicotinamide Adenine Dinucleotide

NADH: Nicotineamide Dehydrogenase

SDH: Succinic Dehydrogenase

Chapter 2
REVIEW OF RELATED LITERATURE

2.1 Introduction

The availability of energy and its subsequent utilization dictates the intensity of work that is performed. Most of the physiological demands placed on the body during the transition from light to moderate to heavy work are causally linked to the requirements of skeletal muscle contractile processes. The supply of energy in a usable form varies with work intensity and duration. In order to identify the shift from easy to more difficult work one must realize the underlying physiological mechanisms associated with changes in work intensity.

The review of literature will be comprised of the following sections:

1. Pathways of Anaerobic and Aerobic Metabolism
2. Physiological Responses to Changes in Workload Intensity
3. Skeletal Muscle Fibre Types: Characteristics and Exercise Implications
4. Skeletal Muscle Adaptations to Endurance Training
5. Lactate Threshold Determination and Protocols

2.2 Pathways of Anaerobic and Aerobic Metabolism.

An increase in energy production requires the resynthesis of adenosine triphosphate (ATP). The process of energy capture in the form of ATP involves several multienzyme systems. The first or fast system, known as anaerobic glycolysis, degrades glucose to lactic acid.

There is very little free glucose in cells (Orton and Neuhaus, 1982). Intracellular glucose exists as a phosphorylated molecule, glucose-6-phosphate. The process of glucose phosphorylation is powered by an ATP molecule as follows:

$$\text{ATP} + \text{glucose} \rightarrow \text{ADP} + \text{glucose-6-phosphate}$$

The next step in the glycolytic process is the conversion of glucose-6-phosphate to fructose-6-phosphate. This is what is referred to as an isomerization reaction that does not add or delete any atoms from a molecule but merely reorganizes the internal bonding structure. Thus:

$$\text{glucose-6-phosphate} \leftrightarrow \text{fructose-6-phosphate}$$

In the third step a second phosphate is added to the fructose-6-phosphate as follows:

$$\text{ATP} + \text{fructose-6-phosphate} \rightarrow \text{ADP} + \text{fructose-1,6-diphosphate}$$

During the fourth step the six carbon fructose-1,6-diphosphate is split into two three carbon units. Each unit contains one of the phosphates. However, the three carbon units are not identical as one is a dihydroxyacetone phosphate while the other is a glyceraldehyde-3-phosphate. Of the two phosphates present at this point only the glyceraldehyde-3-phosphate can be metabolized further. An enzyme known as triose phosphate isomerase converts the dihydroxyacetone phosphate into glyceraldehyde-3-phosphate through an enzymatic isomerization outlined as follows:

dihydroxyacetone phosphate $\leftrightarrow$ glyceraldehyde-3-phosphate

AT this point the first stage of glycolysis is complete and the original glucose molecule has been transformed into two identical glyceraldehyde-3-phosphate molecules.

In the next stage each glyceraldehyde-3-phosphate is provided with a second phosphate group. Simultaneously, it loses two hydrogen atoms which associate immediately with the coenzyme nicotinamide adenine dinucleotide (NAD^+). The NAD^+ is reduced in the process to NADH and H^+. The phosphate that is used by the enzyme in this reaction is not a high energy phosphate, but inorganic phosphate (H_3PO_4) or P_i. This gives the following:

glyceraldehyde-3-phosphate + NAD^+ + P_i $\leftrightarrow$ 1,3-diphosphoglycerate + NADH + H^+

In the seventh step, ATP molecules are produced. Adenosine triphosphotase (ATPase) transfers a phosphate to an adenosine diphosphate (ADP) molecule thus adding a third phosphate onto the nucleotide:

$$\text{1,3-diphosphoglycerate} + \text{ADP} \leftrightarrow \text{3-phosphoglycerate} + \text{ATP}$$

Phosphoglyceromutase changes the 3-phosphoglycerate into a 2-phosphoglycerate just prior to the removal of a molecule of water by the enzyme enolase. The resultant molecule is called phosphoenolpyruvate:

$$\text{2-phosphoglycerate} \leftrightarrow \text{phosphoenolpyruvate} + H_2O$$

In order to produce another ATP molecule, pyruvate kinase removes the phosphate from the phosphoenolpyruvate and adds it to the ADP molecule:

$$\text{phosphoenolpyruvate} + \text{ADP} \rightarrow \text{pyruvate} + \text{ATP}.$$

The last step in glycolysis involves the addition of two hydrogen atoms to pyruvate to form lactate via the enzyme lactate dehydrogenase (LDH). The hydrogen atoms are provided by the reduced nucleotide NADH + H^+:

$$\text{pyruvate} + \text{NADH} + H^+ \leftrightarrow \text{lactate} + NAD^+$$

Glycolysis metabolizes glucose to pyruvate whether or not oxygen is available to the cell (Lehninger, 1975). Under hypoxic conditions pyruvate is reduced to lactate. However, when oxygen is available to the cell, the pyruvate molecules enter the mitochondria of the cell, where they are oxidized first to acetate with the loss of a CO_2 molecule and two hydrogen atoms to NAD^+. The acetate is never freed by the catalyzing enzymes but temporarily retained and bound to a coenzyme known as coenzyme A. The bonded acetate is then released from the enzyme as acetyl CoA. In this combined form, the acetate component is now able to proceed through a second pathway known as the Krebs cycle. The oxidation of pyruvate to acetyl CoA is an irreversible process and is summarized as follows:

$$\text{pyruvate} + NAD^+ + CoA \rightarrow \text{acetyl CoA} + NADH + H^+ + CO_2$$

The acetyl CoA combines with a four carbon unit oxaloacetate to form a six carbon unit citrate and the coenzyme A is released and used again. The citrate is gradually degraded in a way that produces two molecules of CO_2 and regenerates oxaloacetate. Thus, there is no net acetate loss and the cycle is able to continue.

More precisely, the first step of the Krebs cycle involves the enzymatic isomeration of citrate to isocitrate.

Secondly, isocitrate is oxidized to α-ketoglutarate. The catalyzing enzyme decarboxylizes the isocitrate molecule and also transfers two hydrogen atoms from the isocitrate ot the coenzyme NAD^+. The reaction is as follows:

$$\text{isocitrate} + NAD^+ \leftrightarrow \alpha\text{-ketoglutarate} + CO_2 + NADH + H^+$$

The third step is the oxidation of α-ketoglutarate to succinyl CoA. The α-ketoglutarate molecule is decarboxylated and dehydrogenated and energized by combining with coenzyme A. The reaction is summarized by:

$$\alpha\text{-ketoglutarate} + NAD^+ + CoA \rightarrow \text{succinyl CoA} + NADH + H^+ + CO_2$$

As a fourth step the succinyl CoA utilizes its energy to phosphorylate a molecule of guanosine diphosphate (GDP) to guanosine triphosphate (GTP) by using inorganic phosphate. This molecule of GTP, in turn, catalyzes the phosphorylation of ADP to ATP. Thus the sequence of reactions is as follows:

$$\text{succinyl CoA} + P_i + GDP \leftrightarrow \text{succinate} + GTP + CoA$$

Then:

$$GTP + ADP \leftrightarrow GDP + ATP$$

The fifth step employs a coenzyme termed flavin adenine dinucleotide (FAD), which accepts two hydrogen atoms. The dehydrogenation reaction removes two hydrogen atoms from succinate to yield one molecule of fumarate:

$$\text{succinate} + \text{enzyme-FAD} \leftrightarrow \text{fumarate} + \text{enzyme-}FADH_2$$

Malate is produced as a sixth step by the addition of a molecule of water to the fumarate. Hence:

$$\text{fumarate} + H_2O \leftrightarrow \text{malate}$$

The last step of the Krebs cycle is yet another enzymatic dehydrogenation reaction which removes two hydrogen atoms from malate and transfers them to the coenzyme NAD^+. The reaction is as follows:

$$\text{malate} + NAD^+ \leftrightarrow \text{oxaloacetate} + NADH + H^+$$

The overall result of one complete Krebs cycle is that four pairs of hydrogen atoms are released in the dehydrogenation reactions. Three of the four pairs are in the NADH H^+ combination and one pair of hydrogens is combined in the $FADH_2$ (Lehninger, 1975).

The pairs of hydrogen atoms released from glycolysis and the Krebs cycle are potential sources of large amounts of energy. When released from the enzymatic reactions that produced them, the hydrogen atoms are bonded to either coenzyme NAD^+ or FAD. The electron transport chain (ETC) consists of a series of electron carrier enzymes that are incorporated into the membranes of the mitochondrial cristae. The system operates by transferring first the hydrogen atoms, and then just their electrons, through a system of carrier molecules that concludes by reducing molecular oxygen. The

important consequence of this transport process is that portions of the energy carried by the hydrogen atoms and electrons are gradually released. Most of the energy is given off as heat, but some of the energy is conserved in the formation of ATP. This process of oxidative phosphorylation is coupled into the ETC and a portion of the energy released is captured and used to drive the reaction:

$$ADP + P_i \rightarrow ATP$$

Glucose is not the primary substrate metabolized to provide energy during prolonged muscular exercise. Brooks and Fahey (1984) have pointed out that free fatty acids (FFA) constitute an important portion of the fuel utilized during physical work. They have also illustrated that increased FFA metabolism during exercise can effectively decrease the use of other metabolic substrates.

The metabolic degradation of fatty acids is carried out in the matrix of the mitochondria. There, a series of soluble enzymes catalyze a process referred to as beta oxidation. In this process, the long-chain molecules are reduced to two carbon units of acetic acid bound to CoA.

The first step of fatty acid oxidation requires the transport of fatty acid from the cytoplasm of the cell into the mitochondrial matrix. This step is a complex reaction and requires energy. An ATP molecule is hydrolyzed to adenosine monophosphate (AMP) and the energy is used to bond the fatty acid to CoA:

$$FFA + ATP + CoA \rightarrow \text{Fatty Acyl CoA} + AMP + PP_i$$

Once activated, the fatty acid is then transferred to the transport molecule, carnitine, located in the inner mitochondrial membrane. Thus:

$$\text{Acyl carnitine} + CoA \rightarrow \text{Acyl CoA} + \text{carnitine}$$

This fatty acyl CoA complex presents the fatty acid to the enzymes of the beta oxidation pathway (Orton and Neuhaus, 1982). A scheme of the major biochemical pathways for production of ATP is presented in figure 1.

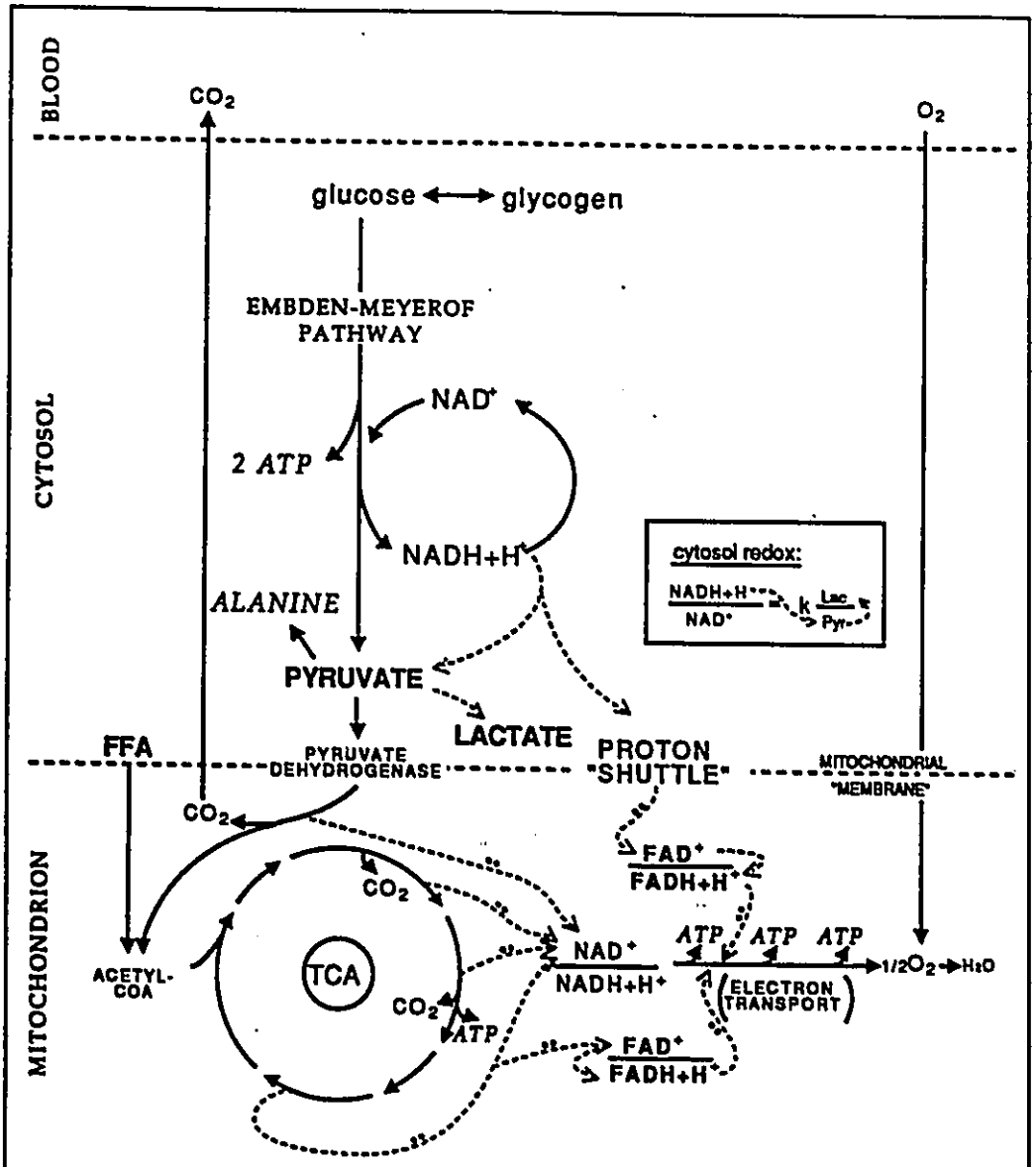


Figure 1: Scheme of the Major Biochemical Pathways for Production of ATP. Redrawn from Wasserman et al., (1987).

2.3 Physiological Responses to Changes in Workload Intensity

Substrates and their subsequent metabolic degradation provide the necessary energy required during muscular exercise. This allows for the physiological changes which accompany physical work.

During low level intensity exercise, there is an increased amount of oxygen extracted by the working muscles (Cerretelli et al., 1979). This results in a decreased fraction of oxygen in the expired air (F_EO_2). More CO_2 is produced, and this results in an increase in the CO_2 fraction of the expired air (F_ECO_2). With increasing levels of low intensity exercise, there is a linear increase in the $\dot{V}O_2$, in ventilation ($\dot{V}_E$) and in the volume of CO_2 expired ($\dot{V}CO_2$). Relatively little lactate is produced during this period indicating that low level intensities are primarily aerobic in nature (Skinner and McLellan, 1980; Jorfeldt et al., 1978).

As the exercise level reaches a point somewhere between 40% and 70% of $\dot{V}O_2max$, the $\dot{V}O_2$ and heart rate continue to rise linearly while the lactate level rises to above normal values (Astrand and Rodahl, 1986). The lactate is buffered by bicarbonate, which results in increased CO_2 production and a further rise in the concentration of CO_2 in expired air:

$$H^+ + HCO_3^- \leftrightarrow H_2CO_3 \leftrightarrow H_2O + CO_2$$

The respiratory center responds to the increased lactate and CO_2 levels by an increase in ventilation. The increased ventilation and the increased CO_2 level in the blood combine to increase the $\dot{V}CO_2$ and, therefore, to maintain a reasonable effective respiratory compensation for the increased levels of lactate. The rises in the $\dot{V}_E$ and $\dot{V}CO_2$ are greater than the rise in $\dot{V}O_2$ and have been attributed to the acid-base disturbance effect on the carotid bodies (Wasserman, 1987). Consequently, there is a relatively lower amount of O_2 extracted per ml of inspired air and the F_EO_2 rises. This intensity of work is best characterized by a nonlinear increase in $\dot{V}_E$ and the volume of expired CO_2, and an increase in the concentration of O_2 in the expired air without a decrease in the concentration of expired CO_2. The lactate levels at this intensity of exercise have been shown to be between 2.0 and 4.0 mM/l (Skinner and McLellan, 1980).

As the level of exercise continues to rise and reaches approximately 90% of $\dot{V}O_2max$, the $\dot{V}O_2$ and heart rate continue to rise linearly until they begin to plateau at near maximum levels. At the onset of this supra-threshold phase of exercise the blood lactate level rises very rapidly until $\dot{V}O_2max$ is reached. Ventilation increases further and there is a continuous rise in the $\dot{V}CO_2$ as part of the compensation for the rise in blood lactate (Wasserman et al., 1987). However, this compensation is inadequate because the increase in $\dot{V}_E$ is greater than the $\dot{V}CO_2$. Thus the F_ECO_2 falls while the F_EO_2 continues to rise. Therefore, supra-threshold exercise is best characterized physiologically

by a sharp rise in lactate, a fall in F_ECO_2, and a marked hyperventilation (Davis, 1985).

The $\dot{V}O_2max$ level of exercise intensity represents the upper limit of oxygen utilization by the body (Astrand and Saltin, 1961). Once this stage is reached both cardiac output (Q) and ventilation increase no further. $\dot{V}O_2$ is said to plateau (Stone and Liang, 1984) while blood lactate continues to increase until the termination of effort or cell-blood equilibrium is reached (jorfeldt et al., 1978).

2.4 Skeletal Muscle Fiber Types: Characteristics and Exercise Implications

There are two basic types of human skeletal muscle (Pette, 1986). Type I is the slow-twitch oxidative muscle. It is characterized by a high aerobic capacity and a high concentration of isoenzyme H-lactate dehydrogenase (H-LDH) or LDH_1 (Karlsson, 1977; Sjodin, 1976). This isoenzyme favors the oxidation of lactic acid to pyruvate. Type I fibres are rich in myoglobin and mitochondria. Because of their high aerobic capacity, these fibres are well adapted for endurance exercise (Ivy et al., 1980).

Type II fibres are fast-twitch glycolytic. Compared to type I, these fibres have a higher concentration of muscle LDH (M-LDH) or LDH_5 (Karlsson, 1974; Sjodin, 1976), which favours the reduction of pyruvate to lactate. They also have a lower capillary to fibre ratio than type I fibres as well as a lower

mitochondrial concentration and rate of oxidative metabolism (Baldwin et al., 1978; Essen et al., 1975). Type II fibres can be subdivided into type IIa, which has a relatively high oxidative capacity, and type IIb, which has a very low oxidative capacity (Pette, 1986; Sjodin, 1976). The latter (type II) has been referred to as "white" muscle, whereas the former (type I) is classified as "red" muscle.

Jansson (1975) documented a further sub-division of type IIb fibres into type IIb and type IIc fibres by their succinic dehydrogenase (SDH) and PFK activities. Type IIb fibres were described as having relatively high PFK activities and low SDH activities whereas type IIc fibres had relatively low PFK and high SDH activities. Astrand and Rodahl (1986) also adopted the type IIc nomenclature but redefined those fibres as being undistinguishable from either type IIa or type IIb. Table 1 provides a summary of selected muscle fibre sub-group contractile characteristics and enzyme profiles.

During sub-threshold activity the active musculature is primarily composed of type I fibres. This has been demonstrated by staining techniques which show that exercise levels between 30% and 85% of $\dot{V}O_2max$ there is preferential depletion of glycogen from the type I muscles (Essen, B., 1977), whereas brief exercise at 120% of $\dot{V}O_2max$ results in glycogen depletion in type II fibres (Brooks and Fahey, 1984). Since type I fibres have high concentrations of H-LDH and a relatively high aerobic capacity, the levels of blood lactate associated with this type of exercise are generally low.

Table 1: Selected Metabolic Characteristics of ST and FT Fibres

Characteristic	ST	FT
myosin ATPase activity	low	high
glycolytic enzyme activity		
PFK	low	high
LDH (total)	low	high
H-LDH	high	low
glycogen stores	varies	varies
triglyceride stores	high	low
capillary density	high	low
myoglobin concentration	high	low
mitochondrial density	high	low

Adapted from Astrand and Rodahl, 1977
Essen et al., 1975
Pette, 1971

In sub-threshold exercise, increasing amounts of FFA are utilized by the active muscles. FFA metabolism, by producing citrate, reduces glycolysis by inhibiting pyruvate oxidation and phosphofructokinase (PFK) activity (Skinner and McLellan, 1980).

During supra-threshold levels of intensity there is an increased recruitment of type IIa and possibly IIb fibres. Increased utilization of ATP further reduces the FFA mediated inhibition of pyruvate production. The

increased pyruvate levels, when coupled with the muscle LDH (M-LDH) pattern in type II fibres, result in increased lactate levels and a compensatory increase in respiration (Sjodin, 1976; Baldwin et al., 1978).

During near maximal exercise intensity there is further recruitment of type IIb fibres. They have a high M-LDH concentration and low oxidative capacity and tend to produce high lactate levels. The high lactate levels decrease FFA availability and consequently increase carbohydrate utilization (Skinner and McLellan, 1980). As the exercise intensity progresses through the sub-threshold range, there is a greater utilization of ATP and thus an increase in concentration of ADP, AMP, NH_4 and Pi (Green et al., 1983). These metabolites have been shown to decrease the activity of PFK, resulting in increased levels of pyruvate, some of which will be reduced to lactate. Thus the slight rise in blood lactate levels during sub-threshold intensity work is possibly due to excess pyruvate and not hypoxia. This concept is supported by the finding that at sub-threshold workloads endurance training reduces the lactate levels without increasing $\dot{V}O_2$.

At threshold intensity workloads there is a shift in recruitment toward type IIa and possibly type IIb fibres (Skinner and McLellan, 1980). Increased utilization of ATP further increases pyruvate production through glycolysis. The increased pyruvate levels, when coupled with the M-LDH pattern of type IIb muscle, result in increased lactate levels and a compensatory increase in $\dot{V}_E$. Supra-threshold exercise results in further recruitment of type IIb fibres.

Their high M-LDH levels and low oxidative capacity cause a further increase in lactate levels. The high lactate levels decrease FFA availability and subsequently increase carbohydrate utilization (Gollnick et al., 1986).

2.5 Skeletal Muscle Adaptations to Endurance Training

Endurance exercise training involves those activities that can be performed by an individual for extended periods of time. This type of exercise results in an increase in VO_2max but not in hypertrophy of skeletal muscle or in an increase in strength (Alway et al., 1988).

Skeletal muscle responds to exercise by an increase in myoglobin concentration (Pattergale and Holloszy, 1967; Woodson, 1984). This molecule serves to increase the rate of oxygen diffusion across the cytoplasm to the mitochondria (Orton and Neuhaus, 1982).

The performance of endurance exercise also results in an increase in mitochondrial respiratory enzymes (Holloszy and Booth, 1976). This results in an increased capacity to oxidize substrates. There is a parallel increase in the capacity of the muscle to generate ATP by oxidative phosphorylation (Gollnick et al., 1973; Mackova et al., 1983; Holloszy and Coyle, 1984). Other enzymes do not increase as much and may actually undergo a decrease in their activity (Mackova et al., 1983).

This increased ability to oxidize fats, carbohydrates and glycolytic end-products (lactate and pyruvate) has been linked to an increased provision

of substrates and an increase in enzyme activity involved in oxidative metabolism (Karlsson et al., 1972; Holloszy and Booth, 1976). Thus, elevated free fatty acid (FFA) levels are made available to the oxidative pathways through increased intracellular triglyceride content (Jansson et al., 1987), and augmented activity in the enzymes responsible for the activation, transport and beta-oxidation of FFA's (Baldwin et al., 1978), the enzymes of the citric acid cycle (Holloszy and Coyle, 1984), and the components of the respiratory chain involved in the oxidation of NADH and succinate (Gollnick and Saltin, 1982). The underlying mechanism of the increased oxidative capacity appears to be related to the proliferation of mitochondria in primarily type I and some type IIa skeletal muscle fibres (Holloszy, 1973; Holloszy and Booth, 1976).

As previously outlined, the various fibre types of skeletal muscle have differing enzymatic compositions. Type I fibres have the highest respiratory activity and a low glycolytic capacity. Type IIa fibres have a moderate respiratory capacity and a high glycolytic activity. Type IIb fibres have a low respiratory capacity and a very high glycolytic activity. The greatest increase in respiratory enzyme activity with endurance training occurs in type I fibres (Ivy et al., 1980). Type IIa has an intermediate increase and type IIb the smallest increase (Holloszy, 1976; Essen, 1977).

Endurance training has also be shown to reduce the accumulation of lactate in blood and skeletal muscle during exercise at any given

sub-threshold, absolute or relative, level of intensity (Bouheys et al., 1966; Brooks, 1985). Astrand and Rodahl (1986) have suggested that the reduced lactate accumulation in the blood of trained individuals results from a greater oxidative capacity and a decreased lactate production in skeletal muscle. Skinner and McLellan (1980) have attributed the decrease to changes in the LDH isoenzyme activity. Similarly, Baldwin et al. (1973) and York et al. (1974) suggested that chronic exercise might cause lactate production to be reduced by a decrease in muscle LDH activity and in the percent M-LDH isozyme. Karlsson et al. (1975) demonstrated this decrease in the total LDH activity with a shift toward the H-LDH isozyme. Hence lower lactate production may parallel an increase in the metabolic clearance rate (MCR) of lactate (i.e., the ratio of blood lactate concentration to lactate turnover) allowing for a lower lactate concentration at any given lactate production in trained individuals (Donovan and Brooks, 1984; Jorfeldt et al., 1978; Granata et al., 1976).

Besides enzyme activity, the skeletal fibre types also differ in the capillary supply. The density of capillaries is quite similar in type I and IIa fibres and both have a higher density than type IIb fibres. However, when expressed in relation to the mean fibre area, the capillary density of type I fibres is greater than that of type IIa, whose capillary density is greater than that of type IIb (Gollnick et al., 1973). It has been shown that with endurance training the capillary density of skeletal muscle can increase significantly (Gollnick et al., 1973).

Endurance training induces significant changes in $\dot{V}O_2$ and the workload at which lactate accumulates exponentially; the lactate threshold. The basis for the change can be equally apportioned between an increase in the cardiac output and an increase in the extraction of oxygen by the working muscles. At sub-threshold levels of exercise, there is a slower depletion of glycogen and a greater utilization of fatty acids as an energy source after a period of training (Vollestad et al., 1984; Jansson and Kaijser, 1987). The blood lactate levels are also lower at a given absolute workload after training. Thus there is said to be an increase in lactate threshold. These findings reflect the changes in enzyme activity noted previously. Because of the increased amount of mitochondrial activity per gram of muscle, less oxygen is utilized at the same sub-maximal workload (Essen, 1977). This results in higher steady state levels of ATP and creatine phosphate and lower levels of ADP and P_i (Bertocci and Gollnick, 1985). This should result in a lower rate of glycolysis. Muscle fatigue during exercise has been attributed to various factors. These include depletion of glycogen stores and increasing lactate levels. Both of these would be favorably affected by the changes noted above since decreased glycolysis would slow glycogen depletion and lactate accumulation at similar absolute workloads (Sahlin and Henriksson, 1984; Sahlin, 1986). Table 2 provides a summary of selected adaptations to endurance training.

Table 2: Selected Physiological Adaptations to Endurance Training

Adaptation	Response	Author(s)
Mitochondrial Size	Increased	1, 2
Mitochondrial Number	Increased	1, 2
FFA Oxidation	Increased	1, 2
Pyruvate Oxidation	Increased	1, 2
Lactate Oxidation	Increased	1, 2
Malate-Aspartate Shuttle	Increased	1, 2
Cytochrome Concentration	Increased	2, 4
Buffer Capacity	Increased	3
Glycogen Depletion (ST)	Decreased	3
Myoglobin Concentration	Increased	1, 5
Hemoglobin Concentration	Increased	5

Adapted from:

1. Holloszy and Coyle, 1984.
2. Holloszy and Booth, 1976.
3. Sahlin and Henriksson, 1984.
4. Gollnick and Saltin, 1982.
5. Woodson, 1984.

2.6 Lactate Threshold Determination and Protocols

Recently, there has been much discussion surrounding the significance of the lactate threshold and rises in blood and muscle lactate as indices of endurance capacity (Yoshida et al., 1987; Rusko et al., 1986; Brook, 1985; Davis, 1985). The most controversial parameter to date seems to be the identification of the lactate threshold.

A number of researchers have described exercise protocols using steady state work to assess blood lactate responses during various intensities of workload (Coyle et al., 1983; Rusko et al., 1986; Schnabel et al., 1982). Londeree and Ames (1975) first used a "discontinuous steady state protocol" to induce submaximal blood lactate responses to exercise. The maximal steady state (MSS) was defined as the exercise intensity which elicited a blood lactate level of 2.2 mM/l after 10 minutes of exercise. No objective rationale was given for justification of the 10 minutes used to achieve steady state. This time seems excessive if one is to consider that aerobic steady state is attained within three to five minutes (Karlsson et al., 1987; Karlsson, 1987) and lactate efflux from muscle to blood is approximately 4-5 mM/minute (Jorfeldt et al., 1978). Farrel (1979) and his research group defined the onset of plasma lactate accumulation (OPLA) as that exercise intensity which elicited a 1.0 mMol/l increase in plasma lactate concentration above those derived while working between 40% and 60% of $\dot{V}O_2max$. Coyle et al. (1983) originally paralleled the criterion of Farrel except that Coyle used blood

lactate instead of plasma lactate accumulation. Later, however, they and others redefined it as that exercise intensity which induced an absolute blood lactate value of 2.5 mMol/l after 10 minutes of exercise (Allen et al., 1985). The rationale offered by Coyle was that steady state endurance capacities were being predicted from blood lactate levels during steady state exercise and were therefore more representative of field conditions.

The protocols used by Sjodin and Jacobs (1981) and by Kindermann, Stegmann and Keul (1979) are somewhere between the 10 minute steady state protocol and the standard continuous incremental protocol. Sjodin and Jacobs define OBLA as the exercise intensity that elicits a 4.0 mMol/l blood lactate level during a continuous protocol with four minute stages. Kindermann and co-researchers (1979) originally defined a transition phase of exercise as the intensity associated with a blood lactate level of 4.0 mMol/l during an incremental test protocol with three minute stages. Since that time the IAT has been proposed by the same research group which follows the identical three minute stage incremental test procedure. Stegmann et al. (1981) reported IAT blood lactate levels ranging from 1.4 mMol/l to 7.5 mMol/l depending upon an individual's lactate kinetics.

Other researchers have not committed themselves to an absolute blood lactate value as lactate threshold (Hughson et al., 1987; Yoshida et al., 1987; Farrel and Ivy, 1987; Yoshida, 1984; Green et al., 1983). Moreover, they have purported that lactate threshold occurs at the $\dot{V}O_2$ or workload at which blood lactate levels begin an exponential rise.

Kumagai and co-workers (1982) reported an interesting approach to lactate threshold although it was nearly identical to the exponential rise model previously presented. Kumagai used the first breakaway point of lactate (the onset of metabolic acidosis) as a standardized reference point in time. That is, all lactate response curves determined during incremental running exercise on a treadmill were reclassified relative to the first lactate break point or lactate threshold. This process has allowed for relative comparisons in blood lactate response between individual subjects. In the study presented by Kumagai et al. (1982) the subjects employed were all high school runners ranging in age from 16 to 18 years. The subjects had been regularly participating in intensive endurance training for several years prior to testing.

The specificity of physiological landmarks to performance modality has been investigated by Withers and co-workers (1981). They suggested that the adaptive responses to exercise are in part a function of the specific movement patterns executed in training. Consequently, if laboratory tests are to be considered accurate, the tests must allow optimal activation of the specifically trained muscle fibres. Therefore, laboratory tests should simulate the movement patterns of training if valid measurements are to be attained.

Many procedures/protocols have been offered by a number of research groups in an attempt to explain the blood lactate threshold phenomenon. The discrepancy for blood lactate values associated with lactate threshold is

great as most investigators have reported values ranging from 2.0 mMol/l (Green et al., 1983) to 7.5 mMol/l (Stegmann et al., 1981). However, most authors report blood lactate values at lactate threshold between 2.0 mMol/l and 4.0 mMol/l (Heck et al., 1985; Sjodin and Jacobs, 1981).

Pilot work has shown the lactate threshold induced through continuous incremental exercise testing, using a sport specific ergometer, with a homogenous group of endurance trained athletes, to occur at an absolute blood lactate value of approximately 4.0 mMol/l. Therefore, one could expect to statistically show that the rise in blood lactate above 4.0 mMol/l should be significantly different from those lacate levels achieved during sub-threshold (below 4.0 mM/l) work intensities.

In consideration of the controversy surrounding lactate threshold it would appear that many researchers have offered many different hypotheses toward the possible mechanism of lactate threshold (Walsh and Banister, 1988). Suggestions concerning the measurement/identification of this phenomenon are equally diverse (Chwalbinska-Moneta et al., 1989).

It would be of interest to statistically investigate the LT phenomenon in order to objectively determine the blood lactate concentration at which LT occurs. It is possible that such an investigation may contribute in further describing the distinctive characteristics of blood lactate levels to increases in exercise intensity.

Chapter 3
METHODOLOGY

3.1 Introduction

This chapter outlines the methodology uses for the detection of change, if any, in the dependent variables associated with this study. The following sections are included in this chapter:

1. Introduction
2. Subjects
3. Procedure
4. Gas Analysis
5. Lactate Assay Procedure
6. Lactate Analysis Procedure
7. Ergometer
8. Criteria for Lactate Threshold Determination
9. Statistical Design

3.2 Subjects

Twenty male and seventeen female national team cross-country skiers participated in the study. These skiers were highly trained endurance athletes who had been competing at the national and international level for several years. The skiers comprised both a junior and senior ski team referred to as team 92 and team 88 respectively. They trained year round with a weekly training schedule ranging from 25 to 30 hours per week. The testing took place over an eighteen month period. During this eighteen month period the skiers went through cycles of training and detraining according to a preset program (Wilmore et al., 1988). It was the variation of the lactate response over the entire 18 eighteen month period which was of primary interest.

3.3 Procedure

Following informed consent and a complete orientation session on the testing equipment, subjects were fitted with appropriate skis, poles and a Douglas valve head gear according to individual requirements (figure 2). Each subject wore a Polar Electro PE3000 Sportester which digitally recorded their heart rate at five second intervals throughout the duration of the test (Polar Electro KY). Karvonen et al. (1984), and Leger et al. (1988) have shown the heart rate microcomputer (PE3000) heart rate values to be non-significantly different from those obtained via a standard electrocardiograph and Holter monitor respectively.

Subjects performed an progressive incremental ski-treadmill test until fatigue according to the protocol of Reed and MacKenzie (1986). The initial warm-up speed was 6.0 or 5.5 km/h for males and females respectively, and was five minutes in duration. For each successive three minute load the angle was increased 1 degree, the smallest change possible on the ski treadmill, until volitional fatigue was reached by the subject. Table 3 provides a summary of the gender dependent protocol.

Table 3: VO_2max Progressive Incremental Ski-Treadmill Protocol

	Females		Males	
Stage	Speed	Angle*	Speed	Angle*
Warmup	5.5 kph	+1	6.0 kph	+1
stage 1	5.5 kph	+2	6.0 kph	+2
stage 2	6.0 kph	+3	6.5 kph	+3
stage 3	6.5 kph	+4	7.0 kph	+4
stage 4	7.0 kph	+5	7.5 kph	+5
stage 5	7.0 kph	+6	7.5 kph	+6
stage 6	7.0 kph	+7	7.5 kph	+7
stage 7	7.0 kph	+8	7.5 kph	+8
stage 8	7.0 kph	+9	7.5 kph	+9
stage 9	7.0 kph	+10	7.5 kph	+10
stage 10	7.0 kph	+11	7.5 kph	+11
stage 11	7.0 kph	+12	7.5 kph	+12

* (Degrees)

Gas samples were measured throughout the whole test and Tissot backup samples were taken during the last 30 seconds of each stage. Blood samples

were taken during the first 20 seconds of the last minute of each stage. At the point of exhaustion the treadmill was stopped and recovery blood samples were taken immediately and 1, 2, and 3 minutes post exercise. Heart rates, which were stored on the PE3000 Sportester units were downloaded to an IBM PC/XT via an Polar Electro PE3000 interface and stored on 5.25 inch floppy diskettes. Figure 2 depicts a subject with experimental apparatus.

Figure 2: Photo-illustration of subject with experimental apparatus.

3.4 Gas Analysis

Gas analyses were performed using an open-circuit Roxon Rapid Response metabolic cart. Samples were analyzed with a Godart Capnograph and Oxygen Analyzer. Gas volumes were measured with a turbine ventilometer attached to the room air intake port and these values were validated against a Collins 100 litre Tissot tank. $\dot{V}O_2$ values were calculated every 30 seconds using an online computerized calculation/plot program. MVO_2 was determined as the highest oxygen consumption value attained by an individual during the ski-treadmill test. In-house laboratory testing has shown the precision of the gas measurement system to be +/- 2.0 ml/kg/min at $\dot{V}O_2max$.

3.5 Lactate Assay Procedure

Forty μl of mixed venous blood was taken from the fingertip during the first twenty seconds of the last minute of each stage. The fingertip was cleaned with 70% isopropyl alcohol and then dried using lint-free paper wipes. The skin was punctured with a gape incision lance. One 40 μl heparinized capillary tube was filled with blood and the incision was covered with sterile tape. A twenty μl sample of blood was immediately hemolysed and subsequently analyzed for blood lactate concentration with a Kontron Medical Lactate Analyser 640 (Kontron Medical Equipment Inc., Switzerland).

3.6 Lactate Analysis Procedure

Hemolyzing test tubes were pipetted with 380 μl of diluting solution and then sealed before the test session. Immediately after drawing blood from the subjects, 20 μl of whole blood was pipetted into the prepared test tubes and hemolyzed. This volume of hemolyzed whole blood was injected into the lactate analyzer in 100 μl aliquotes. The electric current produced in the oxidation of lactate to pyruvate was proportional to the lactate concentration of the sample. This current was translated to a digital signal which was recorded as the sample blood lactate concentration (Racine et al., 1975). The error involved with this method of lactate concentration determination has been demonstrated to be +/- 0.05 mM/l (Geyssant et al., 1985).

3.7 Ergometer

The ergometer used was a sport-specific Posi-Trac ski treadmill (Blue Klister, Inc.). The ski treadmill is a motorized, hydraulic ergometer. Its central fulcrum allows for 15 degrees of both positive and negative incline. The speed range of the Posi-Trac is 0.25 to 10.0 km/h. There is a rotating belt similar to standard treadmills although a unique inlaid track provides for the facilitated use of cross-country skis on the ski treadmill. A calibration for speed was done prior to each test session. Figure 3 schematically illustrates the Posi-Trac Ergometer.

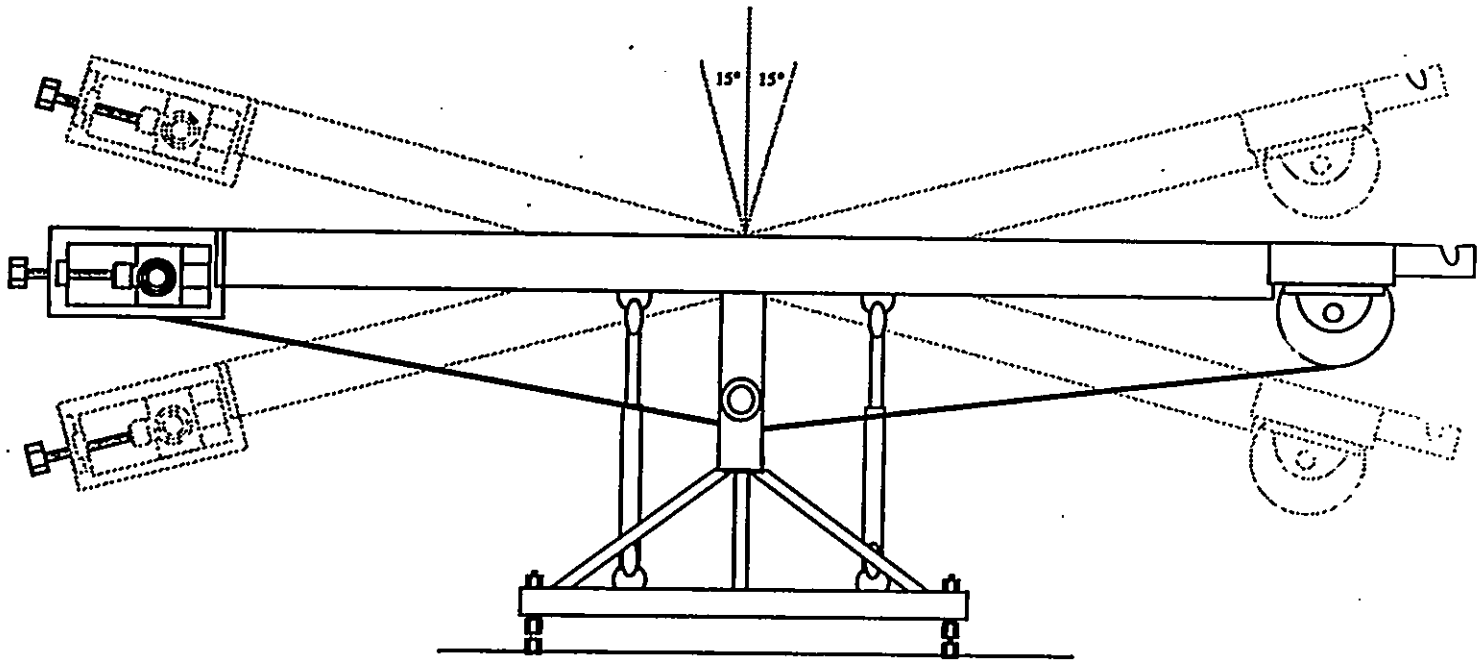


Figure 3: Schematic diagram of Posi-Trac ski treadmill ergometer.

3.8 Criteria for Lactate Threshold Determination

Mainframe computer generated plots of blood lactate concentration against time, and workload were produced. OBLA (Sjodin and Jacobs, 1981) was determined by the intersection of a reference line and the 4.0 mMol/l point on the lactate concentration plots. The stage with the smallest absolute delta lactate value from OBLA (4.0mM/l) was redefined as LT (Reid, 1981; Kumagai et al., 1982). All other stages and their associated lactate, VO_2, and heart rate values were reclassified relative to LT based on the logic sequence found in Appendix A.

LA, OX and HR are the unclassified dependent variables; X is the absolute value of delta LA; Y is the minimum delta LA; FLAG is a tagged array element with the minimum delta LA; and REL is the new variable label for RELative stage in the array algorithm in Appendix A.

LT was thus defined as that workload which elicited a blood lactate level closest to 4.0 mM/l regardless of the absolute stage during the ski treadmill protocol at which it occured. This, in effect, controlled for fluctuations in training state among the skiers over the 18 month collection period.

3.9 Statistical Design

The data were analysed using the following statistical procedures after reclassification, where stage, gender and team designation were the independent variables in the analysis ; while LA concentration, VO_2, and heart rate served as the dependent variables:

1. Condescriptive analyses of selected physiological characteristics for the whole group, gender and team designation.
2. Pearson product moment correlation coefficients to measure the relationship between lactate, VO_2, and heart rate for the whole group, gender and team designation.
3. A 3 way repeated measures ANOVA was run, where stage, gender, and team designation were the independent variables, of the blood lactate values, heart rates and oxygen consumption levels, to see if an overall significance was achieved. Where statistical significance was achieved, post-hoc analyses using a modified Tukey procedure were employed to determine the source of the overall significance (Hays, 1988).

Chapter 4
RESULTS

4.1 Introduction

The purpose of this study was to identify the concentration of lactate at which the first statistically significant increase occurred during progressive incremental exercise by cross country skiers on a ski treadmill. The correlationship between blood lactate , heart rate and oxygen consumption was also examined. To this end the results are subdivided into three (3) sections:

1. Physiological characteristics of the subjects/subject groups.
2. Correlational matrices for dependent variables.
3. Inferential summaries for independent data pooling and overall significance determination.

4.2 Physiological Characteristics of the Subjects/Subject Groups.

Thirty-seven highly trained endurance athletes (seventeen women and twenty men) completed a total of 101 progressive incremental exercise tests to exhaustion. The subjects were divided into Senior (N=12) and Junior (N=25) team designations and further subdivided into Senior Men (N=6), Senior Women (N=6), Junior Men (N=14) and Junior Women (N=11). Tables 4 through 8 summarize selected physiological characteristics overall and by subdivision.

Table 4: Physiological Characteristics of Subjects.

	N	MEAN	STD
Age (Years)	37	21.3	3.3
Height (cm)	37	173.5	7.9
Weight (kg)	37	65.8	10.3
VO2max (ml/kg/min)	37	66.1	5.5
VO2max (l/min)	37	4.4	0.9

Table 5 contains the selected physiological information specific to gender differentiation while table 6 serves to subdivide the subjects into their respective team designation. The number of years of endurance training is

subjectively represented by the team designation variable. Senior skiers have more training years behind them than do junior skiers.

Table 5: Physiological Characteristics of Subjects By Gender.

	Women		
	N	MEAN	STD
Age (Years)	17	21.5	3.5
Height (cm)	17	167.6	4.4
Weight (kg)	17	56.6	5.2
VO2max (ml/kg/min)	17	61.9	3.5
VO2max (l/min)	17	3.5	0.4
	Men		
	N	MEAN	STD
Age (Years)	20	21.1	3.2
Height (cm)	20	178.6	6.6
Weight (kg)	20	73.6	6.1
VO2max (ml/kg/min)	20	69.7	4.3
VO2max (l/min)	20	5.1	0.5

Table 7 provides for the most detailed condescriptive analysis of the sub-group population. Regardless of the size of the sub-populations the range

Table 6: Physiological Characteristics of Subjects By Team Designation

	Senior		
	N	MEAN	STD
Age (Years)	12	24.2	3.2
Height (cm)	12	173.4	7.6
Weight (kg)	12	64.4	9.4
VO2max (ml/kg/min)	12	68.3	6.6
VO2max (l/min)	12	4.4	1.0
	Junior		
	N	MEAN	STD
Age (Years)	25	19.9	2.4
Height (cm)	25	173.6	8.2
Weight (kg)	25	66.5	10.8
VO2max (ml/kg/min)	25	65.1	4.7
VO2max (l/min)	25	4.3	0.9

of values for each variable infringes upon the 95% confidence interval of the same variable for all sub-groups, thus indicating a high degree of homogeneity within the group/sub-groups.

Table 7: Physiological Characteristics of Subjects By Team Designation and Gender

Senior Women

	N	MEAN	STD
Age (Years)	6	24.0	3.0
Height (cm)	6	168.4	5.4
Weight (kg)	6	56.8	4.7
VO2max (ml/kg/min)	6	63.1	3.9
VO2max (l/min)	6	3.6	0.4

Senior Men

	N	MEAN	STD
Age (Years)	6	24.3	3.5
Height (cm)	6	178.5	5.9
Weight (kg)	6	72.1	5.6
VO2max (ml/kg/min)	6	73.5	3.8
VO2max (l/min)	6	5.3	0.4

Junior Women

	N	MEAN	STD
Age (Years)	11	20.2	3.1
Height (cm)	11	167.1	4.0
Weight (kg)	11	56.4	5.7
VO2max (ml/kg/min)	11	61.3	3.3
VO2max (l/min)	11	3.5	0.4

Junior Men

	N	MEAN	STD
Age (Years)	14	19.6	1.8
Height (cm)	14	178.6	7.1
Weight (kg)	14	74.3	6.3
VO2max (ml/kg/min)	14	68.2	3.3
Vo2max (l/min	14	5.1	0.5

4.3 Correlation Matrices for Dependent Variables.

Pearson product moment correlation coefficients relating lactate $\dot{V}O_2$ and heart rate are presented in tables 8 and 9. The relationship between lactate and $\dot{V}O_2$ has been previously demonstrated by a number of authors (Brooks, 1985; Wasserman, 1986; Harkonen, 1986; Roston et al., 1987) and is further illustrated in Figure 4. The change in polarity of the correlation points is of particular interest as one progresses from sub-threshold through LT to supra-threshold intensities. The stage by stage correlations depict a three-part physiological picture.

Table 8: Pearson Product Moment Correlation Coefficients Overall

Relative Stage	LA-VO_2 (n)	LA-Heart Rate (n)	VO_2-Heart Rate (n)
LT-9	-0.75 (4)	-0.54 (4)	0.33 (4)
LT-8	-0.21 (11)	0.24 (11)	0.56 (11)
LT-7	-0.24 (23)	-0.06 (23)	0.69 (23)*
LT-6	-0.43 (38)**	-0.33 (38)**	0.61 (38)**
LT-5	-0.41 (61)**	-0.25 (61)*	0.51 (61)**
LT-4	-0.30 (80)**	-0.28 (78)**	0.51 (78)**
LT-3	-0.27 (89)**	-0.31 (87)**	0.09 (87)
LT-2	-0.16 (99)	-0.14 (97)	0.19 (97)
LT-1	0.01 (96)	0.00 (93)	0.05 (93)
LT	-0.07 (100)	0.16 (98)	-0.05 (98)
LT+1	0.23 (92)*	0.26 (90)*	0.00 (90)
LT+2	0.34 (65)**	0.33 (63)**	0.00 (62)
LT+3	0.22 (39)	0.56 (38)**	0.06 (38)
LT+4	0.21 (21)	0.24 (10)	0.35 (10)
LT+5	0.86 (3)	0.99 (3)	0.91 (3)

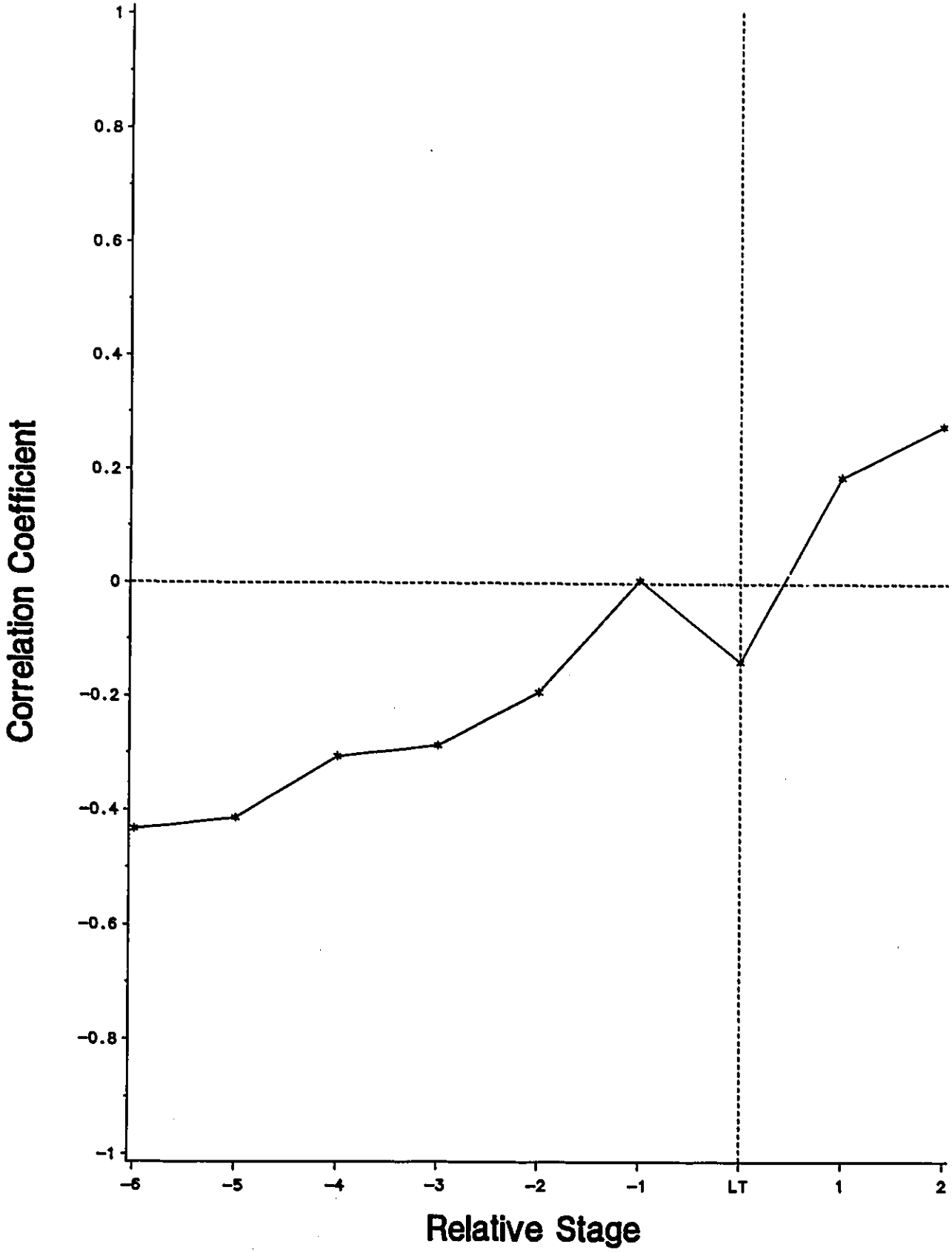
Note: *=0.05 significance, **=0.01 significance.

Table 9: Composite Correlation Table

Group	LA-VO_2 (n)	LA-Heart Rate (n)	VO_2-Heart Rate (n)
Overall	0.61 (811)	0.62 (795)	0.73 (791)
Senior Team	0.62 (475)	0.59 (465)	0.76 (464)
Junior Team	0.64 (336)	0.64 (330)	0.75 (327)
Men	0.68 (444)	0.63 (437)	0.85 (433)
Women	0.67 (367)	0.60 (358)	0.80 (358)

Note: All values significant at 0.01 level.

Figure 4
Lactate/Oxygen Correlation VS Relative Stage



As presented in table 9, all three dependent variables were found to be moderately correlated with one another and significant at the 0.01 level. This correlational trend was found to exist regardless of the independent sub-division and is evidenced in tables 8 through 17. Further, the correlational polarity maintained its trend of negative to positive as the workload progressively increased from sub-threshold to supra-threshold intensities.

4.3.1 Correlational Matrices for Dependent Variables by Independent Sub-Groups

Overall correlations between lactate and VO_2 were moderately positive and ranged from r=0.61 to r=0.68 (table 9). The correlation values between VO_2 and heart rate ranged somewhat higher from r=0.73 to r=0.85 (table 9) with each independent subdivision. However, the relationship between lactate and heart rate remained within a relatively small range with respect to the population breakdown (table 9).

Table 10: Pearson Product Moment Correlation Coefficients for Senior Team by Relative Stage

Relative Stage	LA-VO_2 (n)	LA-Heart Rate (n)	VO_2-Heart Rate (n)
LT-9	-0.75 (4)	-0.54 (4)	0.33 (4)
LT-8	-0.21 (11)	0.24 (11)	0.56 (11)
LT-7	-0.24 (18)	-0.34 (18)	0.75 (18)*
LT-6	-0.55 (29)**	-0.51 (28)**	0.73 (28)**
LT-5	-0.45 (43)**	-0.46 (42)**	0.57 (42)**
LT-4	-0.36 (52)**	-0.31 (51)*	0.56 (51)**
LT-3	-0.04 (53)	-0.27 (52)	0.03 (52)
LT-2	-0.01 (54)	-0.35 (53)*	0.17 (53)
LT-1	0.15 (54)	-0.23 (53)	0.08 (53)
LT	0.18 (54)	0.05 (53)	0.04 (53)
LT+1	0.37 (51)**	0.25 (50)	0.13 (50)
LT+2	0.68 (31)**	0.41 (30)*	0.05 (30)
LT+3	0.74 (16)**	0.58 (15)*	0.26 (15)
LT+4	0.72 (3)	0.93 (3)	0.44 (3)

Note: *=0.05 significance, **=0.01 significance.

Table 11: Pearson Product Moment Correlation Coefficients for Junior Team by Relative Stage

Relative Stage	LA-VO_2 (n)	LA-Heart Rate (n)	VO_2-Heart Rate (n)
LT-7	0.71 (4)	0.85 (5)	0.73 (4)
LT-6	0.55 (9)	0.51 (10)	0.54 (9)
LT-5	-0.23 (18)	0.09 (19)	0.56 (18)
LT-4	-0.15 (28)	-0.37 (27)	0.51 (27)**
LT-3	-0.37 (36)*	-0.51 (35)**	0.25 (35)
LT-2	-0.13 (45)	-0.09 (44)	0.32 (44)
LT-1	-0.01 (42)	0.06 (40)	0.19 (40)
LT	-0.30 (46)*	0.22 (45)	-0.01 (45)
LT+1	0.04 (41)	0.39 (40)*	0.06 (40)
LT+2	0.08 (34)	0.30 (33)	0.09 (33)
LT+3	-0.19 (23)	0.64 (23)**	0.00 (23)
LT+4	-0.04 (8)	0.32 (7)	0.37 (7)

Note: *=0.05 significance, **=0.01 significance.

Table 12: Pearson Product Moment Correlation Coefficients for Women by Relative Stage

Relative Stage	LA-VO_2 (n)	LA-Heart Rate (n)	VO_2-Heart Rate (n)
LT-6	0.01 (9)	0.00 (9)	-0.04 (9)
LT-5	-0.34 (23)	-0.30 (23)	0.58 (23)
LT-4	-0.23 (36)	-0.42 (36)*	0.51 (36)**
LT-3	-0.29 (44)	-0.46 (43)**	0.10 (43)
LT-2	-0.16 (50)	-0.17 (48)	0.31 (48)*
LT-1	0.21 (48)	0.19 (47)	0.27 (47)
LT	0.00 (50)	0.09 (49)	0.13 (49)
LT+1	0.24 (46)	0.25 (45)	0.18 (45)
LT+2	0.29 (32)	0.37 (30)*	0.31 (30)
LT+3	-0.18 (19)	0.46 (19)*	-0.01 (19)
LT+4	-0.33 (7)	0.03 (6)	0.81 (6)

Note: *=0.05 significance, **=0.01 significance.

Table 13: Pearson Product Moment Correlation Coefficients for Men by Relative Stage

Relative Stage	LA-VO_2 (n)	LA-Heart Rate (n)	VO_2-Heart Rate (n)
LT-9	-0.75 (4)	-0.54 (4)	0.33 (4)
LT-8	-0.21 (11)	0.25 (11)	0.56 (11)
LT-7	-0.29 (20)	-0.05 (21)	0.63 (21)**
LT-6	-0.47 (29)*	-0.32 (29)	0.68 (28)**
LT-5	-0.41 (38)*	-0.22 (38)	0.62 (37)**
LT-4	-0.29 (44)	-0.19 (42)	0.65 (42)**
LT-3	-0.43 (45)**	-0.23 (44)	0.43 (44)**
LT-2	-0.36 (49)**	-0.11 (49)	0.49 (49)**
LT-1	-0.21 (48)	-0.16 (46)	0.35 (46)*
LT	0.29 (50)*	0.21 (49)	0.11 (49)
LT+1	0.47 (46)**	0.30 (45)*	0.17 (45)*
LT+2	0.63 (33)**	0.32 (33)	0.07 (32)
LT+3	0.62 (20)**	0.63 (19)**	0.14 (19)
LT+4	0.99 (4)**	0.45 (4)	0.39 (4)

Note: *=0.05 significance, **=0.01 significance.

4.4 Inferential Summaries for Independent Data Pooling and Overall Significance Determination.

Table 18 provides an ANOVA summary for gender differences. No significant differences as determined by a Tukey post-hoc analysis were found. Figure 5 clearly illustrates the non-differences for gender by relative stage.

Table 14: Summary Lactate ANOVA Table for Gender Differences by Relative Stage

Relative Stage	Df	Sum Squares	F Value	PR > F
LT-7	22	10.81	0.09	0.7612
LT-6	39	18.53	1.30	0.2621
LT-5	61	26.38	2.47	0.1214
LT-4	80	30.24	1.86	0.1770
LT-3	88	29.61	0.08	0.7844
LT-2	98	27.88	0.19	0.6658
LT-1	95	28.70	0.10	0.7492
LT	99	27.39	4.77	0.0314
LT+1	91	89.44	0.07	0.7979
LT+2	65	141.95	0.01	0.9170
LT+3	38	121.88	0.00	0.9925
LT+4	10	34.81	0.00	0.9672
LT+5	2	0.47	1.47	0.4395

Note: **=0.01 significance.

Figure 5
Mean Lactate Differences VS Relative Stage By Gender

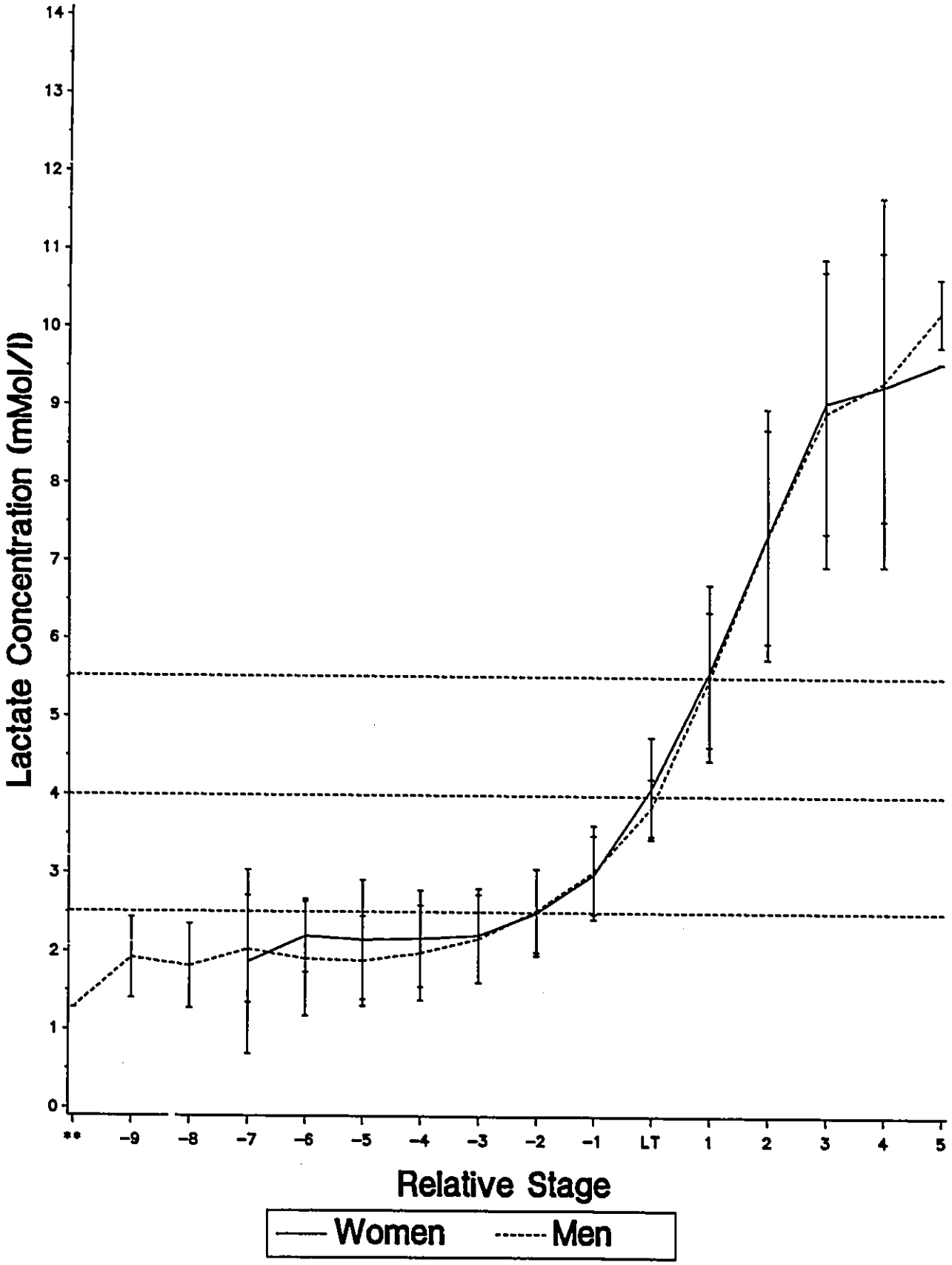


Table 19 summarizes Tukey post-hoc comparisons for team designation differences by relative stage. Two differences were found to exist at the 0.01 level and were at LT-3 and LT-2 respectively. Further ANOVA summaries were required to determine if the source of the between team designation differences would be influenced by the within team designation differences. Across workload differences were identified within the Senior team at (LT-2 - LT-1) (table 16, 17) and within the Junior team at (LT-1 - LT) (tables 18, 19). Although between team designation differences were originally detected at LT-3 and LT-2, analyses revealed (table 16, 17, 18, 19) that these differences did not overlap the within group across workload differences of (LT-2 - LT-1) and (LT-1 - LT) for Seniors and Juniors respectively. Thus it was determined to be advantageous to pool the sample values to get an unbiased estimate (Hays, 1988). These pooled estimates are in fact weighted averages of the estimates from the different samples, which was necessary to adjust unequal sample sizes at each stage. The advantage lies in the fact that the sampling error will tend to be smaller for the pooled estimate than that for any single sample's value taken alone. Another advantage is that the pooled estimates reflect values for all subjects in the study over the entire collection period.

Table 15: Summary Lactate ANOVA Table for Team Designation Differences by Relative Stage

Relative Stage	Df	Sum Squares	F Value	PR > F
LT-7	22	4.69	16.03	0.0006**
LT-6	39	18.53	0.07	0.7872
LT-5	61	26.38	0.92	0.3415
LT-4	80	30.24	2.85	0.0952
LT-3	88	29.61	16.14	0.0001**
LT-2	98	27.88	18.84	0.0001**
LT-1	95	28.70	5.47	0.0215
LT	99	27.39	1.76	0.1873
LT+1	91	89.44	1.17	0.2830
LT+2	65	141.95	0.02	0.9014
LT+3	38	121.88	0.15	0.7020
LT+4	10	34.81	0.94	0.3586
LT+5	2	0.47	1.47	0.4395

Note: **=0.01 significance.

Figure 6
Mean Lactate Differences VS Relative Stage By Team Designation

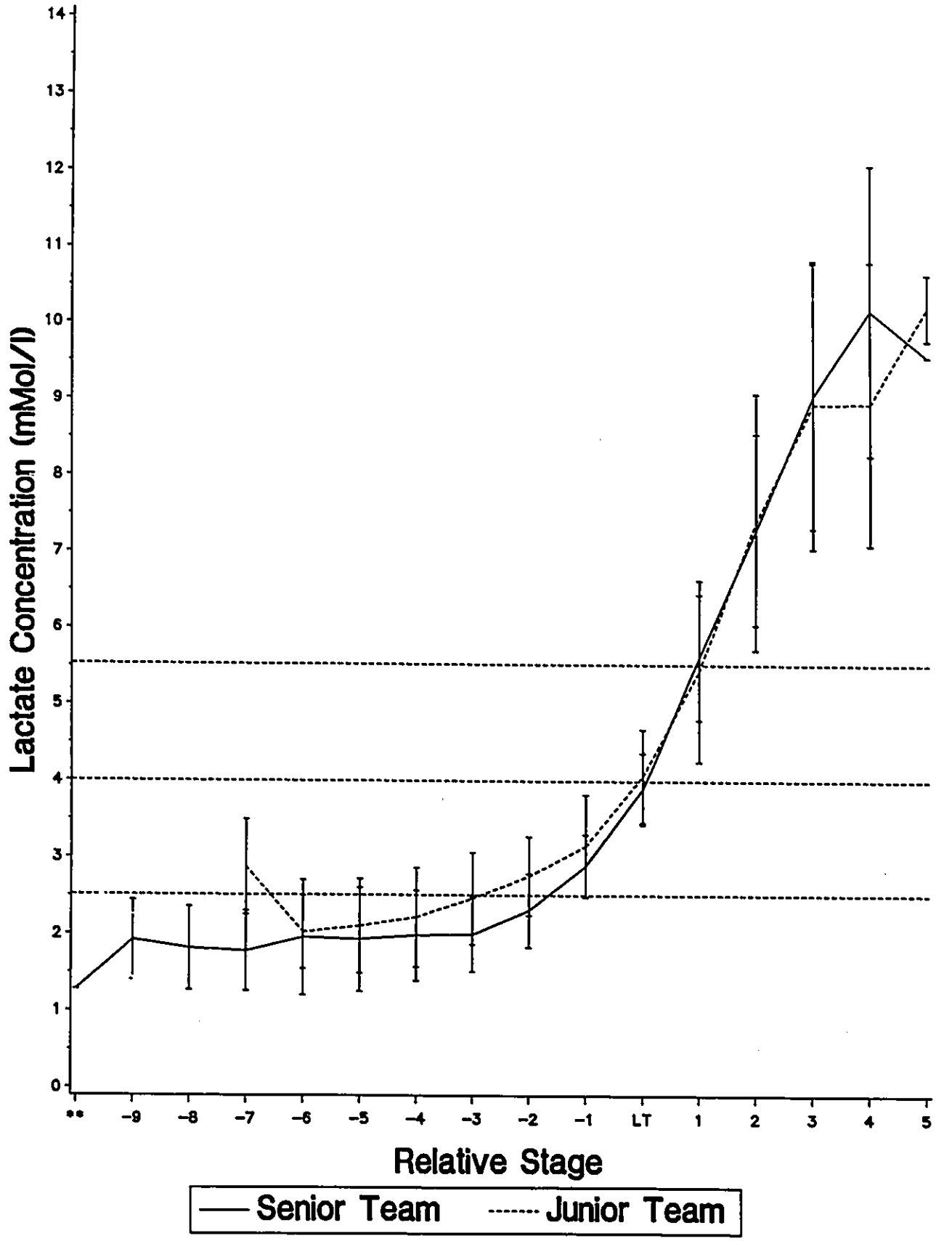


Table 16: Summary Lactate Means Table for Senior Team by Relative Stage

Relative Stage	N	MEAN (mM/l)	STD
LT-9	4	1.92	0.52
LT-8	11	1.81	0.54
LT-7	18	1.78	0.52
LT-6	30	1.96	0.75
LT-5	43	1.93	0.68
LT-4	52	1.98	0.59
LT-3	53	2.00	0.48
LT-2	54	2.31	0.48
LT-1	54	2.90	0.41
LT	54	3.90	0.47
LT+1	51	5.63	0.82
LT+2	32	7.31	1.26
LT+3	16	9.07	1.75
LT+4	3	10.19	1.91

The means and standard deviations of the pooled lactate values with increasing workloads are presented in Table 20 and illustrated in Figure 7. As expected, blood lactate values remained stable for a period of time prior to LT until the onset of an exponential lactate accumulation, thus indicating a change in the relationship between production and removal as outlined by Donovan and Brooks (1983) and Kowalchuk et al. (1988).

A summary of the subsequent ANOVA is provided in Table 23. Significance was obtained across workloads at the 0.01 level. A stepwise comparison of means was conducted using a Tukey post-hoc analysis (Hays, 1988).

The first statistically significant increase in blood lactate values occurred across stages LT-2 and LT-1, whose mean blood lactate values were 2.51

Table 17: Summary Lactate ANOVA Table for Senior Team by Relative Stage Differences

Relative Stage Comparison	Difference Between Means	PR > F
LT-10 - LT-9	-0.6400	0.4299
Lt-9 - LT-8	0.1055	0.8033
LT-8 - LT-7	0.0334	0.9041
LT-7 - LT-6	-0.1766	0.4140
LT-6 - LT-5	0.0268	0.8765
LT-5 - LT-4	-0.0536	0.7201
LT-4 - LT-3	-0.0142	0.9199
LT-3 - LT-2	-0.3148	0.0511
LT-2 - LT-1	-0.5832	0.0001**
LT-1 - LT	-1.0057	0.0001**
LT - LT+1	-1.7259	0.0001**
LT+1 - LT+2	-1.6790	0.0001**
LT+2 - LT+3	-1.7639	0.0001**
LT+3 - LT+4	-1.1221	0.0001**
LT+4 - LT+5	0.6133	0.0142

Note: **=0.01 significance.

Table 18: Summary Lactate Means Table for Junior Team by Relative Stage

Relative Stage	N	MEAN (mM/l)	STD
LT-7	5	2.88	0.62
LT-6	10	2.03	0.48
LT-5	19	2.10	0.61
LT-4	29	2.22	0.64
LT-3	36	2.46	0.61
LT-2	45	2.74	0.52
LT-1	42	3.16	0.50
LT	46	4.04	0.67
LT+1	41	5.40	0.58
LT+2	34	7.35	1.17
LT+3	23	8.84	1.68
LT+4	8	8.97	1.85
LT+5	2	10.23	1.86

mMol/l and 3.01 mMol/l respectively. The critical difference required for

Table 19: Summary Lactate ANOVA Table for Junior Team by Relative Stage Differences

Relative Stage Comparison	Difference Between Means	PR > F
LT-7 - LT-6	0.8490	0.1222
LT-6 - LT-5	-0.0777	0.8425
LT-5 - LT-4	-0.1177	0.6905
LT-4 - LT-3	-0.2412	0.3346
LT-3 - LT-2	-0.2797	0.2121
LT-2 - LT-1	-0.4119	0.0558
LT-1 - LT	-0.8868	0.0001**
LT - LT+1	-1.3619	0.0001**
LT+1 - LT+2	-1.9490	0.0001**
LT+2 - LT+3	-1.4910	0.0001**
LT+3 - LT+4	-0.1236	0.7636
LT+4 - LT+5	-1.2625	0.1114

Note: **=0.01 significance.

Table 20: Summary Lactate Means Table for Pooled Data by Relative Stage

Relative Stage	N	MEAN (mM/l)	STD
LT-9	4	1.92	0.52
LT-8	11	1.81	0.54
LT-7	23	2.02	0.70
LT-6	40	1.98	0.69
LT-5	62	1.98	0.66
LT-4	81	2.07	0.61
LT-3	89	2.19	0.58
LT-2	99	2.51	0.53
LT-1	96	3.01	0.55
LT	100	3.97	0.53
LT+1	92	5.53	0.99
LT+2	66	7.33	1.48
LT+3	39	8.94	1.79
LT+4	11	9.30	1.87
LT+5	3	10.01	0.49

significance by the Tukey test was determined to be 0.50 mMol/l of blood

Table 21: Summary Heart Rate Means Table for Pooled Data by Relative Stage

Relative Stage	N	MEAN (bpm)	STD
LT-9	4	121.3	12.6
LT-8	11	125.4	14.7
LT-7	23	132.2	14.2
LT-6	38	136.0	17.1
LT-5	61	145.8	13.8
LT-4	78	153.1	13.6
LT-3	87	163.4	9.3
LT-2	97	170.0	10.3
LT-1	93	177.0	9.3
LT	98	182.1	8.8
LT+1	90	187.4	8.4
LT+2	63	190.4	8.6
LT+3	38	192.4	8.3
LT+4	10	190.6	9.5
LT+5	3	187.7	19.5

lactate. Thus the experimental hypothesis is therefore rejected as the first statistically significant increase in blood lactate acid concentration did not occur at an OBLA of 4.0 mM/l but at a lower concentration of blood lactate somewhere between 2.51 mM/l and 3.01 mM/l. However, statistical significance was achieved over a range of blood lactate concentrations from 2.5 mMol/l to 5.5 mMol/l which encompassed the OBLA value of 4.0 mMol/l.

Figure 7
Mean Lactate Differences VS Relative Stage for Pooled Data

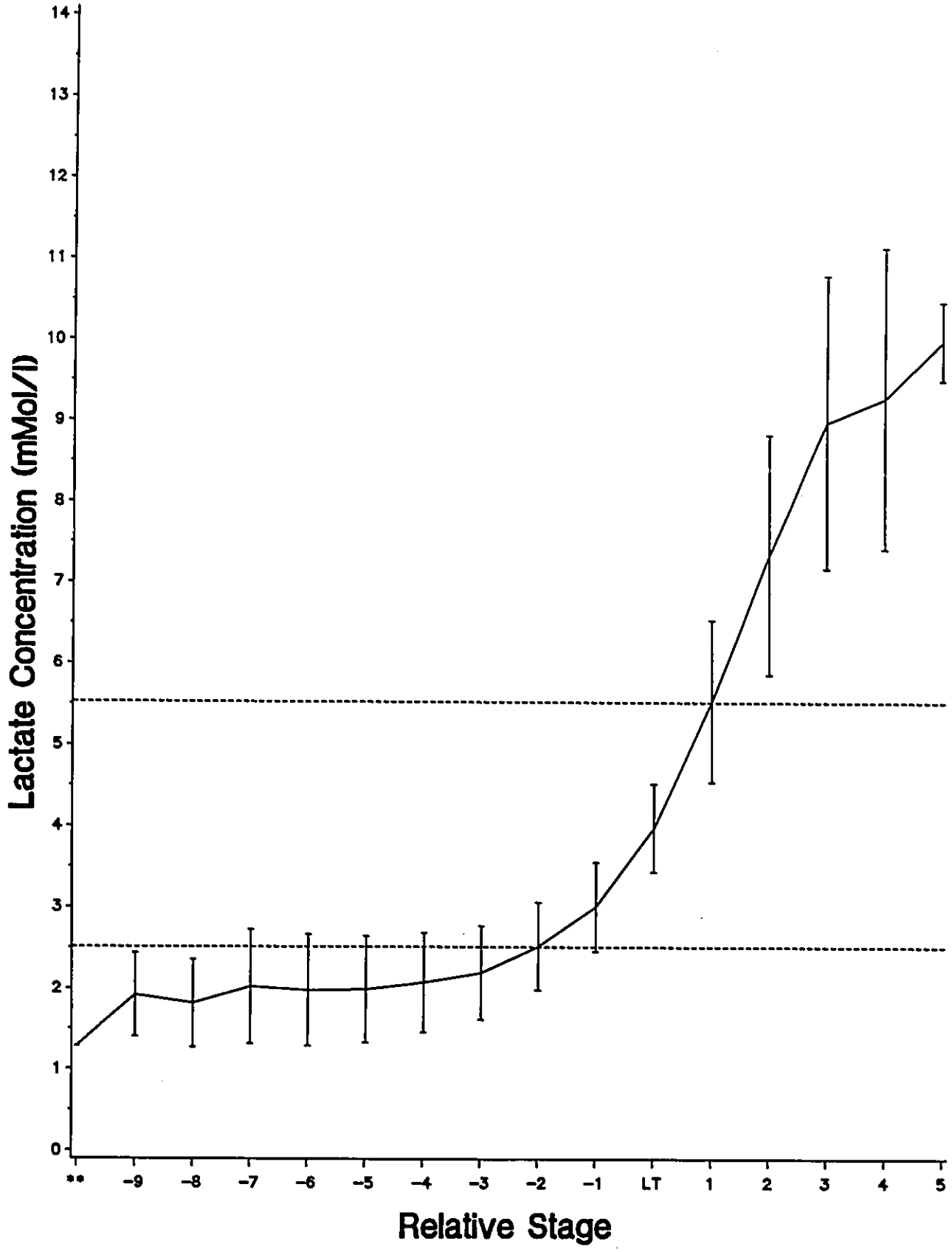


Table 22: Summary Oxygen Consumption Means Table for Pooled Data by Relative Stage

Relative Stage	N	MEAN (ml/kg/min)	STD
LT-9	4	38.2	6.3
LT-8	11	41.9	4.7
LT-7	22	42.3	6.1
LT-6	38	42.3	6.5
LT-5	61	44.5	7.2
LT-4	80	46.6	7.1
LT-3	89	49.8	6.5
LT-2	99	52.7	6.4
LT-1	96	56.4	5.8
LT	100	59.2	6.1
LT+1	92	62.6	6.3
LT+2	65	63.9	5.6
LT+3	39	65.0	5.9
LT+4	11	65.7	4.3
LT+5	3	65.3	5.5

Table 23: Summary Lactate ANOVA Table for Relative Stage Differences

Relative Stage Comparison	Difference Between Means	PR > F
LT-10 - LT-9	-0.6400	0.5057
Lt-9 - LT-8	0.1055	0.8336
LT-8 - LT-7	-0.2046	0.5164
LT-7 - LT-6	0.0441	0.8447
LT-6 - LT-5	-0.0091	0.9582
LT-5 - LT-4	-0.0855	0.5559
LT-4 - LT-3	-0.1171	0.3753
LT-3 - LT-2	-0.3221	0.0105
LT-2 - LT-1	-0.5010	0.0001**
LT-1 - LT	-0.9568	0.0001**
LT - LT+1	-1.5617	0.0001**
LT+1 - LT+2	-1.8025	0.0001**
LT+2 - LT+3	-1.6064	0.0001**
LT+3 - LT+4	-0.3646	0.2144
LT+4 - LT+5	-0.7115	0.2042

Note: **=0.01 significance.

Chapter 5
DISCUSSION

In this study, thirty-seven (37) highly trained endurance athletes completed a total of 101 progressive incremental exercise tests to volitional fatigue. The heights, weights and ages of the subjects were average in comparison with similarly trained athletes (Niinimaa et al., 1978).

Cross-country skiers have been reported to have the highest maximal oxygen uptake of any international class athletes (Saltin and Astrand, 1967). Heavy demands are placed upon the cardio-respiratory system during cross-country ski events (Jetté et al., 1976; Niinimaa et al., 1978). The maximal oxygen uptake of the male and female Canadian cross-country skiers was somewhat lower than those of the Swedish and Finnish skiers reported by Rusko and co-workers (1978). However, the subjects maximal oxygen consumption values are comparable to those values of elite middle distance runners published by Svedenhag et al. (1984), and considerably higher than those values of citizen cross-country skiers reported by Ng et al. (1988).

A measure other than maximal oxygen uptake, to ascertain endurance capacity has been reported. The blood lactate threshold (Kumagai et al., 1982;

Coyle et al., 1988; Wasserman, 1984). According to Mader and his associates (1976), endurance capacity is best characterized by the exercise intensity at which a complete coverage of the energy needs can be made oxidatively following the "initial" production of lactate. The transition area between the purely aerobic to partially anaerobic coverage of the metabolic energy needs of the body was termed the "aerobic-anaerobic threshold". Mader et al. (1976) further noted that this aerobic-anaerobic threshold was crossed gradually and not abruptly. The rise in lactate concentration to 4.0 mMol/l in peripheral blood during graded exercise was considered as the criteria for the establishment of threshold.

The use of absolute blood lactate levels to define the lactate threshold has been attributed in part to two reasons. First, the change in blood lactate concentration during incremental exercise does not always conform to a typical pattern (Davis and Gass, 1981). It is possible for blood lactate concentration to increase gradually right from the start of incremental exercise. By selecting an absolute threshold, the subjectivity of determining a point that represents the beginning of a systematic increase in blood lactate would be obviated.

The second reason for selecting the lactate threshold at a fixed, absolute blood lactate concentration is based on the findings previously mentioned by Mader et al (1976) and of those by Kindermann et al (1979). These researchers empirically found that athletes could exercise at an intensity

resulting in a blood lactate concentration of 4.0 mMol/l for 30 minutes. Exercise above that intensity resulted in a progressive increase in blood lactate and hence and inability to sustain work. Conversely , exercise below that intensity resulted in a progressive fall toward pre-exercise values of blood lactate and cound be sustained for periods longer than 30 minutes.

The findings of the present study support the work of Mader et al. (1976) and show a compartmentalization effect during the progressive intensity changes elicited through graded exercise testing. The sub-threshold, threshold, supra-threshold model is clearly illustrated by the correlational matrices polarity changes (table 8, figure 4). Distinct separations are evident at sub LT-2, LT-2 - LT+1, and supra LT+1. Interestingly, these separation points coincide with the sub-threshold, threshold, supra-threshold approach commonly utilized (Kindermann et al., 1979). The blood lactate concentrations associated with the previous compartments were: resting to 2.5 mMol/l, 2.5 mMol/l to 5.53 mMol/l, and 5.53 mMol/l to maximal values respectively and are summarized in table 24.

This compartmental model is not new. Wells et al (1957) developed three classifications of work intensity which were direct functions of lactate concentration expressed as a multiple of resting concentrations: 1) light work causing no increase in lactate, 2) heavy work causing 1.5 to 2 fold increases, and 3) severe work causing lactate to increase five times resting concentrations. Previously noted was the work of Mader et al (1976) and

Table 24: Summary Table for Compartmental Model.

Zone	[LA] (mMol/l)	Correlation (LA vs. VO2)
Under Transition	<2.5	Significantly Negative
Transition	2.5 - 5.5	Non-Significant
Over Transition	>5.5	Significantly Positive

others (Kindermann et al, 1979; Mader et al, 1980) who furthered the compartmental approach proposed by Wells et al (1957). The concensus was that the exercise intensity which induces an optimal qualitative stimulus for adaptation to endurance training should elicit a sustained lactate concentration of 4.0 mMol/l. This optimal lactate concentration will most likely differ between individuals however the present study demonstrates that it will probably occur within the transition zone of 2.5 mMol/l to 5.53 mMol/l.

This concept of an ideal or optimal blood lactate concentration is difficult to quantify. Sjodin et al. (1982), in a study where the lactate levels of middle and long distance runners were monitored while they trained on a treadmill at a running velocity calculated to elicit 4.0 mMol/l lactate, showed that those runners who were able to remain closest to the 4.0 mMol/l concentration during this training run exhibited the greatest increases in running velocity at 4.0 mMol/l lactate after the training period.

Kindermann et al. (1984) noted that endurance trained persons have their thresholds at lower lactate concentration levels than do untrained persons. Kindermann observed that work rates in training corresponding to the 4.0 mMol/l threshold value were poorly tolerated by trained individuals, but were well tolerated by untrained persons. Wasserman (1984) further illustrated this when he studied ten endurance trained adult males during cycle ergometry at three fixed work rates, each with a target exercise duration of 50 minutes. The target work duration could be achieved by all subjects only at those work loads where their arterial lactate increased less than 1.0 mMol/l above resting. No subjects with an increase in blood lactate above 2.5 mMol/l could sustain pedalling for 50 minutes. The greater the increase in arterial lactate, the less the endurance time. In comparison to the present study values of 2.5 mMol/l to 5.53 mMol/l, the value of 2.5 mMol/l reported by Wasserman (1984) as a ceiling steady state is considered low. One possible explanation for the difference is that the subjects in Wasserman's paper were performing lower body exercise (cycle ergometry) as opposed to whole body exercise (ski ergometry). A greater muscle mass involvement in the latter could potentially allow for a higher circulating lactate concentration in so far as a greater oxidation potential per unit mass recruitment. Thus the maximal steady state lactate values could be greater than the 2.5 mMol/l level proposed by Wasserman (1984), and provide a base for the LT range exposed by the present study.

It is frequently assumed the LT as determined on an ergometer could directly control the regulation of training. This is principally possible since the heart rate response is known to be linear with workload (Astrand and Rodahl, 1986). However, there is a need to completely identify the blood lactate values associated with this threshold transition zone in order to determine training sub-zones within it.

According to Astrand and Rodahl (1986), one of the basic principles of exercise physiology is progressive overload for training. In the present study it was demonstrated that the threshold transition zone occurs across a range of lactate concentrations. By elevating the location of the transition zone within one's own oxidative capacity, the potential for enhanced endurance performance increases without necessarily increasing one's maximal oxidative capacity.

A means of obtaining a more homogeneous adaptation to endurance training in a group of athletes may be facilitated through the prescription of training intensity as a function of the blood lactate concentrations as opposed to functions of maximal heart rate or percentages of maximal oxygen uptake. Such comparisons of the effectiveness of various means of establishing training have yet to be examined.

Chapter 6
CONCLUSIONS AND RECOMMENDATIONS

The results of the present study provide evidence for the following conclusions:

1. The first statistically significant increase in blood lactate occured at a concentration between 2.51 mMol/l and 3.01 mMol/l.
2. Overall correlations between blood lactate concentration, heart rate and oxygen consumption were statistically significant and moderately positive. The values went from significantly negative, to non-significant , to significantly positive as one progressed through the three intensity derived compartments.
3. Both the correlational matrices and the ANOVA support the findings that blood lactate concentration, heart rate and oxygen consumption respond to a progressive incremental exercise test in three distinct phases.

Based on these conclusions the following recommendations seem warranted:

1. The transition phase should be examined further to determine whether the 0.5 mMol/l increase in blood lactate concentration is a valid indicator of LT during field testing.

2. A longitudinal study is required to identify LT shift patterns with training over time.

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Appendix A

A.1 LT Reclassification Array

```
DATA A B C;
     SET DATA.SKIBASE;
          IF TESTTYPE='MVO2' AND
          (TEAMID='TEAM92' OR TEAMID='TEAM88')
          THEN OUTPUT A;
DATA;
     SET A;
           X0=ABS(4.0-LA0);
           X1=ABS(4.0-LA1);
           X2=ABS(4.0-LA2);
           X3=ABS(4.0-LA3);
           X4=ABS(4.0-LA4);
           X5=ABS(4.0-LA5);
           X6=ABS(4.0-LA6);
           X7=ABS(4.0-LA7);
           X8=ABS(4.0-LA8);
           X9=ABS(4.0-LA9);
           X10=ABS(4.0-LA10);
           X11=ABS(4.0-LA11);
           X12=ABS(4.0-LA12);
           X13=ABS(4.0-LA13);
           X14=ABS(4.0-LA14);
           X15=ABS(4.0-LA15);
           Y1=MIN(X0,X1,X2,X3,X4,X5,X6,X7,X8,X9,
                    X10,X11,X12,X13,X14,X15);
           IF X0 = Y1 | X1 = Y1 THEN
           Y=MIN(X2,X3,X4,X5,X6,X7,X8,X9,
                  X10,X11,X12,X13,X14,X15);
           ELSE Y = Y1;
     ARRAY X  (I) X0-X15;
     ARRAY LA (I) LA0-LA15;
     ARRAY OX (I) VO0-VO15;
     ARRAY HR (I) HR0-HR15;
           DO I=1 TO 16;
            IF X=Y THEN DO;
                                REL=0;
                                FLAG=I;
                                LAC = LA;
                                OXYGEN=OX;
                                HRTRATE=HR;
              IF LAC ¬= . THEN OUTPUT;
                               END;
            END;
           DO I=(FLAG-1) TO 1 BY -1;
```

```
                        REL=I-FLAG;
                        LAC = LA;
                        OXYGEN=OX;
                        HRTRATE=HR;
   IF LAC ¬= . THEN OUTPUT;
  END;
 DO I=(FLAG+1) TO 16;
                        REL=I-FLAG;
                        LAC = LA;
                        OXYGEN=OX;
                        HRTRATE=HR;
   IF LAC ¬= . THEN OUTPUT;
  END;
```

Appendix B

B.1 Raw Data

OBS	ID	DATE	HEIGHT	WEIGHT	LA	OXYGEN	HEART RATE
1	1	250187	181.7	72.8	1.82	38.6	120
2	1	250187	181.7	72.8	2.45	49.3	133
3	1	250187	181.7	72.8	1.55	51.4	149
4	1	250187	181.7	72.8	2.03	55.1	151
5	1	250187	181.7	72.8	2.47	59.2	162
6	1	250187	181.7	72.8	2.16	60.8	168
7	1	250187	181.7	72.8	2.70	63.2	173
8	1	250187	181.7	72.8	3.01	66.5	177
9	1	250187	181.7	72.8	4.07	70.1	180
10	1	250187	181.7	72.8	6.10	74.1	182
11	1	041187	182.0	74.0	1.98	36.0	106
12	1	041187	182.0	74.0	1.24	44.4	134
13	1	041187	182.0	74.0	1.38	49.5	136
14	1	041187	182.0	74.0	2.74	52.4	156
15	1	041187	182.0	74.0	2.08	56.6	163
16	1	041187	182.0	74.0	2.20	58.7	169
17	1	041187	182.0	74.0	2.60	60.7	174
18	1	041187	182.0	74.0	3.42	64.1	174
19	1	041187	182.0	74.0	4.12	65.3	180
20	1	041187	182.0	74.0	6.18	67.5	183
21	1	041187	182.0	74.0	8.62	74.6	180
22	1	070188	182.4	73.6	1.28	42.2	114
23	1	070188	182.4	73.6	1.30	47.5	130
24	1	070188	182.4	73.6	1.44	52.4	141
25	1	070188	182.4	73.6	1.92	53.5	145
26	1	070188	182.4	73.6	1.80	57.0	153
27	1	070188	182.4	73.6	1.80	62.2	158
28	1	070188	182.4	73.6	2.34	60.7	165
29	1	070188	182.4	73.6	2.12	63.4	168
30	1	070188	182.4	73.6	2.54	66.2	170
31	1	070188	182.4	73.6	3.42	70.4	177
32	1	070188	182.4	73.6	4.28	74.3	179
33	1	070188	182.4	73.6	6.28	75.8	181
34	1	310788	181.7	73.5	2.30	34.1	114
35	1	310788	181.7	73.5	2.04	41.9	133
36	1	310788	181.7	73.5	1.34	44.1	139
37	1	310788	181.7	73.5	1.48	49.4	147
38	1	310788	181.7	73.5	1.80	50.3	151
39	1	310788	181.7	73.5	1.94	54.0	160
40	1	310788	181.7	73.5	2.10	57.9	166
41	1	310788	181.7	73.5	2.98	62.0	171
42	1	310788	181.7	73.5	3.90	70.8	174
43	1	310788	181.7	73.5	5.66	75.6	178

44	1	310788	181.7	73.5	9.24	76.8	176
45	10	051186	165.3	56.7	2.79	29.7	140
46	10	051186	165.3	56.7	2.56	36.6	143
47	10	051186	165.3	56.7	1.87	43.2	160
48	10	051186	165.3	56.7	2.07	44.8	164
49	10	051186	165.3	56.7	2.25	45.8	166
50	10	051186	165.3	56.7	3.81	53.6	171
51	10	051186	165.3	56.7	5.90	58.7	181
52	10	250187	165.0	57.0	2.16	37.6	133
53	10	250187	165.0	57.0	1.62	42.8	151
54	10	250187	165.0	57.0	1.63	48.6	157
55	10	250187	165.0	57.0	1.90	50.2	166
56	10	250187	165.0	57.0	2.390	51.0	168
57	10	250187	165.0	57.0	3.030	51.9	172
58	10	041187	164.3	56.5	3.320	36.2	141
59	10	041187	164.3	56.5	4.000	48.9	157
60	10	041187	164.3	56.5	4.460	53.7	163
61	10	041187	164.3	56.5	4.520	56.2	169
62	10	041187	164.3	56.5	5.240	59.7	174
63	10	041187	164.3	56.5	7.980	62.7	173
64	10	041187	164.3	56.5	8.000	61.1	176
65	10	041187	164.3	56.5	9.580	59.0	169
66	10	070188	165.0	56.3	2.200	34.3	134
67	10	070188	165.0	56.3	2.060	44.9	150
68	10	070188	165.0	56.3	2.400	52.1	161
69	10	070188	165.0	56.3	2.320	51.5	166
70	10	070188	165.0	56.3	2.840	52.6	170
71	10	070188	165.0	56.3	3.400	54.7	172
72	10	070188	165.0	56.3	4.480	58.2	175
73	10	070188	165.0	56.3	6.120	60.6	176
74	10	310788	165.1	57.1	2.980	33.3	141
75	10	310788	165.1	57.1	2.860	45.8	158
76	10	310788	165.1	57.1	3.360	48.3	163
77	10	310788	165.1	57.1	3.200	52.2	168
78	10	310788	165.1	57.1	3.680	52.8	171
79	10	310788	165.1	57.1	4.340	54.6	171
80	10	310788	165.1	57.1	5.160	56.2	169
81	10	310788	165.1	57.1	5.740	57.6	172
82	10	050888	166.2	57.5	2.540	32.7	139
83	10	050888	166.2	57.5	3.320	44.9	157
84	10	050888	166.2	57.5	2.460	48.9	164
85	10	050888	166.2	57.5	2.900	51.9	167
86	10	050888	166.2	57.5	3.180	54.8	170
87	10	050888	166.2	57.5	3.820	55.0	173
88	10	050888	166.2	57.5	4.900	57.2	173
89	11	250187	176.5	64.0	2.700	31.4	113

90	11	250187	176.5	64.0	2.360	41.9	120
91	11	250187	176.5	64.0	2.020	45.0	152
92	11	250187	176.5	64.0	2.150	48.9	165
93	11	250187	176.5	64.0	2.820	51.4	170
94	11	250187	176.5	64.0	2.660	53.8	181
95	11	250187	176.5	64.0	3.190	58.9	185
96	11	250187	176.5	64.0	4.610	63.1	194
97	11	250187	176.5	64.0	6.210	61.6	197
98	11	310787	177.3	63.7	3.040	28.5	128
99	11	310787	177.3	63.7	2.240	41.9	156
100	11	310787	177.3	63.7	2.263	42.7	163
101	11	310787	177.3	63.7	1.901	47.4	167
102	11	310787	177.3	63.7	2.040	49.5	176
103	11	310787	177.3	63.7	2.860	52.7	183
104	11	310787	177.3	63.7	3.720	53.5	186
105	11	310787	177.3	63.7	4.920	55.9	193
106	11	310787	177.3	63.7	5.820	58.6	197
107	11	310787	177.3	63.7	9.200	62.7	198
108	11	041187	177.7	67.6	4.100	32.0	126
109	11	041187	177.7	67.6	3.160	41.1	156
110	11	041187	177.7	67.6	2.960	43.3	164
111	11	041187	177.7	67.6	2.820	47.5	171
112	11	041187	177.7	67.6	2.960	49.4	177
113	11	041187	177.7	67.6	3.960	52.1	184
114	11	041187	177.7	67.6	4.680	54.8	187
115	11	041187	177.7	67.6	6.020	55.3	191
116	11	041187	177.7	67.6	8.040	58.4	194
117	12	051186	168.9	53.1	1.510	34.2	174
118	12	051186	168.9	53.1	1.330	39.0	176
119	12	051186	168.9	53.1	2.910	45.9	190
120	12	051186	168.9	53.1	3.450	47.6	193
121	12	051186	168.9	53.1	5.630	52.9	195
122	12	051186	168.9	53.1	7.710	61.1	199
123	12	250187	168.4	51.9	2.010	37.3	134
124	12	250187	168.4	51.9	1.741	47.2	171
125	12	250187	168.4	51.9	1.470	55.5	182
126	12	250187	168.4	51.9	2.550	55.5	191
127	12	250187	168.4	51.9	3.220	59.9	194
128	12	250187	168.4	51.9	5.050	62.9	197
129	12	250187	168.4	51.9	7.570	63.1	198
130	12	310787	168.2	53.3	2.060	39.1	146
131	12	310787	168.2	53.3	1.800	42.7	166
132	12	310787	168.2	53.3	1.800	45.6	181
133	12	310787	168.2	53.3	2.680	51.5	187
134	12	310787	168.2	53.3	5.260	60.8	193
135	12	310787	168.2	53.3	6.420	57.9	199

136	12	310787	168.2	53.3	6.620	55.5	.
137	12	041187	168.1	53.2	2.500	32.2	122
138	12	041187	168.1	53.2	2.640	40.9	142
139	12	041187	168.1	53.2	2.340	46.5	159
140	12	041187	168.1	53.2	2.240	49.0	170
141	12	041187	168.1	53.2	2.720	52.6	180
142	12	041187	168.1	53.2	3.760	54.1	191
143	12	041187	168.1	53.2	5.000	57.9	192
144	12	041187	168.1	53.2	6.580	58.9	196
145	12	041187	168.1	53.2	8.880	62.8	198
146	12	070188	167.5	52.3	2.140	30.8	126
147	12	070188	167.5	52.3	1.500	40.5	152
148	12	070188	167.5	52.3	1.240	43.2	166
149	12	070188	167.5	52.3	1.260	46.2	174
150	12	070188	167.5	52.3	1.480	49.6	181
151	12	070188	167.5	52.3	2.660	53.7	187
152	12	070188	167.5	52.3	3.980	58.2	197
153	12	070188	167.5	52.3	5.630	62.9	196
154	12	070188	167.5	52.3	8.180	66.7	200
155	12	050888	169.0	53.4	2.380	31.9	148
156	12	050888	169.0	53.4	2.520	44.4	162
157	12	050888	169.0	53.4	2.580	45.6	173
158	12	050888	169.0	53.4	2.360	49.5	180
159	12	050888	169.0	53.4	3.260	52.5	189
160	12	050888	169.0	53.4	5.260	58.9	195
161	12	050888	169.0	53.4	6.820	61.1	201
162	12	050888	169.0	53.4	8.640	61.3	197
163	13	310787	170.5	62.3	2.620	41.8	133
164	13	310787	170.5	62.3	2.000	45.1	153
165	13	310787	170.5	62.3	1.520	49.5	163
166	13	310787	170.5	62.3	1.76	50.4	167
167	13	310787	170.5	62.3	2.44	52.5	175
168	13	310787	170.5	62.3	3.20	56.6	180
169	13	310787	170.5	62.3	4.50	59.2	184
170	13	310787	170.5	62.3	7.08	58.6	188
171	13	041187	171.7	62.4	1.78	41.0	143
172	13	041187	171.7	62.4	1.88	47.6	155
173	13	041187	171.7	62.4	1.66	51.9	166
174	13	041187	171.7	62.4	2.20	53.2	170
175	13	041187	171.7	62.4	2.72	59.8	173
176	13	041187	171.7	62.4	3.52	57.5	178
177	13	041187	171.7	62.4	4.62	58.7	181
178	13	041187	171.7	62.4	6.68	61.6	186
179	13	041187	171.7	62.4	11.00	65.1	187
180	13	070188	172.0	61.1	1.04	35.0	122
181	13	070188	172.0	61.1	1.14	47.6	154

182	13	070188	172.0	61.1	1.62	50.9	159
183	13	070188	172.0	61.1	1.50	53.4	166
184	13	070188	172.0	61.1	1.92	56.7	171
185	13	070188	172.0	61.1	3.32	60.2	180
186	13	070188	172.0	61.1	4.46	65.0	182
187	13	070188	172.0	61.1	7.82	67.6	185
188	15	140187	165.0	46.7	2.69	35.2	138
189	15	140187	165.0	46.7	2.53	42.1	162
190	15	140187	165.0	46.7	2.46	46.1	170
191	15	140187	165.0	46.7	2.24	46.1	173
192	15	140187	165.0	46.7	2.90	49.2	183
193	15	140187	165.0	46.7	2.03	52.2	189
194	15	140187	165.0	46.7	5.25	57.6	194
195	15	140187	165.0	46.7	8.98	54.9	195
196	16	051186	162.3	52.7	1.37	33.1	135
197	16	051186	162.3	52.7	1.40	37.7	150
198	16	051186	162.3	52.7	1.40	40.0	155
199	16	051186	162.3	52.7	1.97	44.1	163
200	16	051186	162.3	52.7	2.85	48.7	170
201	16	051186	162.3	52.7	4.53	51.1	176
202	16	051186	162.3	52.7	6.59	57.1	185
203	16	250187	161.2	54.3	1.40	37.0	148
204	16	250187	161.2	54.3	1.13	43.2	165
205	16	250187	161.2	54.3	1.38	49.2	172
206	16	250187	161.2	54.3	1.71	52.3	179
207	16	250187	161.2	54.3	2.70	53.9	182
208	16	250187	161.2	54.3	3.10	61.1	185
209	16	250187	161.2	54.3	5.04	65.5	190
210	16	120687	161.5	53.9	2.08	35.2	94
211	16	120687	161.5	53.9	2.30	45.1	136
212	16	120687	161.5	53.9	2.32	49.1	150
213	16	120687	161.5	53.9	2.16	54.4	160
214	16	120687	161.5	53.9	2.70	55.2	165
215	16	120687	161.5	53.9	3.20	58.6	170
216	16	120687	161.5	53.9	4.66	59.9	175
217	16	120687	161.5	53.9	6.16	63.1	185
218	16	120987	161.8	55.1	2.08	36.0	143
219	16	120987	161.8	55.1	2.58	45.5	168
220	16	120987	161.8	55.1	2.22	46.9	175
221	16	120987	161.8	55.1	2.72	50.3	182
222	16	120987	161.8	55.1	3.20	54.5	188
223	16	120987	161.8	55.1	4.46	57.3	192
224	16	120987	161.8	55.1	5.84	61.8	198
225	17	050888	190.0	80.0	3.72	40.0	149
226	17	050888	190.0	80.0	3.04	44.6	157
227	17	050888	190.0	80.0	1.78	49.7	161

228	17	050888	190.0	80.0	1.74	50.5	164
229	17	050888	190.0	80.0	1.96	54.5	168
230	17	050888	190.0	80.0	2.14	57.8	174
231	17	050888	190.0	80.0	2.62	60.8	180
232	17	050888	190.0	80.0	4.18	61.8	185
233	17	050888	190.0	80.0	5.20	66.4	190
234	17	050888	190.0	80.0	8.90	67.3	193
235	18	140187	158.8	50.4	1.61	30.9	149
236	18	140187	158.8	50.4	2.12	39.6	163
237	18	140187	158.8	50.4	2.52	43.6	173
238	18	140187	158.8	50.4	3.10	49.9	184
239	18	140187	158.8	50.4	4.87	54.0	187
240	18	140187	158.8	50.4	8.01	58.3	199
241	18	140187	158.8	50.4	10.42	61.4	198
242	18	120687	160.5	51.1	4.14	38.7	145
243	18	120687	160.5	51.1	2.46	46.9	155
244	18	120687	160.5	51.1	2.44	48.9	155
245	18	120687	160.5	51.1	4.52	56.0	162
246	18	120687	160.5	51.1	3.40	56.6	175
247	18	120687	160.5	51.1	4.84	62.8	185
248	18	120687	160.5	51.1	6.56	62.3	192
249	18	120687	160.5	51.1	6.58	67.0	195
250	18	050888	159.8	50.2	3.86	34.2	154
251	18	050888	159.8	50.2	2.24	43.9	174
252	18	050888	159.8	50.2	2.58	49.2	186
253	18	050888	159.8	50.2	3.28	52.5	191
254	18	050888	159.8	50.2	4.46	55.4	195
255	18	050888	159.8	50.2	6.38	59.4	197
256	19	120687	165.0	56.3	3.42	39.4	142
257	19	120687	165.0	56.3	2.84	44.9	155
258	19	120687	165.0	56.3	2.60	48.7	168
259	19	120687	165.0	56.3	3.24	53.0	173
260	19	120687	165.0	56.3	4.28	54.6	179
261	19	120687	165.0	56.3	6.16	57.4	188
262	19	120687	165.0	56.3	8.32	60.2	190
263	19	120687	165.0	56.3	10.30	59.9	194
264	19	120987	165.0	56.0	2.90	37.4	142
265	19	120987	165.0	56.0	3.20	46.5	158
266	19	120987	165.0	56.0	4.54	52.0	175
267	19	120987	165.0	56.0	7.30	56.6	180
268	19	120987	165.0	56.0	9.84	58.5	190
269	19	120987	165.0	56.0	12.54	58.6	195
270	19	050888	165.2	51.9	1.40	.	.
271	19	050888	165.2	51.9	2.02	45.5	171
272	19	050888	165.2	51.9	2.84	53.6	179
273	19	050888	165.2	51.9	3.38	55.7	184

274	19	050888	165.2	51.9	4.46	59.5	188
275	19	050888	165.2	51.9	6.08	62.3	193
276	19	050888	165.2	51.9	9.400	62.5	193
277	2	250187	168.5	66.3	1.730	35.7	116
278	2	250187	168.5	66.3	1.750	47.6	133
279	2	250187	168.5	66.3	1.800	50.2	142
280	2	250187	168.5	66.3	2.010	54.2	151
281	2	250187	168.5	66.3	2.440	61.1	162
282	2	250187	168.5	66.3	2.680	64.1	168
283	2	250187	168.5	66.3	3.160	66.8	173
284	2	250187	168.5	66.3	4.020	70.3	178
285	2	250187	168.5	66.3	6.450	77.4	185
286	2	310787	169.2	63.3	2.700	41.5	124
287	2	310787	169.2	63.3	2.180	45.3	137
288	2	310787	169.2	63.3	2.120	51.0	144
289	2	310787	169.2	63.3	2.520	52.3	152
290	2	310787	169.2	63.3	2.400	57.5	156
291	2	310787	169.2	63.3	3.080	60.7	164
292	2	310787	169.2	63.3	3.440	63.8	170
293	2	310787	169.2	63.3	3.880	67.6	177
294	2	310787	169.2	63.3	5.500	72.4	180
295	2	041187	169.0	64.5	2.520	34.6	114
296	2	041187	169.0	64.5	2.580	43.3	130
297	2	041187	169.0	64.5	1.980	48.4	137
298	2	041187	169.0	64.5	1.820	52.9	146
299	2	041187	169.0	64.5	2.320	52.3	155
300	2	041187	169.0	64.5	2.940	56.6	161
301	2	041187	169.0	64.5	3.400	57.4	167
302	2	041187	169.0	64.5	4.940	59.0	173
303	2	041187	169.0	64.5	5.680	63.4	177
304	2	041187	169.0	64.5	7.360	69.3	181
305	2	070188	170.0	64.0	1.420	33.9	115
306	2	070188	170.0	64.0	1.080	43.3	129
307	2	070188	170.0	64.0	0.980	44.9	129
308	2	070188	170.0	64.0	1.060	46.0	133
309	2	070188	170.0	64.0	1.420	54.8	151
310	2	070188	170.0	64.0	2.020	58.9	158
311	2	070188	170.0	64.0	2.820	63.2	168
312	2	070188	170.0	64.0	3.960	67.5	173
313	2	050888	169.7	65.0	3.520	36.2	118
314	2	050888	169.7	65.0	1.860	46.0	136
315	2	050888	169.7	65.0	1.720	50.3	143
316	2	050888	169.7	65.0	1.880	54.5	157
317	2	050888	169.7	65.0	2.000	59.0	156
318	2	050888	169.7	65.0	2.520	59.6	163
319	2	050888	169.7	65.0	3.760	63.1	168

320	2	050888	169.7	65.0	4.540	65.0	174
321	2	050888	169.7	65.0	7.140	67.9	181
322	20	140187	165.8	54.2	1.791	40.0	171
323	20	140187	165.8	54.2	2.270	46.0	187
324	20	140187	165.8	54.2	3.130	48.9	197
325	20	140187	165.8	54.2	4.650	55.0	201
326	20	140187	165.8	54.2	6.220	57.8	202
327	20	120687	167.7	54.5	2.300	38.7	166
328	20	120687	167.7	54.5	2.840	46.6	185
329	20	120687	167.7	54.5	3.020	50.9	194
330	20	120687	167.7	54.5	4.140	54.6	195
331	20	120687	167.7	54.5	5.08	56.0	200
332	20	120687	167.7	54.5	6.24	56.9	202
333	20	120987	167.9	54.4	2.92	41.0	168
334	20	120987	167.9	54.4	2.92	47.5	180
335	20	120987	167.9	54.4	3.60	55.1	190
336	20	120987	167.9	54.4	4.22	56.7	195
337	20	120987	167.9	54.4	5.36	59.0	200
338	20	120987	167.9	54.4	7.94	63.8	202
339	20	140188	167.7	55.9	2.80	45.2	141
340	20	140188	167.7	55.9	1.92	52.1	158
341	20	140188	167.7	55.9	1.80	54.0	158
342	20	140188	167.7	55.9	2.12	57.2	158
343	20	140188	167.7	55.9	2.60	59.7	190
344	20	140188	167.7	55.9	3.96	63.3	190
345	20	140188	167.7	55.9	6.04	65.7	193
346	20	140188	167.7	55.9	10.30	67.4	197
347	20	050888	167.6	58.9	2.68	44.0	118
348	20	050888	167.6	58.9	3.08	47.5	.
349	20	050888	167.6	58.9	3.02	50.5	.
350	20	050888	167.6	58.9	3.26	51.6	.
351	20	050888	167.6	58.9	4.46	54.9	.
352	20	050888	167.6	58.9	5.78	58.0	.
353	20	050888	167.6	58.9	8.96	59.2	.
354	21	140188	182.5	72.9	1.86	42.5	150
355	21	140188	182.5	72.9	1.82	50.4	164
356	21	140188	182.5	72.9	2.26	56.2	165
357	21	140188	182.5	72.9	2.44	56.2	167
358	21	140188	182.5	72.9	2.72	58.5	175
359	21	140188	182.5	72.9	3.48	60.8	180
360	21	140188	182.5	72.9	4.46	65.1	187
361	21	140188	182.5	72.9	5.74	66.4	187
362	21	050888	182.7	77.4	2.72	41.2	128
363	21	050888	182.7	77.4	3.08	50.9	154
364	21	050888	182.7	77.4	3.04	55.0	164
365	21	050888	182.7	77.4	3.36	55.7	168

366	21	050888	182.7	77.4	3.18	57.9	174
367	21	050888	182.7	77.4	3.98	60.4	179
368	21	050888	182.7	77.4	3.80	62.7	179
369	21	050888	182.7	77.4	6.94	64.0	186
370	21	050888	182.7	77.4	7.48	68.4	189
371	22	120987	172.0	59.9	2.06	37.4	147
372	22	120987	172.0	59.9	2.52	48.7	171
373	22	120987	172.0	59.9	2.64	50.4	172
374	22	120987	172.0	59.9	3.04	53.9	182
375	22	120987	172.0	59.9	3.72	57.4	189
376	22	120987	172.0	59.9	4.48	61.6	194
377	22	120987	172.0	59.9	6.30	62.6	195
378	22	120987	172.0	59.9	9.60	66.7	198
379	22	050888	172.0	57.4	3.04	35.2	145
380	22	050888	172.0	57.4	3.42	50.1	174
381	22	050888	172.0	57.4	3.80	52.8	180
382	22	050888	172.0	57.4	4.18	56.2	185
383	22	050888	172.0	57.4	4.72	58.0	189
384	22	050888	172.0	57.4	6.42	62.5	192
385	22	050888	172.0	57.4	8.00	61.3	194
386	22	050888	172.0	57.4	11.20	63.2	193
387	23	120687	168.4	65.6	1.78	33.0	142
388	23	120687	168.4	65.6	1.24	37.9	157
389	23	120687	168.4	65.6	1.26	39.9	165
390	23	120687	168.4	65.6	1.50	44.4	176
391	23	120687	168.4	65.6	1.82	45.3	177
392	23	120687	168.4	65.6	2.56	49.5	183
393	23	120687	168.4	65.6	3.88	50.1	188
394	23	120987	168.0	65.6	2.22	38.1	136
395	23	120987	168.0	65.6	1.80	42.8	155
396	23	120987	168.0	65.6	1.74	48.4	164
397	23	120987	168.0	65.6	1.60	49.6	172
398	23	120987	168.0	65.6	2.58	52.0	176
399	23	120987	168.0	65.6	3.00	52.5	183
400	23	120987	168.0	65.6	3.56	55.7	189
401	23	120987	168.0	65.6	5.30	58.7	193
402	24	140188	173.2	62.7	3.32	41.5	163
403	24	140188	173.2	62.7	2.30	45.7	178
404	24	140188	173.2	62.7	2.78	48.4	180
405	24	140188	173.2	62.7	3.58	51.0	182
406	24	140188	173.2	62.7	4.92	53.8	186
407	24	140188	173.2	62.7	5.42	54.7	186
408	24	140188	173.2	62.7	9.98	58.3	.
409	25	140188	164.9	57.9	2.16	38.3	142
410	25	140188	164.9	57.9	2.04	51.2	169
411	25	140188	164.9	57.9	2.56	53.4	177

412	25	140188	164.9	57.9	2.76	54.0	182
413	25	140188	164.9	57.9	3.84	56.1	186
414	25	140188	164.9	57.9	5.28	59.0	191
415	25	140188	164.9	57.9	6.86	58.8	192
416	25	140188	164.9	57.9	8.78	59.1	194
417	26	140188	169.2	61.0	2.42	40.5	170
418	26	140188	169.2	61.0	2.70	48.3	184
419	26	140188	169.2	61.0	3.20	51.5	187
420	26	140188	169.2	61.0	3.62	54.8	193
421	26	140188	169.2	61.0	4.60	57.2	194
422	26	140188	169.2	61.0	6.28	60.1	200
423	26	140188	169.2	61.0	8.98	62.5	202
424	27	120687	170.6	56.8	2.60	33.8	174
425	27	120687	170.6	56.8	3.56	40.7	181
426	27	120687	170.6	56.8	5.40	40.2	191
427	27	120687	170.6	56.8	7.24	48.6	191
428	27	120687	170.6	56.8	9.22	50.0	192
429	27	120687	170.6	56.8	11.54	52.3	198
430	27	120987	171.0	58.1	3.68	41.9	158
431	27	120987	171.0	58.1	5.04	48.5	186
432	27	120987	171.0	58.1	6.26	50.9	189
433	27	120987	171.0	58.1	6.94	52.1	190
434	27	120987	171.0	58.1	8.36	56.8	193
435	27	120987	171.0	58.1	9.40	59.5	195
436	27	140188	170.1	56.1	2.50	42.1	166
437	27	140188	170.1	56.1	3.38	50.8	178
438	27	140188	170.1	56.1	3.78	53.6	183
439	27	140188	170.1	56.1	5.00	57.0	185
440	27	140188	170.1	56.1	7.68	65.5	192
441	27	140188	170.1	56.1	9.90	66.9	193
442	28	140188	176.5	65.8	3.22	43.2	145
443	28	140188	176.5	65.8	2.18	48.5	158
444	28	140188	176.5	65.8	1.68	50.3	161
445	28	140188	176.5	65.8	1.94	53.8	165
446	28	140188	176.5	65.8	2.24	54.9	165
447	28	140188	176.5	65.8	2.36	57.6	170
448	28	140188	176.5	65.8	3.12	60.3	174
449	28	140188	176.5	65.8	3.94	66.7	177
450	28	140188	176.5	65.8	5.04	67.9	183
451	28	140188	176.5	65.8	7.24	68.6	187
452	28	140188	176.5	65.8	9.50	69.5	189
453	29	120687	169.3	67.3	2.90	44.0	163
454	29	120687	169.3	67.3	3.82	55.7	178
455	29	120687	169.3	67.3	3.86	60.0	188
456	29	120687	169.3	67.3	5.20	63.6	195
457	29	120687	169.3	67.3	6.52	66.7	200

458	29	120687	169.3	67.3	8.32	66.4	201
459	29	120687	169.3	67.3	10.82	71.1	206
460	29	120987	170.0	66.7	3.06	49.4	166
461	29	120987	170.0	66.7	3.66	56.8	.
462	29	120987	170.0	66.7	3.62	56.4	188
463	29	120987	170.0	66.7	4.54	62.9	194
464	29	120987	170.0	66.7	5.20	63.0	199
465	29	120987	170.0	66.7	7.90	64.7	202
466	29	120987	170.0	66.7	10.54	69.4	208
467	29	140188	169.5	68.4	2.40	48.7	160
468	29	140188	169.5	68.4	1.80	53.6	171
469	29	140188	169.5	68.4	2.34	59.7	183
470	29	140188	169.5	68.4	2.78	61.7	183
471	29	140188	169.5	68.4	3.92	62.5	193
472	29	140188	169.5	68.4	5.56	65.9	198
473	29	140188	169.5	68.4	7.12	68.6	200
474	29	140188	169.5	68.4	10.10	72.4	205
475	3	250187	193.0	81.8	1.80	42.1	111
476	3	250187	193.0	81.8	1.80	42.1	111
477	3	250187	193.0	81.8	1.80	42.1	111
478	3	250187	193.0	81.8	1.58	46.3	132
479	3	250187	193.0	81.8	1.58	46.3	132
480	3	250187	193.0	81.8	1.58	46.3	132
481	3	250187	193.0	81.8	1.10	47.7	139
482	3	250187	193.0	81.8	1.10	47.7	139
483	3	250187	193.0	81.8	1.10	47.7	139
484	3	250187	193.0	81.8	1.18	52.7	150
485	3	250187	193.0	81.8	1.18	52.7	150
486	3	250187	193.0	81.8	1.18	52.7	150
487	3	250187	193.0	81.8	1.31	57.2	158
488	3	250187	193.0	81.8	1.31	57.2	158
489	3	250187	193.0	81.8	1.31	57.2	158
490	3	250187	193.0	81.8	1.62	60.1	164
491	3	250187	193.0	81.8	1.62	60.1	164
492	3	250187	193.0	81.8	1.62	60.1	164
493	3	250187	193.0	81.8	1.91	62.0	169
494	3	250187	193.0	81.8	1.91	62.0	169
495	3	250187	193.0	81.8	1.91	62.0	169
496	3	250187	193.0	81.8	2.610	65.8	175
497	3	250187	193.0	81.8	2.610	65.8	175
498	3	250187	193.0	81.8	2.610	65.8	175
499	3	250187	193.0	81.8	3.870	68.8	182
500	3	250187	193.0	81.8	3.870	68.8	182
501	3	250187	193.0	81.8	3.870	68.8	182
502	3	250187	193.0	81.8	6.460	74.8	187
503	3	250187	193.0	81.8	6.460	74.8	187

504	3	250187	193.0	81.8	6.460	74.8	187
505	3	120687	194.8	83.5	2.820	.	121
506	3	120687	194.8	83.5	2.140	.	146
507	3	120687	194.8	83.5	2.040	.	160
508	3	120687	194.8	83.5	1.860	49.2	166
509	3	120687	194.8	83.5	2.940	52.0	168
510	3	120687	194.8	83.5	1.960	55.2	175
511	3	120687	194.8	83.5	2.660	58.5	181
512	3	120687	194.8	83.5	3.380	61.9	186
513	3	120687	194.8	83.5	6.780	61.9	189
514	3	120687	194.8	83.5	6.100	63.9	191
515	3	120987	193.7	86.1	1.440	36.3	117
516	3	120987	193.7	86.1	2.660	49.1	.
517	3	120987	193.7	86.1	2.100	52.4	154
518	3	120987	193.7	86.1	2.300	58.4	164
519	3	120987	193.7	86.1	2.800	59.1	169
520	3	120987	193.7	86.1	3.080	62.1	175
521	3	120987	193.7	86.1	5.121	65.2	179
522	3	120987	193.7	86.1	6.620	67.9	183
523	3	120987	193.7	86.1	7.880	70.3	188
524	30	120687	170.7	67.1	3.100	43.9	155
525	30	120687	170.7	67.1	2.960	54.9	179
526	30	120687	170.7	67.1	2.980	56.5	187
527	30	120687	170.7	67.1	3.724	59.8	194
528	30	120687	170.7	67.1	4.880	62.7	198
529	30	120687	170.7	67.1	6.500	64.1	200
530	30	120687	170.7	67.1	9.620	66.1	202
531	30	140188	171.4	68.5	2.360	44.2	166
532	30	140188	171.4	68.5	1.840	50.3	178
533	30	140188	171.4	68.5	2.140	53.9	183
534	30	140188	171.4	68.5	3.200	58.7	189
535	30	140188	171.4	68.5	3.320	62.8	195
536	30	140188	171.4	68.5	4.140	61.2	197
537	30	140188	171.4	68.5	5.500	64.0	202
538	30	140188	171.4	68.5	7.420	67.0	205
539	30	140188	171.4	68.5	10.180	67.0	205
540	31	120687	181.0	77.1	2.480	39.2	126
541	31	120687	181.0	77.1	2.240	43.5	145
542	31	120687	181.0	77.1	2.260	45.0	155
543	31	120687	181.0	77.1	2.100	46.5	163
544	31	120687	181.0	77.1	2.440	50.3	161
545	31	120687	181.0	77.1	3.220	52.6	167
546	31	120687	181.0	77.1	3.720	58.4	170
547	31	120687	181.0	77.1	4.240	60.5	174
548	31	120687	181.0	77.1	5.440	63.2	179
549	31	310787	180.0	76.1	2.140	34.9	125

550	31	310787	180.0	76.1	1.940	42.6	146
551	31	310787	180.0	76.1	1.80	46.3	152
552	31	310787	180.0	76.1	1.76	46.4	154
553	31	310787	180.0	76.1	2.44	53.0	163
554	31	310787	180.0	76.1	3.20	57.9	169
555	31	310787	180.0	76.1	3.66	60.4	170
556	31	310787	180.0	76.1	3.66	60.4	170
557	31	310787	180.0	76.1	3.66	61.1	174
558	31	310787	180.0	76.1	4.82	65.6	179
559	31	310787	180.0	76.1	9.56	70.0	186
560	32	120987	171.5	64.9	3.74	47.9	158
561	32	120987	171.5	64.9	3.32	48.8	172
562	32	120987	171.5	64.9	3.68	53.2	180
563	32	120987	171.5	64.9	3.52	57.2	184
564	32	120987	171.5	64.9	4.32	58.8	190
565	32	120987	171.5	64.9	5.90	59.2	196
566	32	120987	171.5	64.9	9.12	60.8	197
567	32	120987	171.5	64.9	11.40	64.5	199
568	33	140188	171.1	68.0	1.66	39.2	163
569	33	140188	171.1	68.0	2.44	45.8	175
570	33	140188	171.1	68.0	1.84	47.6	180
571	33	140188	171.1	68.0	2.48	54.3	182
572	33	140188	171.1	68.0	2.66	59.3	186
573	33	140188	171.1	68.0	2.80	61.1	186
574	33	140188	171.1	68.0	3.62	62.2	189
575	33	140188	171.1	68.0	6.08	67.8	188
576	33	140188	171.1	68.0	8.52	74.1	190
577	34	250187	177.0	72.1	3.36	41.1	122
578	34	250187	177.0	72.1	2.39	42.9	142
579	34	250187	177.0	72.1	1.37	50.0	162
580	34	250187	177.0	72.1	1.59	51.9	165
581	34	250187	177.0	72.1	1.82	54.8	170
582	34	250187	177.0	72.1	2.03	60.6	185
583	34	250187	177.0	72.1	3.20	62.8	191
584	34	250187	177.0	72.1	6.07	70.5	203
585	34	250187	177.0	72.1	9.07	72.5	205
586	34	310787	177.9	69.9	1.84	33.9	133
587	34	310787	177.9	69.9	2.18	45.8	149
588	34	310787	177.9	69.9	1.76	47.9	164
589	34	310787	177.9	69.9	1.64	49.8	168
590	34	310787	177.9	69.9	1.58	52.4	168
591	34	310787	177.9	69.9	1.54	56.7	173
592	34	310787	177.9	69.9	2.00	57.5	185
593	34	310787	177.9	69.9	2.66	63.0	186
594	34	310787	177.9	69.9	3.20	67.8	194
595	34	310787	177.9	69.9	4.56	69.0	193

596	34	310787	177.9	69.9	5.36	72.9	198
597	34	041187	178.0	70.8	2.48	41.0	145
598	34	041187	178.0	70.8	1.26	47.4	154
599	34	041187	178.0	70.8	1.34	53.1	171
600	34	041187	178.0	70.8	1.28	55.8	169
601	34	041187	178.0	70.8	1.52	52.1	173
602	34	041187	178.0	70.8	1.72	57.3	179
603	34	041187	178.0	70.8	1.82	59.3	185
604	34	041187	178.0	70.8	2.30	61.5	187
605	34	041187	178.0	70.8	3.44	63.1	195
606	34	041187	178.0	70.8	5.22	69.3	200
607	34	041187	178.0	70.8	9.90	73.3	203
608	34	070188	176.7	70.7	2.42	39.8	128
609	34	070188	176.7	70.7	1.26	46.5	141
610	34	070188	176.7	70.7	1.02	47.1	140
611	34	070188	176.7	70.7	0.88	52.9	156
612	34	070188	176.7	70.7	1.02	54.5	160
613	34	070188	176.7	70.7	1.16	56.4	168
614	34	070188	176.7	70.7	1.60	61.9	176
615	34	070188	176.7	70.7	2.14	64.6	183
616	34	070188	176.7	70.7	3.60	65.0	189
617	34	070188	176.7	70.7	5.14	73.7	193
618	34	070188	176.7	70.7	13.28	79.6	199
619	34	050888	178.7	70.8	2.56	35.5	116
620	34	050888	178.7	70.8	0.68	38.2	115
621	34	050888	178.7	70.8	1.16	46.2	138
622	34	050888	178.7	70.8	0.78	49.6	140
623	34	050888	178.7	70.8	0.84	53.9	151
624	34	050888	178.7	70.8	1.04	56.3	157
625	34	050888	178.7	70.8	1.38	58.3	164
626	34	050888	178.7	70.8	1.86	62.1	171
627	34	050888	178.7	70.8	2.52	65.7	181
628	34	050888	178.7	70.8	3.42	74.9	183
629	34	050888	178.7	70.8	5.62	71.9	191
630	34	050888	178.7	70.8	7.42	77.1	194
631	34	050888	178.7	70.8	10.62	79.1	196
632	35	250187	181.5	81.7	1.21	37.1	117
633	35	250187	181.5	81.7	1.25	44.5	138
634	35	250187	181.5	81.7	1.08	47.7	147
635	35	250187	181.5	81.7	1.49	53.7	161
636	35	250187	181.5	81.7	1.87	56.8	167
637	35	250187	181.5	81.7	2.37	60.7	175
638	35	250187	181.5	81.7	4.03	64.3	180
639	35	250187	181.5	81.7	4.57	64.8	187
640	37	050888	176.3	76.3	3.68	43.6	133
641	37	050888	176.3	76.3	4.02	50.4	146

642	37	050888	176.3	76.3	2.60	53.1	156
643	37	050888	176.3	76.3	3.30	55.8	167
644	37	050888	176.3	76.3	5.24	60.3	174
645	37	050888	176.3	76.3	5.78	65.2	176
646	37	050888	176.3	76.3	8.84	68.1	178
647	37	050888	176.3	76.3	9.92	67.5	186
648	4	250187	185.2	82.1	2.13	41.4	.
649	4	250187	185.2	82.1	1.81	50.5	143
650	4	250187	185.2	82.1	1.55	51.1	153
651	4	250187	185.2	82.1	1.34	56.8	165
652	4	250187	185.2	82.1	2.87	61.7	173
653	4	250187	185.2	82.1	3.37	64.0	175
654	4	250187	185.2	82.1	4.16	65.1	179
655	4	250187	185.2	82.1	6.19	66.7	182
656	4	070188	187.2	81.1	2.48	41.8	131
657	4	070188	187.2	81.1	2.22	51.8	155
658	4	070188	187.2	81.1	1.78	54.2	167
659	4	070188	187.2	81.1	1.88	56.9	168
660	4	070188	187.2	81.1	2.30	59.7	174
661	4	070188	187.2	81.1	3.140	61.7	178
662	4	070188	187.2	81.1	4.620	63.6	180
663	4	070188	187.2	81.1	7.560	65.9	183
664	4	070188	187.2	81.1	7.540	68.4	186
665	4	070188	187.2	81.1	10.540	69.8	188
666	4	050888	186.5	81.6	2.200	.	.
667	4	050888	186.5	81.6	1.900	42.5	.
668	4	050888	186.5	81.6	1.620	48.6	.
669	4	050888	186.5	81.6	1.900	51.4	.
670	4	050888	186.5	81.6	1.920	54.8	163
671	4	050888	186.5	81.6	2.460	57.4	.
672	4	050888	186.5	81.6	4.401	58.0	.
673	4	050888	186.5	81.6	4.464	65.2	.
674	4	050888	186.5	81.6	6.344	66.7	.
675	4	050888	186.5	81.6	8.240	66.7	.
676	46	120687	163.2	52.4	2.010	41.0	137
677	46	120687	163.2	52.4	2.000	42.0	159
678	46	120687	163.2	52.4	4.110	52.5	169
679	46	120687	163.2	52.4	8.220	66.6	202
680	47	140187	176.7	75.2	3.110	41.8	147
681	47	140187	176.7	75.2	2.000	50.5	165
682	47	140187	176.7	75.2	2.620	54.5	174
683	47	140187	176.7	75.2	3.120	58.5	183
684	47	140187	176.7	75.2	6.390	62.0	189
685	5	250187	174.2	73.6	3.220	38.2	111
686	5	250187	174.2	73.6	1.690	42.5	120
687	5	250187	174.2	73.6	2.280	51.3	141

688	5	250187	174.2	73.6	2.360	56.0	155
689	5	250187	174.2	73.6	2.660	59.9	160
690	5	250187	174.2	73.6	3.740	63.2	175
691	5	250187	174.2	73.6	5.810	69.5	183
692	5	250187	174.2	73.6	6.160	.	181
693	5	310787	174.2	71.5	2.120	33.6	105
694	5	310787	174.2	71.5	2.460	46.6	131
695	5	310787	174.2	71.5	2.820	51.3	144
696	5	310787	174.2	71.5	2.960	52.5	150
697	5	310787	174.2	71.5	2.620	57.3	161
698	5	310787	174.2	71.5	3.440	60.4	167
699	5	310787	174.2	71.5	3.760	63.5	170
700	5	310787	174.2	71.5	4.460	63.0	175
701	5	310787	174.2	71.5	7.940	70.8	177
702	5	041187	175.0	74.5	3.540	40.6	111
703	5	041187	175.0	74.5	2.840	47.5	123
704	5	041187	175.0	74.5	2.820	51.8	140
705	5	041187	175.0	74.5	2.820	54.2	149
706	5	041187	175.0	74.5	3.080	56.9	164
707	5	041187	175.0	74.5	3.220	61.6	173
708	5	041187	175.0	74.5	3.900	65.0	176
709	5	041187	175.0	74.5	5.380	68.7	184
710	5	041187	175.0	74.5	7.840	69.5	190
711	5	041187	175.0	74.5	10.160	72.1	190
712	5	070188	175.4	73.0	2.420	35.6	104
713	5	070188	175.4	73.0	1.740	43.9	118
714	5	070188	175.4	73.0	1.380	48.4	128
715	5	070188	175.4	73.0	1.960	51.5	137
716	5	070188	175.4	73.0	1.820	55.3	149
717	5	070188	175.4	73.0	2.260	58.2	159
718	5	070188	175.4	73.0	2.960	63.1	167
719	5	070188	175.4	73.0	4.160	66.4	175
720	5	070188	175.4	73.0	5.380	69.0	181
721	5	070188	175.4	73.0	8.460	73.7	190
722	5	050888	175.5	72.1	2.120	38.2	116
723	5	050888	175.5	72.1	2.760	52.9	145
724	5	050888	175.5	72.1	2.900	54.2	147
725	5	050888	175.5	72.1	3.260	58.2	156
726	5	050888	175.5	72.1	3.540	62.3	163
727	5	050888	175.5	72.1	5.040	63.9	170
728	5	050888	175.5	72.1	6.720	66.7	176
729	5	050888	175.5	72.1	8.760	70.7	182
730	5	050888	175.5	72.1	11.480	73.4	187
731	6	051186	179.1	70.0	2.490	37.5	130
732	6	051186	179.1	70.0	1.780	45.7	152
733	6	051186	179.1	70.0	2.030	49.3	158

734	6	051186	179.1	70.0	2.710	52.7	167
735	6	051186	179.1	70.0	3.490	57.4	169
736	6	051186	179.1	70.0	5.560	60.6	173
737	6	051186	179.1	70.0	7.080	69.5	181
738	7	140187	181.5	76.5	3.160	41.2	141
739	7	140187	181.5	76.5	5.700	50.4	163
740	7	140187	181.5	76.5	3.810	52.5	167
741	7	140187	181.5	76.5	2.680	53.8	170
742	7	140187	181.5	76.5	4.550	59.9	176
743	7	140187	181.5	76.5	4.370	60.9	179
744	7	140187	181.5	76.5	6.200	64.3	185
745	8	140187	176.2	75.0	2.710	35.1	120
746	8	140187	176.2	75.0	2.110	47.2	154
747	8	140187	176.2	75.0	2.590	54.6	172
748	8	140187	176.2	75.0	2.260	52.0	171
749	8	140187	176.2	75.0	3.360	56.5	178
750	8	140187	176.2	75.0	4.890	58.8	185
751	8	140187	176.2	75.0	6.240	63.5	189
752	8	140187	176.2	75.0	8.680	63.4	194
753	8	120687	177.3	75.5	2.300	38.1	135
754	8	120687	177.3	75.5	2.620	46.6	151
755	8	120687	177.3	75.5	2.420	49.0	164
756	8	120687	177.3	75.5	2.700	54.1	168
757	8	120687	177.3	75.5	3.100	56.6	177
758	8	120687	177.3	75.5	3.840	58.9	182
759	8	120687	177.3	75.5	5.580	57.2	186
760	8	120687	177.3	75.5	7.100	65.1	188
761	8	120987	178.2	75.4	1.920	40.6	130
762	8	120987	178.2	75.4	2.220	49.9	150
763	8	120987	178.2	75.4	1.800	54.4	168
764	8	120987	178.2	75.4	2.700	57.7	175
765	8	120987	178.2	75.4	2.580	57.7	183
766	8	120987	178.2	75.4	4.200	64.3	188
767	8	120987	178.2	75.4	6.660	66.1	194
768	8	120987	178.2	75.4	9.420	67.0	198
769	8	050888	177.8	76.6	2.080	38.6	141
770	8	050888	177.8	76.6	1.502	48.0	152
771	8	050888	177.8	76.6	1.560	51.0	164
772	8	050888	177.8	76.6	1.720	52.7	171
773	8	050888	177.8	76.6	2.880	56.8	167
774	8	050888	177.8	76.6	2.500	57.3	176
775	8	050888	177.8	76.6	3.660	59.2	181
776	8	050888	177.8	76.6	4.260	61.6	186
777	8	050888	177.8	76.6	6.500	67.1	191
778	8	050888	177.8	76.6	8.780	68.3	194
779	9	250187	165.6	57.9	2.500	42.1	144

780	9	250187	165.6	57.9	2.240	46.3	163
781	9	250187	165.6	57.9	2.620	51.0	171
782	9	250187	165.6	57.9	3.070	53.5	177
783	9	250187	165.6	57.9	4.380	54.7	181
784	9	250187	165.6	57.9	7.660	65.1	191
785	9	310787	165.8	54.8	1.600	28.4	128
786	9	310787	165.8	54.8	1.620	38.6	152
787	9	310787	165.8	54.8	2.180	42.4	173
788	9	310787	165.8	54.8	2.620	45.8	176
789	9	310787	165.8	54.8	2.620	52.3	177
790	9	310787	165.8	54.8	3.690	54.3	183
791	9	310787	165.8	54.8	5.920	59.8	185
792	9	041187	166.3	55.0	3.080	35.9	142
793	9	041187	166.3	55.0	2.540	43.8	160
794	9	041187	166.3	55.0	2.840	48.3	166
795	9	041187	166.3	55.0	2.820	49.5	170
796	9	041187	166.3	55.0	3.660	52.4	175
797	9	041187	166.3	55.0	4.700	56.6	179
798	9	041187	166.3	55.0	6.120	57.7	183
799	9	041187	166.3	55.0	8.020	61.3	188
800	9	041187	166.3	55.0	11.100	63.6	191
801	9	070188	166.2	54.5	1.400	34.4	127
802	9	070188	166.2	54.5	1.480	42.6	144
803	9	070188	166.2	54.5	1.720	46.5	153
804	9	070188	166.2	54.5	1.580	49.5	165
805	9	070188	166.2	54.5	2.000	53.0	.
806	9	070188	166.2	54.5	3.040	55.3	176
807	9	070188	166.2	54.5	3.640	58.5	181
808	9	070188	166.2	54.5	6.320	62.1	189
809	9	070188	166.2	54.5	9.720	63.8	191
810	9	050888	166.0	57.0	2.760	34.3	147
811	9	050888	166.0	57.0	1.940	41.0	155
812	9	050888	166.0	57.0	1.920	44.7	162
813	9	050888	166.0	57.0	2.140	46.4	169
814	9	050888	166.0	57.0	2.705	51.1	175
815	9	050888	166.0	57.0	3.480	52.9	181
816	9	050888	166.0	57.0	4.540	56.3	184
817	9	050888	166.0	57.0	7.760	58.2	186