MAX VO₂ AND VENTILATORY THRESHOLD IN UNIVERSITY LEVEL HOCKEY PLAYERS

Timothy P. Zachrich

A Thesis
Submitted to the Graduate College of Bowling Green State University in partial fulfillment of the requirements for the degree of

MASTER OF EDUCATION

May 2008

Committee:
Amy L. Morgan, Ph.D., Advisor
Lynn A. Darby, Ph.D.
David A. Tobar, Ph.D.
ABSTRACT

The sport of ice hockey is a unique blend of anaerobic power and aerobic capacity. These athletes perform short bouts (90 sec) of powerful skating, shooting, and body hits. While these are anaerobic bouts of exercise, the effect of repeated on-ice shifts results in a cumulative endurance exercise. The purpose of this study was to analyze the body’s physiological responses, such as maximal oxygen consumption and ventilatory threshold, of National Collegiate Athletic Association (NCAA) Division I level hockey players. Twenty-four male hockey players (n=14 forwards, n=8 defensemen, n=2 goalies; age=20.9 ± 1.18 yrs.) were measured for VO$_2$max and ventilatory threshold (Tvent) on a treadmill, utilizing a progressive, graded exercise test protocol. The measures were collected using the Oxycon Mobile® gas analysis system. The subjects ran on the treadmill for 3-minute stages during which speed and grade increased, until exhaustion. VO$_2$max was expressed in relative terms (ml•kg$^{-1}$•min$^{-1}$), and Tvent was recorded as a percent of VO$_2$max (%VO$_2$max). Heart rate (bpm) and rating of perceived exertion (RPE) were also measured. VO$_2$max for these subjects were significantly higher than the average for this demographic, 57.2 ± 5.04 ml•kg$^{-1}$•min$^{-1}$ (range: 68.0-48.4 ml•kg$^{-1}$•min$^{-1}$). Tvent for these subjects was also significantly higher than average, untrained individuals, 80.7 ± 9.6% VO$_2$max (range: 91.9%-54.0%). Also, VO$_2$ at stage 4 ($p=0.068$, $d=2.42$) and Tvent ($p=0.68$, $d=0.19$) were not shown to be dependent on position.
ACKNOWLEDGEMENTS

I would like to thank, first and foremost, my advisor, Dr. Amy L. Morgan for her time, effort, and useful insight in the development and completion of this thesis. I would also like to thank my committee members, Dr. Lynn A. Darby, for her advanced knowledge and insight in the field of exercise physiology, and Dr. David A. Tobar, for his help and expertise in statistical analysis. I would also like to thank the Mount Carmel Health Sciences Library, Columbus, Ohio for their help in locating research articles for my literature review. Finally, I want to thank The Bowling Green State University men’s varsity hockey coaches, specifically assistant coach Danton Cole and head strength and conditioning coach Rick Court, and the players who sacrificed their time and energy to make this thesis possible.
# TABLE OF CONTENTS

CHAPTER I: INTRODUCTION
- Purpose ........................................................................................................... 4
- Significance ...................................................................................................... 4
- Definitions ........................................................................................................ 4

CHAPTER II: REVIEW OF THE LITERATURE .......................................................... 5
- Maximal Oxygen Consumption ...................................................................... 6
- Criteria for Reaching Maximal Oxygen Consumption ................................... 8
- Limiting Factors of Maximal Oxygen Consumption ...................................... 10
- Exercise Testing and Maximal Oxygen Consumption as a Diagnostic Tool .... 12
- Ventilatory Threshold ....................................................................................... 13
- Graded Exercise Test ....................................................................................... 15
- Hockey Players and Aerobic Capacity ............................................................. 17
- Positional Differences in Ice Hockey ............................................................... 21

CHAPTER III: METHODS ..................................................................................... 23
- Participants ...................................................................................................... 23
- Design .............................................................................................................. 24
- Equipment ...................................................................................................... 25
- Procedure ....................................................................................................... 25
- Statistical Analysis ......................................................................................... 28
- Sample Size Power Determination ................................................................. 29

CHAPTER IV: RESULTS ....................................................................................... 30

CHAPTER V: DISCUSSION .................................................................................... 33
- Limitations ...................................................................................................... 37
- Conclusion ...................................................................................................... 38

REFERENCES ..................................................................................................... 41

APPENDICES ...................................................................................................... 49
- A: Informed Consent Statement ....................................................................... 49
- B: Sample Telephone Recruitment Script ..................................................... 52
- C: Sample E-mail Recruitment Script .............................................................. 54
- D: Medical History Questionnaire ................................................................... 56
LIST OF TABLES

Table 1 .........................................................................................................................24
  Subject Characteristics
Table 2 .........................................................................................................................27
  Protocol for the Graded Exercise Test
Table 3 .........................................................................................................................30
  VO₂max, Heart Rate, and RPE
Table 4 .........................................................................................................................31
  Tvent and VO₂ at Stage 4
Table 5 .........................................................................................................................32
  Tvent and Stage 4 VO₂ as % VO₂max
LIST OF FIGURES

Figure 1 ......................................................................................................................... 14

Ventilatory Threshold
CHAPTER I
INTRODUCTION

Cardiovascular exercise testing, whether the purpose of the test is to determine an athlete’s endurance performance potential, or assess the progress of a patient in cardiac rehabilitation, is an important aspect of health and fitness. Hockey players, as well as athletes from various sports in which cardiovascular fitness is important, can benefit from the knowledge gained through a maximal oxygen consumption (VO$_2$max) test. This information can be helpful in assessing the athlete’s current fitness level, as well as mark the athlete’s progress after participation in a training program. VO$_2$max, ventilatory threshold (Tvent), and heart rate are three of the more common variables measured during cardiovascular exercise testing.

Maximal oxygen consumption (VO$_2$max) is considered the “gold standard” when determining a person’s overall cardiovascular fitness level (Wilmore & Costill, 2004). This variable is defined as the maximum amount of oxygen that the body can metabolize to create adenosine triphosphate (ATP), the energy source used by active to perform work. It can be expressed in absolute terms, in liters per minute (l/min), or in relative terms, in milliliters per kilogram of body weight each minute (ml·kg$^{-1}$·min$^{-1}$). Body mass also plays a role in VO$_2$max. Some studies have shown that differences in body mass and muscle mass account for almost 70% of the differences in VO$_2$max scores between subjects (McArdle et al., 1986). This is why it is useful to express VO$_2$max in relative terms. Expressing VO$_2$max in relative terms allows for comparisons between individuals because the subject’s body weight is taken into account. For example, subject A, a 110 kg person with a VO$_2$max of 5 l/min, will have a lower relative VO$_2$max than subject B, a 75 kg person with a VO$_2$max of 5 l/min. The resulting relative
VO\textsubscript{2}max values would be 45.5 ml·kg\textsuperscript{-1}·min\textsuperscript{-1} and 66.7 ml·kg\textsuperscript{-1}·min\textsuperscript{-1}, respectively. Even though the absolute VO\textsubscript{2}max appears to be equal, when body weight is factored in, a better comparison of fitness level can be made between individuals. Since metabolism and the generation of ATP occurs in the muscle, body composition and more importantly, lean body mass is also a significant contributor to VO\textsubscript{2}max.

Ventilatory threshold is an estimate of the lactate threshold, which is the point at which exercise intensity causes the blood lactate levels to increase (Powers & Howley, 2007). Since fatigue can be caused by an accumulation of blood lactate in the muscle (Cairns et al., 2005), a higher lactate threshold indicates that an athlete can sustain longer bouts of exercise at increasing intensity before fatigue and performance is decreased. Ventilatory threshold is used because it is non-invasive to measure (i.e. expired air is analyzed), as opposed to lactate threshold which requires an invasive, blood-drawing procedure. One way in which the body regulates this build-up of blood lactic acid is to buffer that acid. When the acid is buffered, the result is an increase in carbon dioxide (CO\textsubscript{2}), which is removed from the body during exhalation. Since increased ventilation is triggered through this increased carbon dioxide concentration in the blood, lactate threshold can be estimated by using ventilatory threshold. One way to measure this is to examine the ventilation/oxygen consumption slope. When ventilation (V\textsubscript{E}) is plotted against VO\textsubscript{2} (l·min\textsuperscript{-1}), the slope is linear in a positive direction. There is a certain point, however, where the slope begins to increase exponentially (Wasserman et al., 1973). This V\textsubscript{E} inflection point is known as the ventilatory threshold (Tvent).

Maximal oxygen consumption and ventilatory threshold are very useful in determining an athlete’s aerobic endurance capabilities. Ice hockey is a combination of anaerobic and aerobic activity, therefore hockey players are athletes that can find this type of cardiovascular exercise
testing beneficial to their training programs. Aerobic deficiencies can be targeted and improvements can be made to increase performance. While there seems to be a paucity of literature regarding hockey players and aerobic capacity, some argue that hockey training programs do not need to include aerobic training because the high intensity interval training, which is commonly seen in hockey training regimens, improves aerobic capacity (Carey et al., 2007).

A VO₂max test can be useful in determining the level of aerobic capacity an athlete possesses. With an average hockey on-ice shift of 90 seconds of actual playing time, plus 40 seconds of continuous play with up to three 30 second breaks, the actual time on ice can vary between 160 and 220 seconds (2:40 to 3:40 min.) (Patterson, 1979). This requires a quick recovery from each bout of high intensity exercise. Each shift on ice builds up lactic acid in the blood. The faster the body can remove lactic acid, the quicker the athlete will be closer to full strength for the next on-ice shift (Patterson, 1979). This is where ventilatory threshold becomes relevant. A hockey player with an increased ventilatory threshold will be able to play longer, and participate in more shifts before the threshold and hence, fatigue, is reached.

Hockey players can benefit from an increased aerobic capacity, whether they achieve this higher aerobic capacity through endurance training or interval training. By determining the level of aerobic fitness at which the athletes currently perform, trainers and coaches can determine a goal for improvement, and whether they should actually train aerobically or train at high intensity anaerobic intervals to stimulate aerobic improvement.
**Purpose**

The primary purpose of this investigation was to analyze and discuss physiological variables as these relate to performance in university level hockey players. This was a descriptive analysis of cardiovascular and respiratory measures associated with performance.

**Significance**

By adding to the overall knowledge base of this subject, it will allow further research and growth in the field of kinesiology, as well as help in the future training of high level athletes, specifically hockey players. If coaches and trainers know where improvements can be made to improve their team’s performance, such as aerobic fitness levels, they can more efficiently target and train for deficiencies.

**Definitions**

**Maximal oxygen consumption (VO₂max)** – the maximal amount of oxygen the body can metabolize for use as ATP energy, expressed absolutely in liters per minute (L/min) or relatively in milliliters per kilogram each minute (ml·kg⁻¹·min⁻¹) (Gore, 2000).

**Ventilatory threshold** – the “breakpoint” at which pulmonary ventilation and carbon dioxide output begin to increase exponentially during an incremental exercise test, indicated by a change in the $V_E$ slope, when plotted against $VO_2$ (l·min⁻¹) (Powers & Howley, 2007).

**Respiratory Exchange Ratio (RER)** – the amount of carbon dioxide produced (VCO₂) by respiration compared to the amount of oxygen consumed (VO₂) (i.e., VCO₂/VO₂) (Shephard, 1975).
Maximal oxygen consumption, or VO$_2$max, is thought of as the single best measure of cardiorespiratory endurance and aerobic fitness (Wilmore & Costill, 2004). The measurement of VO$_2$ is routine in the physiological testing of elite athletes (Bosquet et al., 2002). While VO$_2$max can be a good predictor of successful endurance running, it is impossible to predict the winner of a race simply by comparing the runners’ VO$_2$max results from a laboratory experiment (Wilmore & Costill, 2004). This is because other factors contribute to an athlete’s ability to perform endurance events, such as the percentage of VO$_2$max at which the athlete can perform, and how long the athlete can perform at that percentage of VO$_2$max (Bosquet et al., 2002).

Physiological testing is important for both athletes and non-athletes. In order to provide patients with the best care possible, and athletes with the best training advice possible, it is imperative that accurate results are obtained through exercise tests such as the VO$_2$max test. While testing athletes can provide the athletes with knowledge of their personal strengths and weaknesses, this type of testing can also provide athletes with baseline measurements from which exercise prescriptions and training programs can be developed (MacDougall & Wenger, 1982), as well as provide feedback for evaluating the effectiveness of training programs (MacDougall & Wenger, 1982). Athletes can also be provided with information on health status, with a better understanding of his/her body and the demands of his/her sport (MacDougall & Wenger, 1982). However, because there are so many other factors that go into performance, such as the psychological profile of the athlete, results from physiological testing cannot be used as the only predictor of performance in athletic competition (MacDougall & Wenger, 1982).
The testing of maximal oxygen consumption (VO$_{2\text{max}}$) is extremely important to endurance athletes. The measurement of VO$_{2\text{max}}$ is the single most important indicator of endurance potential and aerobic fitness (Wilmore & Costill, 2004; Noakes, 1988) as well as an individual’s ability to perform sustained heavy muscular exercise (Strømme et al., 1977). As indicated before, the results can be used to develop training programs and exercise prescriptions, as well as mark progress of athletes as they go through specific training programs (MacDougal & Wenger, 1982).

When performing cardiovascular exercise tests on athletes or patients, there are certain criteria which the technician examines when determining whether the subject has reached their true maximal exertion level. Howley et al. (1995) described four main criteria when judging whether a person has reached maximal exertion: 1) a plateau in VO$_2$, or no increase in VO$_2$ with an increase in workload; 2) a respiratory exchange ratio (RER) greater than 1.15; 3) elevated levels of blood lactic acid greater than eight millimoles per liter (mmol/l); and 4) achievement of an age-predicted maximal heart rate. These criteria play an important role in completing an exercise test, and accurate results are essential when determining a plateau in VO$_2$ with an increase in workload, which is widely considered to be the most indicative sign that VO$_{2\text{max}}$ has been reached (Bassett & Howley, 2000).

**Maximal Oxygen Consumption**

Maximal oxygen consumption (VO$_{2\text{max}}$) is the rate at which the body can metabolize oxygen to produce ATP energy. Maximal oxygen consumption can be quantified in liters per minute (L·min$^{-1}$) or milliliters per kilogram per minute (ml·kg$^{-1}$·min$^{-1}$). While Noakes (1997) reported that VO$_{2\text{max}}$ may be a relatively elusive quantity, citing that differences in VO$_{2\text{max}}$ depend upon selected muscle groups, altitude, and exercise duration, a study by Astrand & Saltin
(1961) demonstrated a physiological limit to VO$_2$max. Using a discontinuous protocol, Astrand & Saltin (1961) showed that repeated attempts to drive VO$_2$max higher using higher work rates proved ineffective. While using higher work rates drove the subject to reach VO$_2$max faster, the final VO$_2$max value remained relatively unchanged. In other words, the protocol did not ultimately affect VO$_2$max.

The measurement of maximal oxygen consumption can be used in a variety of ways. Results from VO$_2$max tests can be used to diagnose cardiorespiratory disease in a clinical setting, while athletes can use data from VO$_2$max tests to better equip themselves with the knowledge to train smarter by developing a training program from a baseline measure and monitoring their progress during training programs (MacDougall, 1982; Cerny & Burton, 2001). Since cyclists will have a more representative VO$_2$max while cycling than running, and runners will have a more representative VO$_2$max while running than cycling, it is suggested that a sport specific exercise mode be utilized for the sake of comparison when using maximal oxygen consumption to characterize athletes (Bergh et al., 2000). However, it is generally accepted that VO$_2$ depends greatly on the amount of muscle mass activated (McArdle et al., 1986). Although it is widely accepted that a definite test specificity exists because elite swimmers equaling or even exceeding treadmill VO$_2$max scores during swimming protocols, experiments using subjects performing multiple VO$_2$max tests utilizing different modes of exercise usually reported the highest VO$_2$max scores during treadmill exercise (McArdle et al., 1986).

There is also a certain amount of biological variability that exists between subjects’ measured VO$_2$max (Katch et al., 1982). This variation, which can reach as much as ± 5.6%, can be attributed to a number of factors, such as biological nature (biovariation), or the inherent biological fluctuations of an organism (Katch et al., 1982).
Criteria for Reaching Maximal Oxygen Consumption

There are six main criteria to examine when determining if a subject has reached a state of true maximal exertion. While researchers may differ in the criteria that they utilize, or the number of criteria that must be met in order to achieve a true maximal exertion when conducting VO₂ max tests, the same four criteria should apply.

A plateau in oxygen uptake may be the most telling sign that a subject has reached maximal exertion (Bassett & Howley, 2000; Taylor et al., 1995). It is characterized by a leveling off of oxygen consumption, or no increase in oxygen uptake, with an increase in workload or intensity. However, some studies have shown subjects increasing in VO₂ with increases in workload after they had met specified criteria for steady state (Howley et al., 1995). This is not uncommon in intermittent or discontinuous protocols with stages of fixed duration (Howley et al., 1995). However, it was not specified whether these increases past leveling-off criteria were significant (Howley et al., 1995).

Even at rest or in moderate exercise intensity, some lactic acid is formed. However, lactic acid does not build up in the blood and muscle in this situation because its rate of removal equals its rate of production. As exercise intensity increases, lactic acid builds up in the blood and the muscle, and the regeneration of ATP cannot keep up with its utilization, causing fatigue to set in (McArdle et al., 1986). This lactic acid is removed from the blood by being buffered by sodium bicarbonate in the following reaction:

\[
\text{Lactic Acid} + \text{NaHCO}_3 \rightarrow \text{Na lactate} + \text{H}_2\text{CO}_3 \leftrightarrow \text{H}_2\text{O} + \text{CO}_2
\]
The carbon dioxide released in this buffering reaction is exhaled into the atmosphere as venous blood enters the lungs. Astrand (1952) described blood lactic acid levels of eight mmol·L\(^{-1}\) or greater, as a criterion for achieving true maximal exertion.

The respiratory exchange ratio, or RER, is considered secondary criteria for achieving VO\(_2\)\text{max} (Howley et al., 1995). Respiratory exchange ratio has also been used as a simple basis for the prediction of maximal oxygen uptake during submaximal exercise tests (Shephard, 1975). The calculation of RER is simply the ratio of volume of expired CO\(_2\) to the volume of inspired O\(_2\) (VCO\(_2\)/VO\(_2\)). When bicarbonate is introduced to buffer the build-up of lactic acid, CO\(_2\) is generated as a byproduct, of this process, driving ventilation higher as a way to remove the increased CO\(_2\) concentration (Howley et al., 1995). A rise in RER has been shown to be related to the plateau in oxygen uptake and is considered a criterion for achieving VO\(_2\)\text{max} (Howley et al., 1995). It is theorized that an RER of 1.15 or greater is indicative of maximal exertion (Issekutz & Rodahl, 1961; Issekutz et al., 1962). Similar studies comparing the RER at 70\% to 90\% of maximal aerobic power coincided closely with those reported by Issekutz (Shephard, 1975).

While age-predicted estimates of maximal heart rate can be used in addition to other criteria for determining maximal oxygen consumption, the American College of Sports Medicine states that achieving age-predicted maximal heart rates should not be used as an absolute endpoint in test termination (Howley et al., 1995; ACSM, 2006). The standard deviation associated with this estimate is around ±11 beats per minute, making it a very difficult standard to justify (Londeree & Moeschberger, 1984). Other studies that have used age-predicted maximal heart rates as a criterion for achievement of VO\(_2\)\text{max} have noted that maximal heart rate
ranges were too high to use an average maximum value as a criterion for VO$_2$\textsubscript{max} (Howley et al., 1995).

Rating of Perceived Exertion (RPE) and volitional fatigue may also be used as additional criteria for reaching maximal effort. The rating of perceived exertion, or RPE, is a scale that is used to assess “how hard the subject feels that he/she is working” (Borg, 1982). The RPE is a subjective measure dependent solely upon the individual being tested and is based upon the linear relationship between VO$_2$ and heart rate (Borg, 1970). While this scale has undergone many revisions, Borg’s 6-20 scale for RPE is used in many laboratories today.

Volitional fatigue is a term used to note when the subject terminates the test. The subject is the only person involved with the graded exercise test that fully knows when maximal exertion has been reached. For example, the subject may terminate the test if he/she feels they can no longer keep up with the treadmill.

**Limiting Factors of Maximal Oxygen Consumption**

It is also important to understand the factors that limit the maximal amount of oxygen the body can consume. It was originally thought that a number of factors contributed to the limit of VO$_2$\textsubscript{max}. Central limiting factors include the pulmonary diffusing capacity, cardiac output, and the oxygen carrying capacity of the blood (hemoglobin concentration). The peripheral limiting factor is a combination of many variables, including the ability of the exercising skeletal muscles to metabolize the oxygen in the process of generating adenosine triphosphate, or ATP (Bassett & Howley, 2000).

There are certain factors to be considered when discussing the limitations to maximal oxygen consumption. Saltin & Strange (1992) suggest the debate over whether VO$_2$\textsubscript{max} is limited by the cardiovascular system or peripheral diffusion capacity has been ongoing for over
100 years. Early on, the pumping capacity of the heart was suggested as the critical factor to \( \text{VO}_2\text{max} \) limitation. This theory remained unchallenged until the results of muscle plasticity were demonstrated in the 1960-70’s. Due to the capillary bed and mitochondrial volumes being enhanced with training, it was then suggested that these adaptations were required for \( \text{VO}_2\text{max} \) to become elevated (Saltin & Strange, 1992). Around 1985, mainstream viewpoints started to go back to the central limitations of the cardiovascular and respiratory systems, such as a maximal cardiac output (Saltin & Strange, 1992).

In the late 1920’s and early 1930’s, the thought of maximal cardiac output as the limit to \( \text{VO}_2\text{max} \) was suggested after noticing that reductions in submaximal heart rate could be achieved through altering cardiac output, (Saltin & Strange, 1992). This is where the early beliefs of pump capacity of the heart as the limit to \( \text{VO}_2\text{max} \) were formulated. Then in the 1960-70’s, the first reports of oxidative enzyme data for human skeletal muscle were reported (Saltin & Strange, 1992). A study by Pernow & Saltin (1971) showed that after training one leg for four weeks, mitochondrial volume and oxidative enzymes became markedly elevated in the trained limb. These findings, along with several reports of enhanced mitochondrial enzymes in trained rat muscle, sparked debate on the role of the oxidative capacity of skeletal muscle as the critical determinant of human aerobic power.

Green and Palta (1992) suggested that factors other than the availability of oxygen limit muscle fiber metabolism. The limit might be the inability of the mitochondria to metabolize available oxygen given the low flux potential in the respiratory chains of the mitochondria (Green and Palta, 1992). This reasoning would give rise to peripheral diffusion capacity as the main limit to \( \text{VO}_2\text{max} \). While Sutton et al. (1988) suggested that the two theories regarding \( \text{VO}_2\text{max} \) limitations may be linked more than they are differentiated, and that \( \text{VO}_2\text{max} \) may not
be limited solely by factors such as cardiac output or peripheral diffusion capacity, most contemporary viewpoints have cited the cardiovascular system as the limiting factor of VO$_2$max. Bassett & Howley (2000) agreed that VO$_2$max is limited by the cardiovascular system’s ability to deliver oxygenated blood to exercising muscle. They cited three major points: 1) VO$_2$max changes accordingly when oxygen delivery is altered through drugs (beta blockers), blood doping, and hypoxia; 2) the increase in VO$_2$max with training results from the increase in stroke volume; and 3) a small muscle mass has the capacity to consume an extremely high amount of oxygen when it is available, or overperfused. Elite athletes compensate for this effect through decreased O$_2$ saturation (Bassett & Howley, 2000).

The question of what exactly limits VO$_2$max is also somewhat dependent upon the definition of the limiting factor and what context is being addressed (Bassett & Howley, 2000). For example, when the human body is performing maximal, whole-body exercise, the limiting factor is the cardiovascular system. In contrast, if the discussion is of the limiting factor in the increase of VO$_2$ in an isolated limb, the limiting factor is the peripheral diffusion capacity (Bassett & Howley, 2000). Many others still maintain that any number of steps in the O$_2$ pathway could contribute to the integration of the limitation of VO$_2$max, and that there is no single limiting factor (Crystal & West, 1991).

**Exercise Testing and the Measurement of Oxygen Consumption as a Diagnostic Tool**

In today’s society, the ability to accurately diagnose disease in a timely manner saves many lives. Exercise testing, including the graded exercise test, is an integral part of cardiovascular medicine because of its high yield of diagnostic, prognostic, and functional information (Myers & Bellin, 2000). Exercise testing has been used to determine patients’ functional status, to assess the response to therapy, to determine prognosis, and in some cases
with advanced stages of disease, to aid in the selection of appropriate candidates for transplantation (Bittner, 2003). Exercise testing is also used as part of a screening process to evaluate athletes and recognize the “silent” cardiovascular abnormalities that can progress or cause sudden cardiac death (Maron et al., 2005). Exercise testing can be used to evaluate a number of different aspects, such as VO$_2$max, complaints of shortness of breath, physiological effects of acute and chronic disease (functional capacity), exercise induced asthma, and the effects of therapy or rehabilitation, as well as determining possible insurance and disability claims (Cerny & Burton, 2001).

Maximal cardiopulmonary exercise testing is considered the “gold standard” in the assessment of functional capacity and prognosis in patients with heart failure (Bittner, 2003; Guazzi et al., 2005; Sutton, 1992). Investigators have recommended different threshold values for peak VO$_2$ for prognostic classification (Bittner, 2003). Peak VO$_2$, which is what will be measured in this investigation, differs from VO$_2$max in that peak VO$_2$ is the highest achieved value of oxygen uptake, while VO$_2$max refers to the point where oxygen uptake levels off (Wilmore & Costill, 2004).

**Ventilatory Threshold**

The rate and depth of breathing are adjusted in response to the body’s metabolic needs (McArdle et al., 1986). In healthy subjects, arterial pressures of oxygen, carbon dioxide, and pH are regulated to maintain resting values regardless of the intensity of exercise (i.e. homeostasis) (McArdle et al., 1986). During light and moderate exercise, ventilation is closely coupled to metabolic rate, and is proportional to carbon dioxide production (Wasserman & Whipp, 1983). In strenuous exercise, acidity and hydrogen ion concentration increase, providing an additional ventilatory stimulus (Jones, 1984).
Ventilatory threshold (Tvent) is an indirect measure of anaerobic capacity, which is a component of importance to hockey players given the anaerobic nature of the exercise. It is an indirect estimate of lactate threshold. The illustration in Figure 1 demonstrates the lactate threshold and ventilatory threshold, as determined by the V-slope method (Beaver et al., 1986). In this figure, blood lactic acid concentration increases linearly as a function of oxygen uptake up to three liters·min⁻¹. At three liters·min⁻¹, blood lactic acid concentration begins to increase at a much faster rate. Lactate threshold is the point at which the slope linearity changes. Lactic acid begins to accumulate, due to its formation now exceeding its removal, at about 50-65% of VO₂max in healthy untrained subjects, and is often over 80% in more highly trained endurance athletes (McArdle et al., 1986). The point at which blood lactate begins to show a systematic increase above resting baseline levels is termed “onset of blood lactate accumulation”, or OBLA. This can be detected several ways, including a deviation in linearity in the relationship between oxygen consumption and ventilation, also known as ventilatory threshold, due to strong ventilatory stimulus from the increased blood CO₂ concentration, a byproduct of the process of buffering lactic acid through bicarbonate (McArdle et al., 1986). As blood lactate levels begin to accumulate past baseline levels (OBLA), increased ventilation is triggered. The illustration in Figure 1 also demonstrates the ventilatory threshold determination. There is a linear rise in ventilation up to an oxygen uptake to almost 4.0 liters·min⁻¹. At approximately 3.8 liters·min⁻¹ ventilation begins to increase
in a nonlinear fashion. This break in linearity of ventilation is the ventilatory threshold. This is the point at which ventilation increases exponentially at higher workloads (See Figure 1); it usually takes place just after the lactate levels increase exponentially (OBLA), which is around 50 to 65% of VO$_2$max in untrained individuals (Wasserman et al., 1973). This respiratory method is considered the least complex procedure to estimate lactate threshold (Beaver et al., 1986). The highly trained or elite athletes’ ventilatory threshold is usually higher than that of normal, healthy, untrained subjects (Powers et al., 1983), usually over 80% of VO$_2$max (McArdle et al., 1986). There are critics to this technique, but it seems clear to some investigators that this is a useful procedure to estimating success in endurance performance (Powers et al., 1983).

**Graded Exercise Test**

The most common type of exercise testing is the graded exercise test (GXT) (Cerny & Burton, 2001). The GXT is the first test of choice, in most cases, because of the noninvasive nature and cost effectiveness (Ehrman et al., 2003). In individuals with documented coronary artery disease, the GXT is used to determine the severity of the disease, and can be beneficial in evaluating the need for further intervention (Ehrman et al., 2003). However, the GXT holds a greater diagnostic value when evaluating individuals with intermediate to high probability of coronary artery disease, while there appears to be relatively little value in improving patient prognosis when testing young and apparently healthy individuals (Ehrman et al., 2003). Graded exercise tests can be used to evaluate functional capacity (FC) (Ehrman et al., 2003). Using the predicted normal values based on age, sex, and activity level, FC values that fall below the expected values determine one’s functional aerobic impairment (Ehrman et al, 2003). The GXT
can also be used as a screening procedure prior to hospitalization as part of the triage of patients with chest pain (Ehrman et al., 2003).

The GXT was first introduced by Edward Smith in 1846 as a means to evaluate various physiological parameters during exertion, such as heart rate and respiratory rate (Ehrman et al., 2003). The rate of oxygen consumption (i.e., VO\(_2\)) was another important variable able to be assessed through a graded exercise test. Studies have shown that the combination of peak VO\(_2\) values with ventilation/carbon dioxide production (V\(_E\)/VCO\(_2\)) slope values are an important predictor of outcomes in chronic heart failure (Aslam et al., 2003; Bard, 2005).

However, measuring oxygen consumption through a GXT is not the only method of diagnosing cardiovascular disease. Some cases of exercise testing using peak VO\(_2\) have overestimated the severity of hemodynamic dysfunction, and therefore, the need for heart transplant (Wilson et al., 1995). Regardless, since Smith’s first use of the test, the GXT has become a valuable tool to evaluate cardiorespiratory function in many different settings (Ehrman et al., 2003).

There are many accepted protocols of the GXT, however all protocols use incremental increases in work intensity (Cerny & Burton, 2001). Most cardiac stress-testing laboratories employ the Bruce protocol, to allow for easy comparisons across facilities and among patients (Cerny & Burton, 2001). Bard (2005) suggested that since the evaluations of cardiopulmonary exercise tests have dramatic consequences, there is a great need to standardize the evaluation and reporting methods of cardiopulmonary exercise testing data in patients with heart failure. Recommendations for prognostication have been made, ranging from simple dichotomous classifications of VO\(_2\) above or below certain threshold values, to the use of complex prognostic scores (Bittner, 2003). The American College of Cardiology and the American Heart
Association have jointly engaged in the formulation of standardized guidelines in the area of cardiovascular disease (Gibbons et al., 1997).

**Hockey Players and Aerobic Capacity**

Hockey is widely considered an aerobic activity through the accumulation of several repeated bouts of anaerobic exercise (Carey et al., 2007). Today’s players are bigger, stronger, and in better physical condition than ever before. A longitudinal study by Cox et al. (1995) gathered physiological data on over 170 players from the National Hockey League (NHL) from 1980 to 1991. Over this time period, overall body mass, height, and body fat percentage increased, showing these players were getting bigger and stronger. This same time period also saw VO$_2$ max increase from an average of 54 ml·kg$^{-1}$·min$^{-1}$ in 1980, to just over 62 ml·kg$^{-1}$·min$^{-1}$ (N=635) in 1991 in these same players. It was also noted that in 1984, several NHL teams began implementing a variety of rigorous programs that were based on proven scientific methods for improving cardiorespiratory fitness, which at the time, was a sharp contrast to most traditional NHL training methods (Cox et al., 1995). Almost as noteworthy as the overall shift in VO$_2$ max distribution, was the incremental increase in VO$_2$ max for each player. In 1980, 58% of these players had a VO$_2$ max of less than 55 ml·kg$^{-1}$·min$^{-1}$. By 1991, only 15% of the players studied fell below that mark (Cox et al., 1995).

A similar longitudinal study by Montgomery (2006) looked at physiological data, including size, strength, and aerobic fitness, of the Montreal Canadiens of the NHL, beginning in 1917. Compared to players from the 1920’s and 1930’s, current players were an average of 17 kg heavier and 10 cm taller, for an average BMI increase of 2.3 kg·m$^{-1}$. However, percent body fat remained unchanged (Montgomery, 2006). Aerobic fitness (VO$_2$ max) has also shown an
increase from 54.6 to 59.2 ml·kg⁻¹·min⁻¹ between 1992 and 2003, but the variability of the data made it impossible to determine if this increase was significant (Montgomery, 2006).

However, a study by Carey et al. (2007) suggested hockey players need not train aerobically. This study consisted of five, one-lap intervals around a hockey rink, with 30 seconds rest between trials. A VO₂max test was performed on a motor-driven treadmill using a Bruce protocol. A fatigue index was calculated by measuring the total increase in skate time from trial one to trial five. Carey (2007) concluded that the ability to recover from high intensity intermittent exercise was not related to aerobic capacity, due to the correlation coefficient (-0.422) not being significant ($p>0.05$) between the fatigue index and VO₂. He also concluded that coaches and trainers need not to include an aerobic component to their training, because the high intensity intermittent training improves VO₂ (Carey et al., 2007). However, pre-training VO₂ was not measured, and causality of the training cannot be determined. Since on-ice shifts in a typical hockey game last approximately 90 seconds (Paterson, 1979), these short bouts of high intensity exercise draw upon anaerobic metabolism, including the depletion of phosphocreatine stores, which are depleted in six to 10 seconds (Carey et al., 2007). This depletion results in the inability to generate more ATP, thus activating the glycolytic system. There is also a corresponding increase in inorganic phosphates, lactate formation, H+ ions, and a decrease in pH (Carey et al., 2007). Carey et al. (2007) also suggested that aerobic metabolism plays an important role in the restoration of these metabolites used during anaerobic exercise, such as the regeneration of phosphocreatine (PCr) stores.

While Tesch (1983) reported that recovery from high intensity exercise was related to capillary density and the increase in oxygen supply to the fatigued muscles, a study of highly trained athletes by Tomlin and Wenger (2001) concluded that recovery from high intensity
interval exercise was attributed to a high aerobic response, increased lactate removal, and enhanced PCr regeneration. Takahashi et al. (1995) also reported a strong relationship between increased aerobic capacity and faster anaerobic recovery, showing that trained runners have faster rates of phosphocreatine (PCr) re-synthesis.

Due to the difficulty in obtaining blood samples during an actual hockey game, few reports exist documenting lactate accumulation between shifts and following games (Green et al., 1976). Lactate removal usually depends on fitness level, state of training, active muscle mass, muscle fiber composition, nutrition, blood flow, and fatigue (Cox et al., 1995). Some NHL teams have begun implementing lactate clearance protocols, having players ride cycle ergometers for at least 20 minutes at 130 Watts as a form of active recovery. However, this non-individualized protocol for lactate clearance is questionable (Cox, et al., 1995). Previous reports, using primarily non-athlete populations, have shown optimal workloads for lactate removal during active recovery ranging from 28 to 68% VO\(_2\)max, with results depending on the individual and the type of active recovery employed (Cox et al., 1995).

Green et al. (2006) conducted a study of an NCAA Division I hockey team and how their physiological profiles, including VO\(_2\)max, blood lactate, and percent body fat, related to their performance. Using a discontinuous protocol in which blood lactate was measured between three-minute stages of treadmill running, blood lactate levels averaged 8.9 ±2.1 mmols·L\(^{-1}\) at the end of the fourth stage, the highest stage every subject completed. This stage corresponded to 12.9 km·h\(^{-1}\) and seven percent grade on the treadmill. Aerobic fitness (VO\(_2\)max) accounted for 17% of the variance in performance, which was based on overall scoring chances while a particular player was on the ice. It was concluded that only VO\(_2\)max significantly predicted performance (Green et al., 2006).
While some previous literature suggests that an increased aerobic capacity would be beneficial to performance in sports such as ice hockey, which is a game of high intensity interval bouts of exercise, there is literature suggesting otherwise. Wadley and LeRossignol (1998) reported 20 meter sprints with 20 second recovery and found no significant difference between the recovery of those athletes with high aerobic capacity and those with lower aerobic capacity; however, this was not comparable to an on-ice hockey shift. Patterson (1979) examined the cardiovascular demands of intermittent exercise as it relates to ice hockey. He found that the intermittent exercise represented a greater demand on both central circulation and oxidative metabolism in the muscle cell. He concluded that training programs to increase aerobic capacity would be beneficial to intermittent exercisers such as ice hockey players.

Sport specificity is also important when testing aerobic capacity and trying to get an accurate picture of the aerobic demands of the sport being completed (Bergh et al., 2007). Because most athletes ambulate in some way, treadmill VO₂max protocols have been shown to report higher scores than other ergometers (Cooper & Storer, 2001), while other test modes, such as a cycle ergometer are only specific to cyclists. Since it would be best to test runners on a treadmill, just as it would be best to test cyclists on a cycle ergometer, the same would apply for the sport of ice hockey. Nobes et al. (2003) compared skating economy between on-ice and skating treadmill protocols. Using male varsity hockey players with an average age of 21 years, the investigators found that the greatest differences in values between on-ice and skating treadmill occurred at low workloads (Nobes et al., 2003). At submaximal workloads, VO₂ and heart rate were significantly higher on the skating treadmill (Nobes, et al., 2003), which can probably be attributed to the fact that skating on a treadmill is not quite comparable to skating on open ice.
Dregger and Quinney (1999) tried developing a hockey-specific skating treadmill protocol to measure VO₂max. The subjects in this investigation completed VO₂max tests on a skating treadmill and a cycle ergometer. They concluded that even though the physiological responses were similar for both protocols (skate treadmill=60.4 ml·kg⁻¹·min⁻¹ versus cycle ergometer=59.0 ml·kg⁻¹·min⁻¹), the skating treadmill replicated the hockey skating stride, which could provide more accurate and applicable information for the development of training protocols (Dregger & Quinney, 1999). Tvent occurred at 59% of VO₂max.

**Positional Differences in Ice Hockey**

There are three different positions that one can play in the sport of ice hockey: forwards, defensemen, and goalies. The typical ice hockey shift consists of three forwards, two defensemen, and one goalie. The forward position spends the most time skating up and down the ice, changing from offense to defense and covering the entire ice as their defensive assignment dictates, while defensemen usually only make it just past mid-ice, into the offensive zone, since they are the last line of defense before the goalie and need to be the first players back when they go on defense. Physiologically, this would require forwards to possess a greater aerobic capacity and ventilatory threshold than their defensemen and goalie counterparts. Increased VO₂ and Tvent would allow this position to be able to skate the length of the ice over the course of an entire game without fatigue. Previous investigations have shown body fat percentages ranging from 10.1 to 17.1%, with defensemen being the heaviest players with the most body fat (Agre et al., 1988). Among all positions, Agre et al. (1988) reported VO₂max values (53.4 ± 0.8 ml·kg⁻¹·min⁻¹).
approximately 10% greater than similarly aged (24.9 ± 0.7 yrs.) sedentary men, but 20 to 25% lower than that of well conditioned endurance athletes.
CHAPTER III

METHODS

The purpose of this study was to examine physiological parameters of performance, such as oxygen consumption and ventilatory threshold in university level hockey players. In this section, the participants, the design of the study, the equipment used, the procedures, and the method of analyzing the data will be discussed.

Participants

The participants for this study included 24 apparently healthy, college-aged, male, university level hockey players of moderate to high training levels. By position, these participants consisted of 14 forwards, eight defensemen, and two goalies (See Table 1). These subjects had an average vertical jump of 25.1 ± 2.4 inches, which calculated out to an average power index of 68.4 ± 4.9.
Table 1: Participant Characteristics

<table>
<thead>
<tr>
<th></th>
<th>Forwards N=14</th>
<th>Defensemen N=8</th>
<th>Goalies N=2</th>
<th>Total N=24</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Age (yrs.)</strong></td>
<td>20.7 ± 1.2</td>
<td>21.3 ± 1.3</td>
<td>21 ± 0</td>
<td>20.9 ± 1.2</td>
</tr>
<tr>
<td><strong>Height (in.)</strong></td>
<td>70.4 ± 2.7</td>
<td>72.1 ± 1.8</td>
<td>72.0 ± 0.7</td>
<td>71.2 ± 2.4</td>
</tr>
<tr>
<td><strong>Weight (lbs.)</strong></td>
<td>187.3 ± 14.5</td>
<td>187.4 ± 13.9</td>
<td>195.0 ± 2.8</td>
<td>188.0 ± 13.4</td>
</tr>
<tr>
<td><strong>Body Fat (%)</strong></td>
<td>12.6 ± 4.0</td>
<td>10.7 ± 2.4</td>
<td>15.7 ± 3.3</td>
<td>12.2 ± 3.6</td>
</tr>
<tr>
<td><strong>Lean Mass (lbs.)</strong></td>
<td>161.4 ± 13.7</td>
<td>167.2 ± 10.5</td>
<td>164.4 ± 4.1</td>
<td>163.8 ± 1.99</td>
</tr>
<tr>
<td><strong>Body Mass Index (kg/m^2)</strong></td>
<td>26.6 ± 1.5</td>
<td>25.4 ± 1.8</td>
<td>26.5 ± 0.1</td>
<td>26.2 ± 1.6</td>
</tr>
<tr>
<td><strong>Power Index (lbs./in.)</strong></td>
<td>67.6 ± 5.5</td>
<td>68.9 ± 4.5</td>
<td>71.2 ± 2.4</td>
<td>68.4 ± 4.9</td>
</tr>
</tbody>
</table>

Participation in this study was based upon specific coronary artery disease risk factors, according to the American College of Sports Medicine (2006), as obtained from a medical history questionnaire completed by each participant. These risk factors include: 1) a family history of heart attack or sudden death, 2) current cigarette smoking, 3) high blood pressure (systolic > 140 mmHg or diastolic > 90 mmHg), 4) high cholesterol (total > 200 mg·dl\(^{-1}\)), 5) diabetes mellitus, and 6) obesity (BMI > 30 kg·m\(^{-2}\)) (ACSM, 2006). Exclusions were made based on participants having two (2) or more of these risk factors. No exclusions were made.

**Design**

This was a descriptive study of maximal oxygen consumption (VO\(_2\)max), ventilatory threshold (Tvent), and other physiological characteristics of hockey players. Three positions of hockey players were studied: forwards, defensemen, and goalies. Two dependent variables were measured: VO\(_2\)max and Tvent. These two dependent variables were broken down by the three
types of positions played. Comparisons were made between the three positions of hockey players on VO₂max, Tvent, and Stage 4 VO₂.

**Equipment**

The equipment involved in this study included: 1) Oxycon Mobile® metabolic system (Viasys Healthcare, Yorba Linda, CA), including the face mask apparatus, 2) Quinton® Q65 treadmill linked to a Quinton® Q4000 (Bothell, WA) with electrocardiogram, allowing an increase in the incline, or percent grade of the treadmill, and 3) Borg’s RPE scale. Borg’s rating of perceived exertion (RPE) scale ranges from six, representing “no exertion at all” to 20, representing “maximal exertion.” The Oxycon Mobile® is a mobile version of the Oxycon Pro® (Viasys Healthcare, Yorba Linda, CA). Carter & Jeukendrup (2002) tested the Oxycon Pro® against the use of Douglas bags for reliability. It was concluded that the Oxycon Pro® was a validity method of measuring VO₂ (Carter & Jeukendrup, 2002).

**Procedure**

After approval from the Human Subjects Review Board, recruitment for this study included personal contact with the assistant coach of the Bowling Green State University hockey team about possible participation in the study. Following recruitment for this investigation, the participants were asked to complete an informed consent and medical history questionnaire. The informed consent served to ensure that participants knew the purpose of the study, exactly what would be measured, and to also ensure that the volunteers knew that they could exclude themselves from the study at any time.

An initial visit allowed the participants to fill out the informed consent and medical history questionnaire and to ask any questions they may have had. Participants then had an opportunity to become familiarized with the VO₂ testing procedures by performing part of the
test, or the whole test if they desired. At this meeting, the participants were instructed to get plenty of sleep the night before testing, to not consume alcohol within 48 hours before testing, to not have any exercise within 12 hours before testing, to make sure that they ate a light meal within four hours before testing, and to be well hydrated. Participants also received a handout outlining these instructions.

The second visit involved the VO$_2$max graded exercise test using the Oxycon Mobile® system. After allowing the subject to warm up appropriately, height, weight, and age, as well as temperature and barometric pressure of the room were recorded before the subject was connected to the Oxycon Mobile® portable metabolic system. The progressive, graded exercise test protocol was utilized for all VO$_2$max tests. During the first stage of this protocol, the subject walked on the treadmill at three miles per hour (mph) and a zero percent grade. This stage lasted three minutes. The second stage increased to four mph and two percent grade. Each stage lasted three minutes with each successive stage increased by one mph and two percent grade. For example, the seventh stage was performed at nine mph and a 12% grade, and the subject would have been walking/running for 21 minutes (See Table 2). Measurements of heart rate and RPE were taken at the end of every three-minute stage, before workload was increased, giving a measurement that reflected the effects of that stage.

Body composition and Power Index (PI) measures were taken by the team strength and conditioning coach during their biannual evaluations, just prior to this VO$_2$ testing (March 2007). Body composition was measured using the three-site (chest, abdomen, and thigh) skinfold caliper method, and percent body fat was calculated using the Jackson-Pollock formula (Jackson & Pollock, 1985):
Body density = 1.10938 – (0.0008267* sum of three skinfolds) + (0.0000016*sum of three skinfolds)² – (0.0002574*age)

% Body Fat = (457/body density) – 414.2 (Brozek et al., 1963)

PI measures were determined through the vertical jump test. Vertical jump (inches) was measured on the VERTEC® (Columbus, OH) vertical jump trainer. Each subject attempted two jumps and the highest jump was recorded, with height being recorded to the nearest tenth of an inch (0.1). PI was then calculated using the following equation: PI = Square Root (body weight, lbs)*Square Root (vertical jump). For example, a 200 lb. person (√200 = 14.14) with a vertical jump of 30 inches (√30 = 5.48) calculates to a PI of 77.49 (14.14*5.48). A PI between 70 and 80 is good, while a PI over 80 is considered excellent.

Table 2: Graded Exercise Test Protocol

<table>
<thead>
<tr>
<th>Stage</th>
<th>Speed (mph)</th>
<th>Grade (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>3</td>
<td>0</td>
</tr>
<tr>
<td>2</td>
<td>4</td>
<td>2</td>
</tr>
<tr>
<td>3</td>
<td>5</td>
<td>4</td>
</tr>
<tr>
<td>4</td>
<td>6</td>
<td>6</td>
</tr>
<tr>
<td>5</td>
<td>7</td>
<td>8</td>
</tr>
<tr>
<td>6</td>
<td>8</td>
<td>10</td>
</tr>
<tr>
<td>7</td>
<td>9</td>
<td>12</td>
</tr>
</tbody>
</table>

*Note: Each stage lasted 3 minutes.

There are six criteria that can be measured to determine if someone has reached a true maximal exertion level: 1) no increase in VO₂ with an increase in exercise intensity (Taylor et
al., 1955), 2) RPE equal to or greater than 17, 3) heart rate equal to or within 10 beats per minute of the subject’s age-predicted maximal heart rate (Howley et al., 1995), 4) blood lactic acid levels reaching 8 mmoles·liter\(^{-1}\) (Astrand, 1952), 5) the subject has reached volitional fatigue (the subject terminates the test), and 6) RER equal to or greater than 1.15 (Issekutz et al., 1962). Blood lactic acid levels were not measured so subjects achieving at least two of the five remaining criteria levels were considered to have reached a state of maximal exercise.

Ventilatory threshold (Tvent) was determined by the V-slope method (Beaver et al., 1986). Using this method, the ventilatory threshold was determined by locating the point at which ventilation (l·min\(^{-1}\)) began to increase at a faster rate when plotted against oxygen uptake (l·min\(^{-1}\)). This point was plotted and determined by the Oxycon Mobile® software and observed by the primary investigator. Tvent was recorded as a value of VO\(_2\), and expressed as a percent of VO\(_2\)\(_{\text{max}}\). However, true Tvent can only be determined when using a ramp protocol. The protocol used in this study used steady state stages of exercise, and three-minute stages may obscure the detection of metabolic threshold as compared to protocols with one-minute stages (Cooper & Storer, 2001). By examining VO\(_2\) at the highest common stage completed by every subject, an estimation of which subjects will have an increased Tvent can be made based on which subjects who are at a lower VO\(_2\), relative to their VO\(_2\)\(_{\text{max}}\), at that highest common stage of intensity. Stage four was the highest stage of intensity completed by all subjects.

### Statistical Analysis

One sample t-tests were used to compare means of this sample to norms for this age group using SPSS. An independent samples t-test was used to compare positional differences in VO\(_2\)\(_{\text{max}}\), Tvent, and VO\(_2\) of Stage 4. Given the low sample size of goalies (n=2), they were omitted for comparisons among positions. Cohen’s d was calculated to determine effect size for
each t-test (Thomas & Nelson, 1990). An effect size of 0.2 is considered a small difference, while an effect size of 0.5 is a moderate difference, and an effect size above 0.80 or larger is considered a large difference (Thomas & Nelson, 1990).

**Sample Size Power Determination**

A G-Power analysis was done to determine adequate sample size for this study. Based on a desired power of 0.80, alpha of 0.05, and an effect size of 0.80, it was determined that a sample size of 15 was adequate for an independent t-test (Faul et al., 2007). For the independent samples T-tests, when comparing between positions, another analysis determined that the sample size in this study (n=22) resulted in a power of 0.40, when an effect size of 0.80 and alpha of 0.05 were used.
CHAPTER IV

RESULTS

Maximal Oxygen Consumption

Descriptive statistics for VO2max, heart rate, and RPE have been provided in Table 3. The range in VO2max for this population has been reported to be 45-55 ml·kg\(^{-1}\)·min\(^{-1}\) (Wilmore & Costill, 2004). The VO2max for this sample (n=24) was 57.2 ± 5.0 ml·kg\(^{-1}\)·min\(^{-1}\) (See table 3). This value was significantly greater than the upper value (i.e., 55 ml·kg\(^{-1}\)·min\(^{-1}\)) for this population’s range (\(t_{(23)}= 2.18, p<0.05, d=0.44\)) (Wilmore & Costill, 2004).

Table 3: Maximal Oxygen Consumption, Heart Rate, and RPE of Hockey Players (N=24)

<table>
<thead>
<tr>
<th>VO2max (ml·kg(^{-1})·min(^{-1}))</th>
<th>HRmax (bpm)</th>
<th>RPE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean</td>
<td>57.2</td>
<td>186</td>
</tr>
<tr>
<td>SD</td>
<td>5.0</td>
<td>10</td>
</tr>
<tr>
<td>Range</td>
<td>48.4-65.6</td>
<td>172-204</td>
</tr>
</tbody>
</table>

*Note: RPE scale = 6-20

Ventilatory Threshold

The range in Tvent for untrained individuals has been reported to be 50-65% of VO2max (McArdle et al., 1986). Ventilatory threshold (Tvent), measured as a percentage of VO2max, was shown as the point at which the \(V_E\) slope changes as plotted by the Oxycon Mobile® software (See Table 4). A one-sample t-test found that this sample’s VO2 at Tvent (46.2 ml·kg\(^{-1}\)·min\(^{-1}\), or 80.9% VO2max) were greater than the upper value (i.e., 65% VO2max) of this
population’s range ($t_{(23)}=8.08, p<0.05, d=1.65$) (McArdle et al., 1986). However, since a non-ramp protocol was used, a true Tvent cannot be determined. At the end of stage four (see Table 4), the stage that every subject completed, VO$_2$ was also greater (45.5 ml·kg$^{-1}$·min$^{-1}$, or 79.8% VO$_2$max) when compared to the upper value (i.e., 65% VO$_2$max) for this population’s range ($t_{(23)}=9.10, p<0.05, d=2.49$). When comparing the Tvent plotted by the Oxycon Mobile® software to the VO$_2$ at Stage 4, there was no statistical difference ($t_{(23)}=0.48, d=0.13$). However, they also were not correlated ($r=0.110, p=0.61$).

Table 4: Ventilatory Threshold and VO$_2$ at Stage 4 (N=24)

<table>
<thead>
<tr>
<th></th>
<th>VO$_2$ @ Tvent (% VO$_2$max)</th>
<th>Stage 4 VO$_2$ (% VO$_2$max)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Mean</strong></td>
<td>46.2 (80.9%)</td>
<td>45.5 (79.8%)</td>
</tr>
<tr>
<td><strong>SD</strong></td>
<td>5.9 (9.7%)</td>
<td>4.7 (8.0%)</td>
</tr>
<tr>
<td><strong>Range</strong></td>
<td>33.5-57.0 (55.5-96.7%)</td>
<td>33.8-54.7 (60.4-87.4%)</td>
</tr>
</tbody>
</table>

**Heart Rate**

Maximal heart rate (HRmax) for these subjects was also measured (beats per minute). These athletes averaged 186 ± 10 bpm (See Table 3). This is significantly lower than the athletes’ average age-predicted HRmax of 199.1 ± 1.8 bpm ($t_{(23)}=-6.89, p<0.05, d=1.41$).

**Position Comparisons of Respiratory Measures**

Descriptive statistics for VO$_2$max and VO$_2$ at Tvent for each position are presented in Table 5. The average VO$_2$max was not significantly different between forwards and defensemen ($t_{(20)}=1.49, p=0.24, d=0.62$). Goalies (N=2) average VO$_2$max was 57.1 ± 5.8 ml·kg$^{-1}$·min$^{-1}$ (See
Table 5). At Tvent, VO$_2$ was not significantly different between forwards and defensemen ($t_{(20)}=0.42, p=0.68, d=0.19$). Further, when analyzing VO$_2$ at the end of stage 4 (See Table 5), the highest common stage each subject completed, there was no significant difference between forwards and defensemen ($t_{(20)}=1.93, p=0.068, d=0.20$).

Table 5: VO$_2$max, VO$_2$ and %VO$_2$max at Tvent and at Stage 4 by position

<table>
<thead>
<tr>
<th>Position</th>
<th>VO$_2$max (ml·kg$^{-1}$·min$^{-1}$)</th>
<th>VO$_2$ @ Tvent (% VO$_2$max)</th>
<th>VO$_2$ @ Stage 4 (% VO$_2$max)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Forwards</strong></td>
<td>Mean 58.4</td>
<td>46.5 (80.0%)</td>
<td>46.4 (79.7%)</td>
</tr>
<tr>
<td></td>
<td>n=14 SD 5.4</td>
<td>5.7 (10.2%)</td>
<td>3.9 (5.8%)</td>
</tr>
<tr>
<td><strong>Defensemen</strong></td>
<td>Mean 55.3</td>
<td>45.3 (81.9%)</td>
<td>42.8 (77.8%)</td>
</tr>
<tr>
<td></td>
<td>n=8 SD 4.2</td>
<td>7.0 (10.3%)</td>
<td>4.9 (11.0%)</td>
</tr>
<tr>
<td><strong>Goalies</strong></td>
<td>Mean 57.1</td>
<td>47.9 (84.0%)</td>
<td>50.1 (87.8%)</td>
</tr>
<tr>
<td></td>
<td>n=2 SD 5.8</td>
<td>2.6 (3.9%)</td>
<td>4.8 (0.5%)</td>
</tr>
</tbody>
</table>
CHAPTER V
DISCUSSION

The purpose of this study was to describe, analyze, and discuss physiological parameters of performance in university level hockey players. Included in this chapter are the discussion and conclusion from the results of this investigation.

The athletes’ VO$_2$max in this study were higher than the average for this specific demographic of college-aged males. The average maximal oxygen consumption, or maxVO$_2$, for college aged males is 45-55 ml·kg$^{-1}$·min$^{-1}$, meaning that most college aged males can utilize between 45 and 55 milliliters of oxygen per kilogram of their body weight, each minute (Saltin & Astrand, 1967). Highly trained athletes, such as the athletes in this study, are usually higher than the average. The hockey players in the present study averaged 57.2 ± 5.0 ml·kg$^{-1}$·min$^{-1}$, and were higher than the norms for this demographic, which is remarkable considering hockey is primarily an anaerobic sport. As noted by Agre et al. (1988), ice hockey players are usually 20-25% below values of well conditioned endurance athletes, which can be over 80 ml·kg$^{-1}$·min$^{-1}$ (Powers & Howley, 2007). VO$_2$max values in the present study were approximately 20 ml·kg$^{-1}$·min$^{-1}$ lower than top endurance athletes.

Body composition also plays a significant role in VO$_2$max, sometimes accounting for as much as 70% of VO$_2$max differences (McArdle et al., 1986). Lean body mass could have contributed to higher VO$_2$max values in the subjects in this study. Since lean muscle mass metabolizes oxygen, these subjects’ body composition (See Table 1) allowed them to consume more oxygen to metabolize and produce energy for performance.
It was also expected that ventilatory threshold, or Tvent, for these athletes would occur at intensities higher than the 55-65% of VO₂max of normal, healthy, untrained individuals. Ventilatory threshold is the point at which the athletes’ ventilation slope diverts from the normal positive linear slope during increasing exercise intensity and increases exponentially at higher oxygen uptake levels, usually around 55% to 65% of VO₂max. The point at which the athletes in this study appeared to reach Tvent averaged 46.2 ± 5.9 ml·kg⁻¹·min⁻¹, which calculated to an average of 80.9% ± 9.7% of VO₂max. This is a great attribute for a hockey player to have. With an increased ventilatory threshold, a hockey player can play longer shifts, and more shifts, at a higher intensity level before reaching their ventilatory threshold.

However, it must be repeated that a true Tvent could not be determined, due to the utilization of a non-ramp protocol. Ramp protocols provide intensity increases that facilitate pattern recognition of physiological variables, such as the Vₑ inflection point (Cooper & Storer, 2001). The subjects’ VO₂ at the end of stage four, which was the stage that every subject completed, was examined as a possible estimation of which subjects might possess increased Tvent. Subjects with a lower percent VO₂max than other subjects at the same intensity have potentially more opportunity to increase VO₂ before Tvent is reached. Oxygen consumption at the end of stage four appeared to be very similar to the average computer generated Tvent (VO₂ at Vₑ slope inflection point) by the Oxycon Mobile®. While it is most likely coincidence that the computer generated Tvent from the Oxycon Mobile® and VO₂ at the end of stage four were very similar, it could suggest that these athletes, on average, were already at ventilatory threshold at the end of stage four, and continued to exercise.

It could have been expected that VO₂max and Tvent would vary according to position of each athlete; forwards would have higher results than defensemen and goalies would have the
lowest results. One of the greater values was recorded by a goalie at 61.2 ml·kg⁻¹·min⁻¹. However, there are a number of variables other than training that could have influenced the results of this goalies test, such as genetic factors and current motivation of the athlete. After goalies were omitted due to low sample size, defensemen were not statistically different from forwards, which could be attributed to forwards and defensemen not having different training programs, other than position specific drills.

When examining Tvent, again it was expected that forwards would average the greatest value, with defensemen lower than forwards, but greater than goalies. No significant differences were observed between forwards and defensemen; goalies were not analyzed due to low sample size. Forwards actually averaged the lowest percent of VO₂max of the three groups. Training and conditioning programs for forwards and defensemen are not different, except for position specific drills that replicate game situations, which could explain why these two groups show no statistical differences.

Heart rate, as it relates to elite athletes, can be lower at maximal exercise intensities, than their non-athlete counterparts (Astrand & Rodahl, 1986; Fox, 2002). This is said to be a compensatory mechanism to allow more time for the ventricles of the heart to fill more completely between beats (Wilmore & Costill, 2004). As heart rate increases, there is less time between heart beats for the ventricles to fill completely, which will decrease stroke volume and could limit maximal cardiac output. The average maximal heart rate for these athletes was 186 ± 10 bpm, which was significantly lower than their age-predicted maximal heart rate.

Sport specificity of training and testing is an important aspect to examine (Bergh et al., 2000). In this case, since the tests were done on a running treadmill, it was expected that these subjects would be within the average of normal, untrained individuals and maybe a little higher.
for VO₂max. Since these athletes were trained for skating, the VO₂ results may have been
greater than the recorded values, had this test been done on a skating treadmill, or on the open ice
of a hockey rink. Physiological data have been reported for hockey players using cycle
ergometers and running treadmills, but cycling and running do not adequately reflect skating
movements, and therefore do not reflect the specific aerobic power developed by elite hockey
players (Nobes, 2003).

The element of anaerobic exercise is also very important in ice hockey. Since the
average ice-hockey shift is about 90 seconds, the anaerobic element may be great enough to
warrant another, more accurate anaerobic power test, such as the Wingate power test, which
measures power for the short bursts of exercise much like a hockey shift. As mentioned earlier,
a Power Index above 80 is rated as “excellent”, while a PI between 70 and 80 is “good” (Fitness
Institute of Texas, 2008). Surprisingly, these athletes PI rated below “good” (See Table 1). With
such a large anaerobic component involved in ice hockey, a higher PI rating would have been
expected.

For this specific group of athletes, these results suggest an average to above average
aerobic capacity (Wilmore & Costill, 2004). This increased aerobic capacity with above average
ventilatory threshold helps these athletes perform at higher levels of intensity for longer periods
of time before performance is affected by fatigue. For the most part, these results did reflect
what was expected. The average VO₂max for these subjects was greater than the norms for this
demographic, which would be expected from highly trained athletes. Also, the average Tvent for
these athletes was greater than the 65% of VO₂max seen in untrained individuals, and was
consistent with values shown in previous literature (McArdle et al., 1986). When the data from
these athletes was broken down by position, the results were inconclusive, showing no statistical
differences between forwards and defensemen which can be attributed to small sample size. The minimal variability in training programs between groups may have contributed to the lack of a statistical difference, but a more likely explanation is the lack of power due to the small sample size. Evaluation of the effect sizes ($d=0.19$ and $0.20$, respectively) suggest a small effect.

**Limitations**

There are ways in which this study could have been improved. In the future, more in-depth examination of anaerobic power characteristics of ice hockey athletes in addition to aerobic capacity could give more insight into the strengths and weaknesses of each individual athlete, and provide the trainers and coaches with better information on how to target an individual athlete’s deficiencies. The Wingate anaerobic power test could be added to the protocol to examine another aspect of each athlete’s metabolism.

As noted by Bergh et al. (2000), sport specific testing could have improved this study. By testing these athletes on a running treadmill, these athletes’ strengths were not being taken advantage of, which is skating on the open ice. If access to a skating treadmill were possible, their mode of training could have been targeted, potentially leading to different accurate VO$_2$ values relative to their sport. However, testing these athletes, which are trained in skating, on a running treadmill may yield more of a “representative” VO$_2$max, since research has shown that treadmill tests yield greater VO$_2$ values than other modes of exercise testing (Cooper & Storer, 2001).

Another method to improve validity would have been to test them on the open ice. The Oxycon Mobile® gas analysis system that was used in this study could have been taken directly to the ice rink and data collection could have been done on location rather than in the laboratory. A protocol using intermittent skating in increasing intensity could be used, yielding a maximal
value. To do this, the protocol requires the subject to skate from point A to point B, in a pre-determined amount of time. The set time to complete each trial decreases with each successive trial, until the subject can no longer make it from point A to point B in the desired amount of time. Using this protocol, a maximal value can be obtained without the use of a motor-driven running or skating treadmill.

However, the greatest limitation to this study was the protocol used for the VO$_{2 \text{max}}$ tests. Since a non-ramp protocol was used, a true Tvent could not be accurately determined. This protocol has three-minute stages of increasing intensity, which allows the subject to reach steady state exercise before the onset of the next level of intensity. When determining Tvent, a ramp protocol, one in which intensity increases continuously in small increments throughout the test (Cooper & Storer, 2001), is needed to adequately determine when the $V_E$ slope changes, known as the inflection point. Treadmill ramp protocols should be designed to increase steadily and terminate at eight to 12 minutes, at VO$_{2 \text{max}}$, or at the limit of subject tolerance (Cooper & Storer, 2001). While a change in $V_E$ slope was noted for these athletes, its validity could be questioned since a non-ramp protocol was utilized.

**Conclusion**

As the primary objective for conducting this study, the data collected showed the increased aerobic capacity of these athletes. Average VO$_{2 \text{max}}$ and Tvent were higher than the norms for this age group, even though the exercise performed during the test was not the type of exercise for which these subjects were trained. All of this evidence suggests that increased aerobic capacity is useful to the sport of hockey, with its unique blend of anaerobic power and aerobic capacity. These results could have come about from training using a purely aerobic component, or through high intensity interval anaerobic training. As mentioned earlier, other
factors, such as genetics and current motivation, could have influenced the data during these tests.

The ventilatory threshold of these athletes showed that they can exercise at a very high intensity, up to 80% of their VO\(_2\)max, before the lactic acid starts to accumulate and fatigue sets in. Since a normal on-ice hockey shift consists of approximately 90 seconds of active exercise (Patterson, 1979), one might assume that these athletes have intermittent recovery time between shifts, they never reach 80% of their VO\(_2\)max, and thus, fatigue should not affect them. In reality, however, the build-up of lactic acid still occurs even though the exercise is not continuous. The multiple 90 second maximal effort on-ice shifts that occur during a hockey game cause a cumulative effect on the build-up of lactic acid, and fatigue will eventually occur (Carey et al., 2007).

While some results of this study did not coincide with what was expected, as a whole, this study produced results that were largely expected. Maximal oxygen consumption was above average for this demographic. Ventilatory threshold was also higher that what would have been expected from untrained individuals in the same demographic. However, the VO\(_2\)max and Tvent values did not correspond to the on-ice position of the athlete, and more research should be done in this specific area to include a larger sample and more extensive testing.

Maximal oxygen consumption (VO\(_2\)max) and ventilatory threshold are two of the more important physiological variables associated with aerobic performance. While VO\(_2\)max can provide information on how much oxygen can be utilized by the exercising muscles to generate ATP energy at maximal workloads, ventilatory threshold is more indicative of how long an athlete can sustain increasing high intensity exercise before fatigue begins to impede performance. An athlete may have a high VO\(_2\)max, but how long the athlete can exercise at
increasing intensity is just as important. Endurance athletes, such as runners and cyclists, as well as athletes exercising in short, high-intensity intervals, such as ice hockey players have shown a need for increased aerobic capacity. The difference between the two is that ice hockey players may not need to specifically train aerobically. It is suggested they achieve their increased aerobic capacity through the high-intensity intermittent exercise associated with the sport (Carey et al., 2007).
REFERENCES


APPENDIX A

INFORMED CONSENT STATEMENT
Informed Consent Statement

Investigator: Tim Zachrich
Phone: (419)308-9919

Project Title: VO₂ Analysis on Hockey Players

You are invited to participate in a research study to analyze oxygen consumption in hockey athletes.

Your participation in this study will last 3-7 days. You may ask questions at any time during your visits to the laboratory. If at any time during the study you would like to stop participating, you may do so. You are not required to complete the study.

Purpose: The primary purpose of this investigation is to collect descriptive data on maximal oxygen consumption and related physiological variables, including ventilatory threshold, which is the point at which the body can no longer buffer the build-up of lactic acid in the blood through the exhalation of carbon dioxide. As a secondary purpose, you, the subject, will be provided with information from your test results, to be used as a future training tool.

Procedure: The research procedures will consist of your voluntary involvement in 1) one pretest screening and acclimation period, and 2) one maximal graded exercise test. All these appointments and tests will be completed in a 3-7 day period. You will volunteer approximately one hour of your time to the project/data collection. You will follow the procedures outlined below for the two visits.

1) During the pretest screening and acclimation period, you will have your resting blood pressure measured, complete a medical history questionnaire, read and voluntarily sign this informed consent statement, and undergo a familiarization period with the graded exercise test protocol as well as the equipment. During this pretest screening, it could be discovered that the mask does not fit you properly. If this is the case, you will be excluded from the study.

2) During the maximal graded exercise test, you will wear a face mask, which will be connected to an automated metabolic analysis system, and you will run on the treadmill. You will begin by running on the treadmill at three miles per hour and zero percent grade (incline). Every three minutes the treadmill will increase by one mile per hour and two percent grade. We will ask you to run to your maximal effort, or exhaustion. An electrocardiogram will monitor heart rhythms during the test. If any abnormalities are present, the test will be terminated and you will be excluded from the study. During the test, standard procedures will be followed in which your expired air will be collected and analyzed to determine oxygen consumption (i.e. caloric cost) of the exercise. You will have a heart rate monitor strapped around your chest so that heart rate can be measured each minute.
For your participation in this study, you will receive an explanation of your graded exercise test results and an evaluation of your fitness level.

**Risks:** Before beginning the test you should understand that the possibility of adverse changes or responses from exercise may occur during the graded exercise test. These may include mild fatigue, slight muscular soreness, slips or falls from the equipment resulting in bodily injury, and sudden death. The risk of sudden death is extremely low, i.e. less than 1 event per 100,000 individuals. In the unlikely event of physical injury immediate medical treatment will be obtained either at the Student Health Services at Bowling Green State University or at the Wood County Hospital, Bowling Green, Ohio. The cost of such treatment will be at the financial expense of the participant.

**Benefits:** The benefit incurred from your participation in this study is your help in providing the investigator with descriptive data on maximal oxygen consumption, as well as other related physiological variables. In addition, you will receive your results from your graded exercise test, which will give you information about your fitness level.

**Confidentiality:** Information you provide will remain confidential and your identity will not be revealed. Only the investigators will have access to this information. Individual results and data will be combined with other subjects’ data for generalized analysis. Your identity will not be revealed in any published results.

**Voluntary Participation:** Your participation in this study is completely voluntary, and you can refrain from answering any or all questions without penalty or explanation. You are free to withdraw consent and to discontinue participation at any time.

**Contact Information:** If you have any questions or comments about this study, you can contact Tim Zachrich at (419)308-9919 or by e-mail (tz_15@yahoo.com), or Dr. Amy Morgan at (419)372-0596 or by e-mail (amorgan@bgnet.bgsu.edu). If you have any questions about the conduct of this study or your rights as a research participant, you may contact the Chair, Human Subjects Review Board, Bowling Green State University at (419)372-7716 or by e-mail (hsrb@bgnet.bgsu.edu).

**Authorization:** I have read this document and the study has been explained to me. I have had all of my questions answered. I volunteer to participate in this study.

I know that I will receive a copy of this letter.

__________________________________________________________________________  
Participant’s Signature                                      Date
APPENDIX B

SAMPLE TELEPHONE RECRUITMENT SCRIPT
**Explanation of study:**

The purpose of my thesis is to determine caloric cost of exercise (i.e. maximal oxygen consumption and ventilatory threshold).

**What will I have to do?**

During the maximal graded exercise test, you will wear a face mask, which will be connected to an automated metabolic system, and you will run on the treadmill. It is possible that during the pretest screening, we could discover that the mask does not fit you properly. If this is the case, you will be excluded from the study. You will begin by running on the treadmill at three miles per hour and zero percent grade (incline). Every three minutes the treadmill will increase by one mph and two percent grade. We will ask you to run to your maximal effort, or exhaustion. However, you may terminate the test at any time. During the test, standard procedures will be followed in which your expired air will be collected and analyzed to determine oxygen consumption (i.e., caloric cost) of the exercise. You will have a heart rate monitor strapped around your chest so that heart rate can be measured each minute. An electrocardiogram will monitor heart rhythms for the first two tests. The EKG will be monitored in accordance with Dubin’s (2000) “Rapid Interpretation of EKG’s.” If any abnormalities are present, the test will be terminated and you will be excluded from the study. You will be tested a total of four times.

**What can this do for me?**

This type of test can give you an overall evaluation of your fitness level, as well as information that can be used to develop an exercise prescription.

**Am I at any risk?**

Before beginning the test you should understand that the possibility of adverse changes or responses from exercise may occur during the graded exercise test. These may include mild fatigue, slight muscular soreness, slips or falls from the equipment resulting in bodily injury, and sudden death. The risk of sudden death is extremely low, especially for your age group, i.e., less than 1 event per 100,000 individuals. In the unlikely event of physical injury immediate medical treatment will be obtained either at the Student Health Services at Bowling Green State University or at Wood County Hospital, Bowling Green, Ohio. Also, the EMS will be notified prior to your testing session. The cost of such treatment will be at the financial expense of the participant.
APPENDIX C

SAMPLE RECRUITMENT EMAIL
Dear_______,

I am writing to see if you are interested in being part of a research study. I am conducting research for my thesis involving testing maximal oxygen consumption (*caloric cost of exercise*). I am looking for university level hockey players. Please let me know if you are interested in participating. For more information please contact me at 419-308-9919, or e-mail (tz_15@yahoo.com).

Sincerely,

Tim Zachrich
Graduate Assistant
School of Human Movement,
   Sport, and Leisure Studies
Bowling Green State University
APPENDIX D

MEDICAL HISTORY QUESTIONNAIRE
MEDICAL HISTORY QUESTIONNAIRE

All information given is personal and confidential. It will enable us to better understand you and your health and fitness habits. In addition, we will use this information to classify your health status according to the American College of Sport Medicine in ACSM's Guidelines for Exercise Testing and Prescription (2006). Please let us know if and when you have changed your medication (dose & type), diet, exercise or sleeping habits within the past 24 or 48 hours. It is very important for you to provide us with this information.

NAME______________________________________________ AGE___________________
DATE___________________
OCCUPATION________________________________________________________

1. FAMILY HISTORY
Check each as it applies to a blood relative:
* Heart Attack yes______ no______ unsure______
  If yes, age at onset_________ years
* Sudden Death yes______ no______ unsure______
  If yes, relation to you____________________________
  Age of relative at onset____________years.
Father’s Age_____ Deceased_____ Age at death_____.
Tuberculosis yes______ no______ unsure______
Stroke yes______ no______ unsure______
Asthma yes______ no______ unsure______
High Blood Pressure yes______ no______ unsure______
Circulatory Disorder yes______ no______ unsure______
Heart Disease yes______ no______ unsure______
Mother’s Age_____ Deceased_____ Age at death_____.

2. PERSONAL HISTORY
Check each as it applies to you:
* Current Cigarette Smoking yes______ no______ unsure______
* High Blood Pressure yes______ no______ unsure______
  Systolic Blood Pressure ≥140mmHg or diastolic ≥90mmHg
  If yes, give value if known:_________/_________mmHg.
* High Blood Cholesterol yes______ no______ unsure______
  Total Serum Cholesterol >200 mg·dl⁻¹
  If yes, give value if known:_____________mg·dl⁻¹
* Diabetes Mellitus yes______ no______ unsure______
  If yes, age of onset:______________________years
* Obesity – BMI >30 kg·m⁻² yes______ no______ unsure______
  If yes, give value if known:_____________kg·m⁻²
* Sedentary Lifestyle yes______ no______ unsure______
Persons not participating in a regular exercise program or not meeting the minimal physical activity recommendations from the U.S. Surgeon General’s Report.

Have you ever had:

- Tuberculosis: yes______ no______ unsure______
- Heart Attack: yes______ no______ unsure______
- Angina: yes______ no______ unsure______
- EKG Abnormalities: yes______ no______ unsure______
- Asthma: yes______ no______ unsure______
- Emphysema: yes______ no______ unsure______
- Surgery: yes______ no______ unsure______
- Stroke: yes______ no______ unsure______
- Severe Illness: yes______ no______ unsure______
- Hospitalized: yes______ no______ unsure______
- Black Outs: yes______ no______ unsure______
- Gout: yes______ no______ unsure______
- Nervousness: yes______ no______ unsure______
- Joint Problems: yes______ no______ unsure______
- Allergy: yes______ no______ unsure______
- Convulsions: yes______ no______ unsure______
- Paralysis: yes______ no______ unsure______
- Headaches: yes______ no______ unsure______
- Depression: yes______ no______ unsure______
- Chest Pain: yes______ no______ unsure______
- Arm Pain: yes______ no______ unsure______
- Shortness of Breath: yes______ no______ unsure______
- Indigestion: yes______ no______ unsure______
- Ulcers: yes______ no______ unsure______
- Overweight: yes______ no______ unsure______
- Hernia: yes______ no______ unsure______
- Back Pain: yes______ no______ unsure______
- Leg Cramps: yes______ no______ unsure______
- Low Blood Pressure: yes______ no______ unsure______
- Insomnia: yes______ no______ unsure______

For Office Use Only:

Number of coronary heart disease risk factors* (according to Table 2-4 ACSM (2006))

NOTE: All risk factors are explained verbally to each person completing the questionnaire. Classification according to ACSM (2006) (check one): _____ Low risk; _____ Moderate risk; _____ High risk

3. MEDICAL HISTORY

Name of your physician__________________________________________________________
Date of your most recent physical examination

What did the physical examination include?

Have you ever had an exercise EKG? Yes_______ No________

Are you presently taking any medications? Yes___ No____
(Including over-the-counter medications and/or herbs) List name and dosage

Have you ever taken:

Digitalis yes______ no_____ unsure______

Nitroglycerin yes_____ no_____ unsure______

High Blood Pressure yes_____ no_____ unsure______
Medication

Sedatives yes_____ no_____ unsure______

Inderal yes_____ no_____ unsure______

Insulin yes_____ no_____ unsure______

Ponestyl yes_____ no_____ unsure______

Vasodilators yes_____ no_____ unsure______

Other yes_____ no_____ unsure______

If yes, list medications:

4. EXERCISE HISTORY

Do you exercise? Yes_______ No_______ What activity__________________________
How long have you been exercising? ____________________________________________________________

How many days do you exercise?____________________ How many minutes per day?_______________________________

What kinds of shoes do you work out in?____________________________________________________________________

Where do you usually exercise?____________________________________________________________________

Do you monitor your pulse during your workout?____________________________________________________________

5. HEALTH HISTORY

<table>
<thead>
<tr>
<th>Age</th>
<th>At Age 20</th>
<th>At Age 30</th>
<th>At Age 40</th>
<th>One Year Ago</th>
<th>Most Weighed</th>
<th>Least Weighed</th>
<th>After Age 20</th>
</tr>
</thead>
<tbody>
<tr>
<td>Height</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Weight</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Do you use Health Foods?  Yes____ No____ List________________________________________________________

Do you take Vitamin pills?  Yes____ No____ List________________________________________________________

Approximate your daily intake: Coffee______ tea______ coke______ beer______

wine______ liquor______

Do you smoke or use tobacco products?  Yes_____ No____

If yes, approximate your daily usage: Cigarettes______ Cigars______ Pipes______

Chewing Tobacco________

Did you ever smoke?  Yes_____ No_____ How many years?_______________ Age when you quit_________

Approximate the number of hours you work per week?_______________ Vacations weeks per year_______________
Home Status: Very happy________ Pleasant________ Difficult________
Problem________

Work Status: Very happy________ Pleasant________ Difficult________
Problem________

Do you feel you are stressed? Yes_______ No_______ Unsure_______

Are you worried about your health? Yes_______ No_______ Unsure_______

6. APPROXIMATE A TYPICAL 24 HOUR DAY FOR YOU

Number of hours:
_________________________________ Work
_________________________________ TV
_________________________________ Relaxation/Leisure activities
_________________________________ Driving/Riding
_________________________________ Eating
_________________________________ Exercise
_________________________________ Sleep
_________________________________ TOTAL

Additional information from client interview to further assess health/coronary risk status:
____________________________________________________________________________
____________________________________________________________________________
____________________________________________________________________________
____________________________________________________________________________
____________________________________________________________________________
____________________________________________________________________________

_________________________________ ______________________________________________
Signature of Tester Date

1/12/06