THE EFFECTS OF A 10 KM RUN AND 30 KM CYCLING TIME-TRIAL ON VENTILATORY THRESHOLD DURING THE FINAL RUNNING LEG OF AN ITU DUATHLON IN HIGHLY-TRAINED MULTI-SPORT ATHLETES

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ABSTRACT

NATHANIEL T. BERRY: The effects of a 10 km run and 30 km cycling time-trial on ventilatory threshold during the final running leg of an ITU Duathlon in highly-trained multi-sport athletes
(Under the direction of Dr. Claudio L. Battaglini)

This study investigated the effects of a 10 km run and 30 km cycling time-trial on maximal oxygen uptake (VO$_{2\text{max}}$) and ventilatory threshold (V$_T$) during the subsequent run of an ITU Duathlon simulation. Highly-trained multi-sport subjects (n=6) completed three trials; Trial-1: a speed only VO$_{2\text{max}}$ (SOVO$_{2\text{max}}$) protocol to determine VO$_{2\text{max}}$ and V$_T$ during an single-bout run; Trial-2: a 10 km run at 95-98% of V$_T$ followed by a cycle ergometer VO$_{2\text{max}}$ test to determine VO$_{2\text{max}}$ and V$_T$; Trial-3: a 10 km run and 30 km cycling time-trial, each performed at 95-98% of V$_T$, followed by a SOVO$_{2\text{max}}$ protocol to determine VO$_{2\text{max}}$ and V$_T$. No significant difference in VO$_{2\text{max}}$, (p=0.06, 66.8 mL/kg/min ±6.6 and 60.9 mL/kg/min ±3.1 respectively), or V$_T$ (%VO$_{2\text{max}}$) (p=0.36, 75.9% ±3.9 and 77.5% ±10.4, respectively) was observed. A decrease of 1.6 km/h was observed between trials; a 2 minute and 18 second increase in 5 km run time.
ACKNOWLEDGMENTS

I would first like to thank my family for their gracious support throughout my academic endeavors. Without this support, none of my achievements would be possible, nor would they mean as much. I would also like to thank each of my friends for their unrelenting support throughout these past years.

I would also like to thank each of my committee members (Dr. Anthony Hackney and Dr. Edgar Shields) for their support, friendship, and mentorship over these past years. I would like to give a special thank you to my advisor, Dr Claudio Battaglini, for his friendship, mentorship, support, and the great times we have had – I look forward to more.
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CHAPTER I

INTRODUCTION

The duathlon is a multi-sport event consisting of three endurance events (swimming, cycling, and running) performed in immediate and consecutive order. There are several variations of the duathlon, which include variations in terrain, distance, and mode of exercise. At an internationally competitive level, the International Triathlon Union (ITU, 2012) acts as the governing body for all triathlon, duathlon, cross triathlon, winter triathlon, long distance triathlon, aquathlon, team, and paratriathlon events; all considered multi-sport events that encompasses two or more different sports performed in one event. The ITU is responsible for making amendments to the rules and regulations, sanctioning events, and overseeing athlete eligibility. The first recorded modern-day multi-sport event performed in immediate and consecutive order (a triathlon) was performed in 1974 (ITU, 2012). Due to its exponential increase in popularity, the International Olympic Committee (IOC) first included the event into the 1994 Olympic games.

The ITU sanctioned duathlon consists of a 10 km running bout immediately followed by a 40 km cycling time-trial and finishing with a 5 km run (ITU, 2012). As in any endurance sport, oxygen consumption and intensity thresholds play a vital role in athletic performance. Within any multi-sport event, determining optimum race/performance intensity becomes increasingly complex compared to an event consisting of one discipline. Maximizing an athlete’s ability to perform continues to be a major challenge to coaches around the globe. Various physiological measures and performance tests have been adapted
in an effort to develop and perfect a training methodology and be able to most effectively periodize an athlete’s program. Such measures include, but are not limited too; maximal oxygen uptake (VO_{2max}), ventilatory threshold (V_T), and lactate threshold (L_T).

Maximal oxygen uptake (VO_{2max}) is an individual’s maximal capacity to utilize oxygen during exercise. The treadmill is a popular testing platform used in testing an individual’s cardiopulmonary function. Such testing also provides information that can be effectively used to design/prescribe exercise training programs (Balady et al. 2010). The information provided through a VO_{2max} test includes the information used to determine various thresholds and training intensities which can then be used in an effort to increase performance through training (Londeree 1986). These procedures are often performed with endurance athletes as a method of determining an individual’s maximal cardiorespiratory fitness, allowing such values to then be used for prescribing training intensities and monitoring training load.

The method of testing becomes increasingly important when testing trained individuals and attempting to use the physiological information in prescribing exercise intensities. Research has shown that highly-trained single-sport athletes elicit a higher VO_{2max} when tested in their preferred discipline (Bouckaert et al. 1990, Millet et al. 2009). Nevertheless, while highly-trained multi-sport athletes have high relative maximal oxygen uptake values, these values are lower than that of a highly-trained athlete specializing in one event (Sleivert and Rowlands, 1996).

While there have been several studies that have investigated the effects of cycling on a subsequent running bout (Bernard et al., 2003; Gottschall and Palmer, 2000; Hue et al., 1999, 2000, 2001; Suriano and Bishop, 2010; Suriano et al. 2007, Vercruyssen et al. 2002,
2005), there have been far fewer studies which investigate the effects of running on cycling performance (Vallier et al. 2003). There have been two primary studies that have investigated the compounding effect of an entire multi-sport competition. De Vito et al. (1995) examined the effects of the swim and cycling bouts on run performance within an Olympic distance triathlon simulation. Vallier et al. (2003) investigated the compounding effects of the run-cycle-run transitions in the final run performance of a duathlon, finding that the energy cost of the final running bout during the run-cycle-run transition did not elicit the same physiological or biomechanical responses present within a triathlon event.

Statement of Purpose

The purpose of this study was to compare the ventilatory threshold (VT) from a single-bout maximal treadmill protocol to the VT observed in a maximal treadmill test following an ITU Duathlon simulation within a controlled laboratory setting. The secondary purpose of this study was to examine maximal oxygen consumption (VO2max) between the single-bout maximal treadmill protocol and the VO2max assessed following the 10 km run and 30 km cycling time-trial in an ITU Duathlon simulation.

Hypotheses

H1: There will be a significant decline in VT (%VO2max) after performing a 10 km run and 30 km cycling time-trial when compared to a single-bout maximal treadmill protocol.
H2: There will be a decline in $\text{VO}_2\text{max}$ after performing a 10 km run and 30 km cycling time-trial when compared to a single-bout maximal treadmill protocol.

**Limitations**

- The current training phase of each subject was not controlled in this study.
- The use of the cycle ergometer (While the cycle ergometer set up was adjusted for each subject, the bike position may have limited maximal performance due to the dissimilarity between the cycle ergometer and the set-up of each athlete’s time-trial bike. This position may have limited the specific riding mechanics of each athlete).
- Even though all attempts were made to monitor fatigue and diet prior to each testing trial, there was no way to make sure the athlete answered these questions honestly.

**Delimitations**

- All participants were highly-trained multi-sport athletes.
- Hydration status was monitored via urine specific gravity testing before the start of each trial.
- Start times for all trials were consistent within each subject in order to control for the hormonal flux occurring throughout the day.
Definition of Terms

- **ITU Duathlon** – A 10 km run, 40 km cycling time-trial and 5 km run performed consecutively and immediately following one another.

- **Highly-trained multi-sport athletes** – Individuals who have been training a minimum of 15 hours per week for at least 6 months to compete in events such as duathlons and/or triathlons (swim, bike, run).

- **40 km cycling time-trial** – the fastest pace an individual can perform a 40 km cycling bout. For the purposes of this study, the cycling time-trial intensity was controlled so that a comparison could be made between testing trials. In the laboratory setting, riding a 40 km right below the ventilatory threshold (Intensity between 95-98% of Ventilatory Threshold ($V_T$)), takes in average 35-45min longer than covering the same distance while cycling outdoors with variable pace (which is the case during triathlon and duathlon races). Therefore, as an attempt to closely reproduce the total time that takes during a real duathlon event and reduce any adverse affects of extra time spent on the bike, the 40 Km cycling distance regulated by ITU was shortened to 30 Km in this study.

- **Maximal Oxygen Consumption ($VO_{2\text{max}}$)** – The maximal amounts of oxygen that an individual is able to consume, transport, and utilize within working muscle to produce (aerobic) energy.

- **Ventilatory threshold ($V_T$)** – The point at which pulmonary ventilation increases (exponentially) relative to exercise intensity/oxygen consumption. For the purposes of this study, $V_T$ will be determined using the V-slope method (Casaburi et al. 1977)
- **Maximal treadmill protocol (VO₂max test)** – An incremental exercise test, increasing intensity in stages, thus allowing the subject to reach one’s maximal capacity for aerobic exercise. While maximal aerobic exercise can be tested invasively or non-invasively, in the lab or in the field, this study will use both a cycle ergometer and treadmill protocol within a laboratory setting.

- **SOVO₂max (Speed only VO₂max) protocol**: protocol for measuring VO₂max using incremental increases in speed while maintaining a constant grade of 0%. Please see Table 2.

**Assumptions**

- It was assumed that all subjects in this experiment abstained from alcohol, drugs, or any other ergogenic aid that could have affected the results of the study.

- It was assumed that subjects maintained a similar diet between trials, avoiding any drastic deviation in their standard dietary regimen. Subjects were provided pre-testing information and asked to complete a questionnaire before each trial to assess whether dietary patterns were consistent.

- It was assumed that all subjects consumed the same foods and liquids that they would consume during competition. It is also assumed that subjects did not ingest irregular amounts of food or liquid during this study.

- It was assumed that performing the 10 km run and 30 km cycling time-trial at 95-98% of VT would have resulted in the fastest possible time for each of these athletes in the laboratory setting.
- It was assumed that all subjects answered the training history questionnaire (Appendix IV) and pre-trial questionnaires (Appendix VI) honestly.

Significance

Performance within any sport or event is a direct reflection upon the training and preparation during the preceding days, weeks, and months leading to competition. Having the knowledge of an athlete’s cardiorespiratory fitness and being able to apply a scientific rationale to the development and periodization of an athlete’s training program is essential to optimizing that particular athlete’s performance. Understanding the effects of a 10 km run and 40 km cycling time-trial on the subsequent run performance in a laboratory setting will contribute to the current body of knowledge necessary for the development of future experiments. Future studies should aim to test specific strategies that can be implemented by the coaches of multi-sport athletes in order to optimize race performance.
CHAPTER II

REVIEW OF LITERATURE

There are many genetic, physiological, and biomechanical aspects that contribute to sport performance. As multi-sport events such as the duathlon and triathlon have received an increasingly large amount of attention within the sport performance field. There are many areas of that must be researched including the specifics of nutrition, hydration, metabolism, thermoregulation, and endocrinological responses. A primary focal point in current physiological and biomechanical research relating to athletic performance has been on the transitions during multi-sport events. Single-bout endurance performance in events such as cycling and running has been investigated in many environments and conditions. Performing each of these events in immediate and successive order (run-cycle-run) is more complex than any single-bout event of the same discipline. The result is that physiological responses and adaptations to performance and training make duathlon performance a unique endeavor.

In order to effectively address the complexity of the duathlon, this literature review has been divided into three sections. Section one will address the major concept of oxygen consumption and its relationship to endurance exercise. Section two will review the specificity of training in multi-sport events. Meanwhile, section three will address the evaluation of oxygen consumption as a mean of the determination of training thresholds.
Oxygen Consumption and Metabolism

Oxygen uptake is the body’s ability to utilize oxygen in order to fuel the metabolic processes that provide the necessary energy to function on a daily basis. Oxygen uptake (VO$_2$) is dependent on exercise intensity and increases in a positive relationship with workload until VO$_2$ will either plateaus or decline. The highest point measured value is defined as an individual’s maximal oxygen uptake (VO$_{2\text{max}}$) (Skinner and McLellan, 1980). Both submaximal and maximal oxygen uptake values are useful in a number of settings including, but not limited to health, research, and sport performance perspectives. Such information is essential in developing and periodizing training programs as well as regulating intensity during competition.

The body’s metabolic processes provide the necessary energy (adenosine triphosphate – ATP) needed to facilitate muscular contraction and move the skeleton. ATP is produced through immediate, non-oxidative, and oxidative pathways. During exercise, each of these three metabolic processes works to maintain ATP homeostasis. Exercise intensity can be determined by measuring oxygen uptake kinetics and further evaluation of thresholds such as the ventilatory threshold (V$_T$) and lactate threshold (L$_T$) can add reliability and precision to an exercise testing/prescription program.

Maximal oxygen uptake is highly dependent upon genetic factors; however, several additional elements can positively or negatively affect one’s ability to utilize oxygen (Brooks et al. 2005). Factors such as disease, infection, lifestyle, training, and environmental conditions can affect maximal oxygen uptake (Brooks et al. 2005). The Fick equation states that oxygen uptake is equal to the product of cardiac output (Q) and the arterio-venous oxygen difference [VO$_2$=Q*a-vO$_{2\text{diff}}$]. A change in any of these three variables requires a
change in the other two. While the arterio-venous oxygen difference (a-v O₂Diff) changes very little in response to training, cardiac output is the primary factor affecting one’s ability to increase oxygen consumption. The heart’s ability to provide increased blood throughout the body is responsible for the majority of change in VO₂max observed through training (Brooks et al. 2005).

While VO₂max can be tested in many ways, the two most popular methods include the treadmill and cycle ergometer. Testing an individual’s VO₂max provides a measure of cardiorespiratory fitness as well as additional information that can be used for exercise prescription and periodization of training programs (Balady et al., 2010). Because endurance performance is focused around an athlete’s ability to produce energy aerobically, VO₂max is often considered a measure of performance potential while the submaximal thresholds, such as Lₜ and Vₜ, are often considered more important measures in endurance performance.

The Lₜ is the point at which lactate accumulation exceeds a linear rate of increase. At this point, the body is unable to remove lactate as fast as it is produced. Exercising below Lₜ is considered a low to moderate intensity and consists of a higher percentage of lipid utilization, which declines as intensity increases. Because lactate is produced through the glycolytic process, performing above Lₜ requires a higher percentage of carbohydrate being metabolized. Although technology has made it easier to assess blood lactate levels in a field setting, the equipment is still expensive and therefore, coaches and athletes often use the highly correlated Vₜ for monitoring intensity. Ventilatory threshold is the point at which ventilation increases at a non-linear rate (Brooks et al. 2005). This non-linear increase in ventilation is due to the accumulation of lactate causing a decline in blood pH. Ventilation
increases in order to restore blood pH levels by blowing off the excess carbon dioxide (CO₂) that is produced from the buffering of pyruvate into lactate.

As previously noted, exercise intensity contributes to the percent contribution between the metabolic processes and the substrate being utilized. Performing just below V₅₀ for an extended period of time will lower blood glucose levels, thus reducing the ability to perform acute bouts of high-intensity exercise. Pre-competition nutrition has a huge impact on substrate availability and should be monitored in order to achieve maximal performance potential. Nevertheless, during-competition nutrition and hydration also become very important for maintaining glucose levels and optimizing performance. Failure to maintain proper hydration can be detrimental to performance due to its effect on hormonal balance and substrate utilization. Inadequate hydration can also result in cardiac drift and has detrimental effects on performance (Brooks et al. 2005). A decrease in hydration results in a reduced plasma volume. As plasma volume decreases, venous return to the heart is reduced, meaning that heart rate must increase in order to maintain cardiac output. Any deviation outside of homeostatic conditions will result in an illicit endocrinological response during exercise.

The endocrine system is often considered the regulator of the body’s physiological systems and while it helps to maintain homeostasis, things such as nutrition and hydration also drastically affect it. These two aspects can easily influence the endocrine response during exercise and while the specific response and mechanisms of the endocrine system are outside the realm of this review, it is important to note that inadequate nutrition or hydration during endurance exercise can cause detrimental effects to hormonal response during exercise which would result in adverse effects on performance.
Sport Specificity: The Multi-Sport Competition

There are five key training principles that affect athletic performance: 1) sport specificity, 2) overload, 3) recovery, 4) adaptation, and 5) reversibility. The concept of sport specificity plays an interesting role within multi-sport events due to the transition phases from one bout to another. The concept of specificity suggests that the greatest performance potential will be obtained when the training and fitness programs are focused on the demands of the sport. As shown in the literature, elite athletes will test better in their preferred discipline as opposed to an alternative mode of exercise (Bouckaert et al. 1990, Millet et al. 2009). The overload principle states that if you do not stress your physiological systems during exercise, then you will not improve. Consequently, the recovery principle states that your body needs adequate time to regenerate, re-fuel, and recover in order to benefit from the effects of training. The body used the recovery phase to adapt and “grow,” which is where/how we quantify an improvement in athletic performance. The concept of reversibility states that without continuing to stress the body, that these benefits observed with prior training will fade.

The ITU Duathlon is an endurance event consisting of a 10 km run, 40 km cycling time-trial, and 10 km run. Performing these bouts in immediate and successive order places a unique physiological and biomechanical stress on the athlete. Current research has investigated the effects of the initial run on subsequent cycling performance (Vallier et al., 2003). There have been a vast number of studies that examine the effects of cycling on subsequent run performance (Bernard et al., 2003; Gottschall and Palmer, 2000; Hue et al., 1999, 2000, 2001; Suriano and Bishop, 2010; Suriano et al., 2007; Vercruyssen et al., 2002, 2005). While each of these studies are applicable to performance during a multi-sport event,
there have been far fewer studies that have investigated the compounding effects of an entire multi-sport event on performance (De Vito et al. 1995, Vallier et al. 2003).

The cycle-run transition has been shown to elicit differences in $V_E$, the ventilatory equivalent ratio for oxygen ($V_E/VO_2$), the ventilatory equivalent ratio for carbon dioxide ($V_E/VCO_2$), breathing frequency ($f$), and heart rate (HR) (Hue et al. 2000). In addition to the physiological parameters associated with the cycle-run transition, researchers have also focused on the biomechanical adaptations associated with the transition. However, confounding variables associated with the research have resulted in conflicting results between studies. Additionally, the applicability of these experiments has been questioned as cycling races and the cycling leg of triathlons consist of large variations in intensity and workload (Bentley et al. 2002), however, it is important to note the goals and hierarchy of research. While the applicability of these studies may be questioned, the overall physiological response must first be proven before further studies can investigate more specific responses. Suriano et al. (2007) demonstrated that variable power output during a 30 minute cycling bout followed with a maximal treadmill test improved run duration compared to run performance following a cycling bout at a constant power output. Although $VO_2$, $V_E$, HR, and blood lactate values showed no statistical significance, the improvement in sub-maximal and maximal running speeds suggest a theoretical improvement in running time during the final stage of a triathlon competition.

Cycling cadence has also been shown to affect run performance (Bernard et al. 2003, Gottschall and Palmer 2000, Vercruyssen et al. 2002). Bernard et al. (2003) showed that a lower cycling cadence (60rpm) resulted in a lower running velocity (m/s) and a higher $VO_2$ during the subsequent run while higher cycling cadences (80 and 100rpm) did not result in
any significant differences in running velocity or VO₂ during the subsequent run. Gottschall and Palmer (2000) observed a lower stride length and higher stride frequency at the initiation of the running bout following a high intensity cycling effort and as the run progresses, stride length has been shown to increase as stride frequency decreases (Gottschall and Palmer 2000). A seven percent (7%) decrease in stride length has also been reported at the start of the running bout of a triathlon simulation when compared to a single bout run (Hausswirth et al. 1997).

To the best of this author’s knowledge, there have been only two studies that have examined the compounding effects of a multi-sport event on physiological performance during a laboratory controlled, experimental race simulation. De Vito et al. (1995) performed a triathlon simulation, measuring VO₂, V̇E, and HR at VT (%VO₂max) and VO₂max. While the final running bout of the triathlon simulation (1500 m swim and 32 km cycling time-trial followed by a treadmill VO₂max test) did elicit a decline in decline in VO₂ and VT (%VO₂max) when compared to a single-bout maximal treadmill protocol, the swim and cycling intensities were not controlled. The fact that the cycling time-trial was performed outside raises many questions as factors such as temperature, air pressure, humidity, and wind could impact pace and effort.

Similarly, Vallier et al. (2003) investigated the compounding effects of a duathlon simulation on run performance. The study included a 5 km run and 30 km cycling time-trial followed by an additional 5 km run. The main result was a lack of any significant difference between the two running bouts. Similar to the De Vito article, this study was performed outdoors raising many questions about potentially confounding variables. While VT was not
measured in this study, the conclusions suggest that there is no difference in run performance between a single-bout run and the final running bout of a duathlon competition.

In review, this review of literature was divided into three sections: the concept of oxygen consumption, the specificity of training, and the evaluation of oxygen consumption as a means to determine training thresholds. As previously noted, several studies have investigated specific transitions within these events, however, the research investigating the effects of an entire multi-sport endurance event is much more limited. De Vito (1995) and Vallier (2003) each produced interesting results, however, the research design within these studies raises a few questions regarding environmental factors that could potentially affect performance.
CHAPTER III

METHODS

Subjects

Six highly-trained multi-sport athletes, ages 18-45 years were recruited to participate in this study. Subjects had been training a minimum of fifteen hours per week for at least six months prior to enrolling in this study. Subjects were healthy (classified as low risk individuals for participation in maximal exercise testing based on the guidelines set forth by the American College of Sports Medicine – ACSM) and free of any orthopedic injury that precluded successful completion of the study. Each subject was given a physical examination, administered a medical history questionnaire, and completed a Par-Q (physical activity readiness questionnaire) prior to being deemed eligible to participate in this study. Subjects were also required to have an organized dietary/nutritional plan during competition.

Instrumentation

Height and weight was recorded using a stature meter (Perspective MO, USA) and Detecto 2381 balance beam scale (Detecto, Webb City, MO, USA) respectively. Urine specific gravity was assessed to determine hydration status prior to the start of each trial with a refractometer (TS Meter, American Optical Corp, Keene, NH, USA). Respiratory gas and oxygen consumption were assessed with a Parvo Medics TrueMax® 2300 Metabolic system (Parvo Medics, Salt Lake City, UT, USA). A Lactate Plus lactate analyzer (Sports Resource Group, Hawthorne, NY) was used to determine blood lactate values while the Borg 6-20
scale (Borg, 1970) was used to quantify rating of perceived exertion throughout each of the trials.

**General Procedures**

This study consisted of three testing sessions, each of which were performed in the Applied Physiology Laboratory (APL) located in Fetzer Gymnasium, room 025. Each testing session occurred on three different days and were completed within three weeks/twenty-one days of the first trial.

Prior to reporting to the APL, recruited subjects were given pre-trial testing guidelines (Appendix V) and instructions on what would happen during the first session (Trial-1). During Trial-1, subjects were screened for participation in the study [physical examination (Appendix I) and the Par-Q questionnaire (Appendix II)], answer a training history questionnaire (Appendix IV), a pre-trial questionnaire (Appendix VI)] and then given further and more detailed information regarding the study protocol and requirements. The objective of the pre-trial questionnaire (Appendix VI) was to subjectively quantify a level of fatigue, sleep, and dietary habits. Each subject was also weighed and provided a urine sample to ensure adequate hydration status. Subjects were then administered an informed consent form that had been approved by the UNC Biomedical IRB before any further involvement in the study.

Trial-1 began once all of the screening processes were completed and consent had been given. Subjects performed a speed-only VO2max (SOVO2max) testing protocol on the laboratory treadmill and metabolic station. Trial-2 consisted of a 10 km run (at 95-95% of VT) on a treadmill followed by an incremental VO2max test on a cycle ergometer while
connected to the metabolic cart. The third and final trial (Trial-3) consisted of a 10 km run and a 30 km cycling time-trial followed by a treadmill SOVO$_{2\text{max}}$ protocol. Subjects completed the laboratory based 10 km run and 30 km cycling time-trial on a treadmill and cycle ergometer respectively. Participants performed each of these exercise bouts at 95-95% of $V_T$. Subjects were taken on and off the metabolic cart throughout various times of the exercise bouts in order to assess and monitor exercise intensity. In addition to the metabolic data, blood lactate, heart rate, and a rating of perceived exertion was also collected throughout each of these three trials. A summary of the testing protocol is listed below in Table 1.
Table 1: Summary of Study Protocol

<table>
<thead>
<tr>
<th>Recruitment</th>
<th>Trial-1</th>
<th>Trial-2</th>
<th>Trial-3</th>
</tr>
</thead>
<tbody>
<tr>
<td>a) Contacted coaches and administrators to ask for permission to approach athletes</td>
<td>a) Subjects reported to the APL where they underwent all screening processes to ensure they were healthy enough to participate in the study</td>
<td>a) Subjects reported to the APL where they completed a questionnaire regarding fatigue, sleep, and diet. Subjects also submitted a urine sample to assure adequate hydration status before beginning the testing session</td>
<td>a) Subjects reported to the APL where they completed a questionnaire regarding fatigue, sleep, and diet. Subjects also submitted a urine sample to assure adequate hydration status before beginning the testing session</td>
</tr>
<tr>
<td>b) Approached potential subjects to introduce study</td>
<td>b) Subjects were administered the informed consent form.</td>
<td>b) All set up for the cycle ergometer VO_{2max} test was completed before beginning the 10 km run.</td>
<td>b) All set up for the cycle ergometer was completed prior to beginning the ITU Duathlon simulation.</td>
</tr>
<tr>
<td>c) Gave information about the study, for those who were interested, set up scheduling for Trial-1 and gave them pretesting information and guidelines</td>
<td>c) Subjects completed a questionnaire regarding training history</td>
<td>c) Subjects completed the 10 km run and then transitioned onto the cycle ergometer to complete the incremental VO_{2max} protocol.</td>
<td>c) Subjects completed the 10k run and 30 km cycling time-trial at 95-95% of V_T before completing a treadmill SOVO_{2max} protocol.</td>
</tr>
<tr>
<td></td>
<td>d) Subjects submitted a urine sample to assure adequate hydration status before beginning the testing session</td>
<td>d) Blood lactate was taken 3 minutes after the completion of the last stage</td>
<td>d) Blood lactate will be taken 3 minutes after the completion of the last stage.</td>
</tr>
<tr>
<td></td>
<td>e) Subjects performed a treadmill SOVO_{2max} protocol</td>
<td>e) Subjects were given strict guidelines in preparation for the next testing session</td>
<td>e) Subjects were given strict guidelines in preparation for the next testing session</td>
</tr>
<tr>
<td></td>
<td>f) Blood lactate was taken 3 minutes after the completion of the last stage</td>
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<td></td>
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<td></td>
<td>g) Subjects were given strict guidelines in preparation for the next testing session</td>
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</tbody>
</table>
Trial-1

Trial-1 consisted of an incremental treadmill test to assess maximal oxygen uptake ($\text{VO}_2\text{max}$). Prior to testing, subjects completed a pre-trial questionnaire (Appendix VI) and submitted a urine sample to assure proper hydration status. Measurement of $\text{VO}_2\text{max}$ was performed using a speed-only protocol ($\text{SOVO}_2\text{max}$) consisting of one-minute stages beginning at 5.0mph. Speed was increased by 1.0mph each minute until a speed of 11.0mph was reached when speed was increased by 0.5mph each minute. Table 2 presents the $\text{SOVO}_2\text{max}$ protocol. Oxygen uptake ($\text{VO}_2$), $V_E$, $\text{VCO}_2$, ventilation ($V_E$), and the respiratory exchange ration (RER) were measured every 15 seconds throughout the testing session. Rating of perceived exertion (RPE) was taken at the conclusion of each stage and at the conclusion of the testing protocol.

Heart rate was monitored via heart rate monitors while blood lactate was being taken by finger-prick three minutes after the conclusion of the last stage. Subjects were asked to sit with their palm facing upwards on the arm of the chair before cleaning the fingertip with an alcohol swab. After disinfected, every effort was taken to not contaminate the area, and if needed, the area was cleaned again. Holding the subject’s finger with one hand, the autolancet was held in the other, placed against the subject’s fingertip and release button pressed. The subject’s finger tip was squeezed and the first beads of blood were wiped off using a sterile gauze pad. The proceeding drops of blood were analyzed via the portable lactate analyzer. Upon completion, the autolancet needle, gauze, and anything else that touched the subjects blood was disposed of into a sharps container.

This trial was used to prescribe a running intensity during Trial-2 and to compare the
VT and VO₂max observed during a single-bout maximal exercise to the observed values during the ITU Duathlon simulation (Trial-3). Subjects were required to achieve no less than three of the following criteria for the trial to be considered a true, and viable, maximal effort:

1) Respiratory Exchange Ratio (RER) > 1.10
2) RPE > 18
3) Heart Rate (within 10 beats of age predicted max)
4) Plateauing (+ 2 ml/kg/min) or decline of VO₂ with increased workload
5) Blood lactate (> 8mmol/L)

Once the subject was cooled down, the following visit was scheduled. In an effort to control for circadian rhythm and any variation that could affect the results of this study, each additional session was scheduled at a similar time of day (± 2 hours).

**Trial-2**

The second testing session consisted of a 10 km run followed by an incremental VO₂max test performed on a cycle ergometer. Prior to testing, each subject completed a pre-trial questionnaire (appendix VI) and submitted a urine sample to assure proper hydration status. Each subject performed the 10 km treadmill run at 95-95% of VT before transitioning onto the cycle ergometer to perform an incremental VO₂max test. Ventilatory threshold was determined using the V-slop method (Casaburi et al. 1977) and expressed as a percentage of VO₂max. If a subject was unable to complete the protocol at this intensity, the intensity was
dropped by an additional 5% so that the exercise bout could be completed. If a subject could not complete the trial at an intensity level equal to 90% of their $V_T$ then the subject was disqualified from the study. Metabolic data was collected during kilometers 0-2, 5-7, and 9-10.

Upon transitioning to the cycle ergometer, subjects began the incremental treadmill protocol at an intensity of 150W and increased by 50W every two minutes until a workload of 250W was reached. At this point, intensity was increased by 30W every two minutes until maximal volitional fatigue was reached. Table 3 describes the cycle ergometer VO$_{2\text{max}}$ protocol. The same criteria used for determining VO$_{2\text{max}}$ in Trial-1 was used in Trial-2. This trial was used to standardize the exercise intensity in the 30 km cycling time-trial during the ITU Duathlon simulation (Trial-3).

_Trial-3_

The third and final testing session consisted of the ITU Duathlon simulation. Prior to testing, each subject completed a pre-trial questionnaire (appendix VI) and submitted a urine sample to assure proper hydration status. This trial consisted of a 10 km run, a 30 km cycling time-trial and treadmill SOVO$_{2\text{max}}$ protocol performed immediately after one another. The initial 10 km run and succeeding 30 km cycling time-trial were performed at an intensity equal to 95-95% of $V_T$. These intensities were calculated using the same methodology discussed in Trial-2. Subjects exercised at an intensity equal to 95-95% of their $V_T$ and if needed, intensity was dropped by 5% in order to complete the trial. If subjects were unable to complete the bouts at an intensity equal to 90% of $V_T$ then they were disqualified from the
study. During the 10 km run, this intensity was equated to a specific running speed while exercise intensity on the cycle ergometer was equated to a specific workload (Watts). During both the 10 km run and 30 km cycling time-trial, metabolic data was collected periodically in order to assess and monitor exercise intensity. Heart rate and RPE was taken every 5 minutes throughout each of these bouts.

Upon completion of these two exercise bouts, the subjects transitioned back onto the treadmill to complete the SOVO$_{2\text{max}}$ protocol. Oxygen uptake, ventilation ($V_E$), and volume of carbon dioxide ($VCO_2$) were measured every 15 seconds throughout the trial while heart rate (HR) was monitored via use of a heart rate monitor and RPE recorded at the end of each stage. Blood lactate was taken three minutes after the completion of the SOVO$_{2\text{max}}$ protocol. Criteria for determining VO$_{2\text{max}}$ will remain the same in Trial-3 as in Trial-1 and Trial-2.
### Table 2: SOVO$_{2max}$ Treadmill Protocol

<table>
<thead>
<tr>
<th>Stage (1 min intervals)</th>
<th>Speed (mph)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>5.0</td>
</tr>
<tr>
<td>2</td>
<td>6.0</td>
</tr>
<tr>
<td>3</td>
<td>7.0</td>
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<tr>
<td>4</td>
<td>8.0</td>
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<tr>
<td>5</td>
<td>9.0</td>
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<tr>
<td>6</td>
<td>10.0</td>
</tr>
<tr>
<td>7</td>
<td>11.0</td>
</tr>
<tr>
<td>8</td>
<td>11.5</td>
</tr>
<tr>
<td>9</td>
<td>12.0</td>
</tr>
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<td>12.5</td>
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<td>13.5</td>
</tr>
<tr>
<td>13</td>
<td>14.0</td>
</tr>
<tr>
<td>14</td>
<td>14.5</td>
</tr>
</tbody>
</table>

### Table 3: Cycle ergometer VO$_{2max}$ Protocol

<table>
<thead>
<tr>
<th>Stage</th>
<th>Time (min)</th>
<th>Workload (W)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0-2</td>
<td>150</td>
</tr>
<tr>
<td>2</td>
<td>2-4</td>
<td>200</td>
</tr>
<tr>
<td>3</td>
<td>4-6</td>
<td>250</td>
</tr>
<tr>
<td>4</td>
<td>6-8</td>
<td>280</td>
</tr>
<tr>
<td>5</td>
<td>8-10</td>
<td>310</td>
</tr>
<tr>
<td>6</td>
<td>10-12</td>
<td>330</td>
</tr>
<tr>
<td>7</td>
<td>12-14</td>
<td>370</td>
</tr>
<tr>
<td>8</td>
<td>14-16</td>
<td>300</td>
</tr>
<tr>
<td>9</td>
<td>16-18</td>
<td>430</td>
</tr>
<tr>
<td>10</td>
<td>18-20</td>
<td>460</td>
</tr>
<tr>
<td>11</td>
<td>20-22</td>
<td>490</td>
</tr>
<tr>
<td>12</td>
<td>22-24</td>
<td>520</td>
</tr>
</tbody>
</table>
Statistical Analyses

All recorded data was entered into an electronic database, analyzed via descriptive statistics, and presented in the form of means ± standard deviation (SD). Analysis was completed using SPSS version 19.0 for Windows; an alpha level of P≤0.05 was used for all analyses.

Hypothesis 1: There will be a significant decline in V_T (%\(\text{VO}_{2\text{max}}\)) after performing a 10 km run and 30 km cycling time-trial when compared to a single-bout maximal treadmill protocol.

*Hypothesis one was analyzed using a dependent samples t-test where the V_T (%\(\text{VO}_{2\text{max}}\)) between the single-bout maximal treadmill protocol (Trial-1) and the V_T (%\(\text{VO}_{2\text{max}}\)) of the final running leg in a laboratory based ITU Duathlon simulation (Trial-3) were used for comparison.*

Hypothesis 2: There will be a decline in \(\text{VO}_{2\text{max}}\) after performing a 10 km run and 30 km cycling time-trial when compared to a single-bout maximal treadmill protocol.

*Hypothesis two was analyzed using a dependent samples t-test where the \(\text{VO}_{2\text{max}}\) between the single-bout maximal treadmill protocol (Trial-1) and the \(\text{VO}_{2\text{max}}\) of the final running leg in a laboratory based ITU Duathlon simulation (Trial-3) were used for comparison.*
CHAPTER IV

RESULTS

The primary purpose of this study was to examine the effects of the initial run and cycling time trial on the final run performance within an ITU Duathlon. Six highly-trained multi-sport athletes were tested in order to compare the effects of a 10 km run and 30 km cycling time trial on running performance during the final running leg of an ITU Duathlon compared to a single-bout run performance. Individual characteristics as well as the mean and standard deviation (SD) of the sample are presented in table 4 below:

Table 4: Subject Characteristics

<table>
<thead>
<tr>
<th>Subject</th>
<th>Age (years)</th>
<th>Height (cm)</th>
<th>Weight (kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>43</td>
<td>179.5</td>
<td>76.2</td>
</tr>
<tr>
<td>2</td>
<td>45</td>
<td>176.0</td>
<td>74.8</td>
</tr>
<tr>
<td>3</td>
<td>22</td>
<td>181.0</td>
<td>74.8</td>
</tr>
<tr>
<td>4</td>
<td>27</td>
<td>183.0</td>
<td>69.2</td>
</tr>
<tr>
<td>5</td>
<td>31</td>
<td>175.0</td>
<td>74.4</td>
</tr>
<tr>
<td>6</td>
<td>42</td>
<td>177.0</td>
<td>77.3</td>
</tr>
<tr>
<td>Mean</td>
<td>35 (± 9.6)</td>
<td>178.6 (± 3.1)</td>
<td>74.5 (± 2.8)</td>
</tr>
</tbody>
</table>

Hypothesis 1 stated “there will be a significant decline in $V_T$ (%$VO_{2\text{max}}$) after performing a 10 km run and 30 km cycling time-trial when compared to a single-bout maximal treadmill protocol.” The mean percentages attained during Trial-1 and Trial-3 were used in the analysis. There was no change in $V_T$ (%$VO_{2\text{max}}$) between the single-bout maximal treadmill test in Trial-1 and the maximal treadmill test following a 10 km run and
30 km cycling time-trial performed in Trial-3 (p=0.36, 75.9% ±3.9 and 77.5% ±10.4, respectively) (Table 5).

Hypothesis 2 stated “there will be a decline in VO$_{2\text{max}}$ after performing a 10 km run and 30 km cycling time-trial when compared to a single-bout maximal treadmill protocol.”

The mean VO$_{2\text{max}}$ values attained during Trial-1 and Trial-3 were used in the analysis. No significant difference in VO$_{2\text{max}}$ between Trial-1 and Trial-3 (p=0.06, 66.8 mL/kg/min ±6.6 and 60.9 mL/kg/min ±3.1 respectively) was observed (Table 5).

Tables 6-9 present the results of the exploratory analyses conducted with the goal of demonstrating the accuracy of the intensity administered during trials. Additionally, this information was presented in an effort to explore other parameters associated with performance during an ITU Duathlon simulation.
Table 5: VO$_{2\text{max}}$, VO$_2$ at $V_T$, and $V_T$ (%VO$_{2\text{max}}$) responses for the VO$_{2\text{max}}$ (Trial-1) and VO$_{2\text{max}}$ test performed following a 10 km treadmill run and 30 km cycling time-trial (Trial-3).

<table>
<thead>
<tr>
<th>Subject</th>
<th>VO$_{2\text{max}}$ (L/min)</th>
<th>VO$_{2\text{max}}$ (mL/kg/min)</th>
<th>$V_T$ (L/min)</th>
<th>$V_T$ (mL/kg/min)</th>
<th>$V_T$ (%VO$_{2\text{max}}$)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Trial-1</td>
<td>Trial-3</td>
<td>Trial-1</td>
<td>Trial-3</td>
<td>Trial-1</td>
</tr>
<tr>
<td>1</td>
<td>4.50</td>
<td>4.51</td>
<td>59.0</td>
<td>59.2</td>
<td>3.51</td>
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<tr>
<td>2</td>
<td>4.60</td>
<td>4.94</td>
<td>61.4</td>
<td>66.0</td>
<td>3.75</td>
</tr>
<tr>
<td>3</td>
<td>5.20</td>
<td>4.50</td>
<td>69.6</td>
<td>60.1</td>
<td>3.84</td>
</tr>
<tr>
<td>4</td>
<td>5.38</td>
<td>4.15</td>
<td>77.8</td>
<td>60.0</td>
<td>4.08</td>
</tr>
<tr>
<td>5</td>
<td>5.03</td>
<td>4.66</td>
<td>67.6</td>
<td>62.7</td>
<td>3.53</td>
</tr>
<tr>
<td>6</td>
<td>5.08</td>
<td>4.43</td>
<td>65.7</td>
<td>57.3</td>
<td>3.85</td>
</tr>
<tr>
<td>Mean (±SD)</td>
<td>4.96 (±0.35)</td>
<td>4.53 (±0.26)</td>
<td>66.9 (±6.6)</td>
<td>60.9 (±3.1)</td>
<td>3.76* (±0.22)</td>
</tr>
</tbody>
</table>

* Significant difference at (p≤0.05) between Trial-1 and Trial-3.
Individual responses as well as mean and standard deviations (SD) for $HR_{\text{max}}$, lactate (post $VO_{2\text{max}}$), $RPE_{\text{max}}$, $RER_{\text{max}}$ and $RER$ at $V_T$ or during the $VO_{2\text{max}}$ Trial-1 and Trial-3 (after running 10 km and riding a 30 km cycling time trial at 95-95% $V_T$) are reported below in Table 6.

Running 10 km and riding a 30 km cycling time trial at 95-95% $V_T$.

<table>
<thead>
<tr>
<th>Subject</th>
<th>$HR_{\text{max}}$ (bpm)</th>
<th>Lactate (mmol)</th>
<th>$RPE_{\text{max}}$</th>
<th>$RER_{\text{max}}$</th>
<th>$RER$ at $V_T$</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Trial-1</td>
<td>Trial-3</td>
<td>Trial-1</td>
<td>Trial-3</td>
<td>Trial-1</td>
</tr>
<tr>
<td>1</td>
<td>171</td>
<td>169</td>
<td>13.4</td>
<td>11.1</td>
<td>20.0</td>
</tr>
<tr>
<td>2</td>
<td>168</td>
<td>167</td>
<td>9.4</td>
<td>6.2</td>
<td>19.5</td>
</tr>
<tr>
<td>3</td>
<td>188</td>
<td>178</td>
<td>13.6</td>
<td>6.4</td>
<td>19.0</td>
</tr>
<tr>
<td>4</td>
<td>191</td>
<td>185</td>
<td>9.5</td>
<td>6.7</td>
<td>19.0</td>
</tr>
<tr>
<td>5</td>
<td>192</td>
<td>190</td>
<td>14.3</td>
<td>8.8</td>
<td>19.0</td>
</tr>
<tr>
<td>6</td>
<td>182</td>
<td>189</td>
<td>15.4</td>
<td>10.0</td>
<td>18.0</td>
</tr>
</tbody>
</table>

| Mean (±SD) | 182 (±10) | 179 (±10) | 12.6* (±2.5) | 8.2* (±2.1) | 19.1 (±0.7) | 18.6 (±0.6) | 1.14 (±0.03) | 1.00 (±0.08) | 0.89 (±0.04) | 0.84 (±0.03) |

* Significant difference at ($p<0.05$) between Trial-1 and Trial-3; $RPE$=Rate of Perceived Exertion; Lactate (obtained 3 minutes post completion of $VO_{2\text{max}}$ tests)
Individual response for VO$_{2\text{max}}$, VO$_2$ at V$_T$, and V$_T$ (%VO$_{2\text{max}}$) performed on the cycle ergometer as well as VO$_{2\text{max}}$, VO$_2$ at V$_T$, and V$_T$ (%VO$_{2\text{max}}$) and mean ± standard deviation (SD) of the sample are presented in Table 7:

**Table 7**: VO$_{2\text{max}}$, VO$_2$ at V$_T$, V$_T$ (%VO$_{2\text{max}}$), blood lactate, RPE, RER$_{\text{max}}$, and HR$_{\text{max}}$ responses on the cycle ergometer VO$_{2\text{max}}$ (Trial-2)

<table>
<thead>
<tr>
<th>Subject</th>
<th>VO$_{2\text{max}}$ (L/min)</th>
<th>VO$_{2\text{max}}$ (mL/kg/min)</th>
<th>V$_T$ (L/min)</th>
<th>V$_T$ (mL/kg/min)</th>
<th>V$<em>T$ (%VO$</em>{2\text{max}}$)</th>
<th>Lactate$_{\text{max}}$ (mmol)</th>
<th>RPE$_{\text{max}}$</th>
<th>RER$_{\text{max}}$</th>
<th>HR$_{\text{max}}$ (bpm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>5.06</td>
<td>66.1</td>
<td>3.90</td>
<td>50.9</td>
<td>77.0</td>
<td>13.6</td>
<td>19.0</td>
<td>1.20</td>
<td>174</td>
</tr>
<tr>
<td>2</td>
<td>4.77</td>
<td>64.1</td>
<td>3.24</td>
<td>43.5</td>
<td>67.9</td>
<td>8.2</td>
<td>20.0</td>
<td>0.92</td>
<td>167</td>
</tr>
<tr>
<td>3</td>
<td>4.83</td>
<td>65.0</td>
<td>3.91</td>
<td>52.6</td>
<td>80.9</td>
<td>10.2</td>
<td>18.0</td>
<td>1.01</td>
<td>185</td>
</tr>
<tr>
<td>4</td>
<td>5.21</td>
<td>75.1</td>
<td>3.75</td>
<td>54.1</td>
<td>72.0</td>
<td>9.9</td>
<td>19.0</td>
<td>1.07</td>
<td>195</td>
</tr>
<tr>
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<td>5.01</td>
<td>65.3</td>
<td>3.95</td>
<td>51.46</td>
<td>78.8</td>
<td>12.8</td>
<td>17.0</td>
<td>1.06</td>
<td>192</td>
</tr>
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<td>6</td>
<td>4.56</td>
<td>59.9</td>
<td>3.99</td>
<td>52.37</td>
<td>87.4</td>
<td>11.2</td>
<td>19.0</td>
<td>1.08</td>
<td>188</td>
</tr>
<tr>
<td>Mean (±SD)</td>
<td>4.91 (±0.23)</td>
<td>65.1 (±5.00)</td>
<td>3.80 (±0.28)</td>
<td>50.8 (±3.75)</td>
<td>77.3 (±6.85)</td>
<td>11.0 (±2.0)</td>
<td>18.7 (±1.0)</td>
<td>1.06 (±0.09)</td>
<td>183.5 (±10.9)</td>
</tr>
</tbody>
</table>
Individual responses as well as mean and standard deviations (SD) for HR, RPE, and RER during the 10 km treadmill run in Trial-2 and Trial-3 at the prescribed 95-98% of ventilatory threshold are presented in Table 8 below:

Table 8: Descriptive statistics for the 10 km treadmill run in Trial-2 and Trial-3.

<table>
<thead>
<tr>
<th>Subject</th>
<th>10 km Run (Trial-2)</th>
<th>10 km Run (Trial-3)</th>
<th>Exercise Intensity</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>HRavg</td>
<td>RPEavg</td>
<td>RERavg</td>
</tr>
<tr>
<td>1</td>
<td>146</td>
<td>12.9</td>
<td>0.94</td>
</tr>
<tr>
<td>2</td>
<td>152</td>
<td>13.6</td>
<td>0.80</td>
</tr>
<tr>
<td>3</td>
<td>162</td>
<td>15.0</td>
<td>0.84</td>
</tr>
<tr>
<td>4</td>
<td>180</td>
<td>14.3</td>
<td>0.86</td>
</tr>
<tr>
<td>5</td>
<td>172</td>
<td>13.1</td>
<td>0.87</td>
</tr>
<tr>
<td>6</td>
<td>163</td>
<td>12.25</td>
<td>0.86</td>
</tr>
<tr>
<td>Mean</td>
<td>163</td>
<td>13.5</td>
<td>0.86</td>
</tr>
</tbody>
</table>

* Significant difference at (p<0.05) between Trial-1 and Trial-3; HRavg = Heart rate average during trial. RPEavg = Rate of Perceived Exertion average during trial; RERavg = Respiratory Exchange Ration average during trial.
Individual responses as well as mean and standard deviations (SD) for HR, RPE, RER and workload (watts) during the 30 km cycling time trial in Trial-3 at the prescribed 95-98% of ventilatory threshold are presented in Table 9 below:

**Table 9: Physiological characteristics responses during the 30 km cycling time-trial in Trial-3.**

<table>
<thead>
<tr>
<th>Subject</th>
<th>HR&lt;sub&gt;avg&lt;/sub&gt;</th>
<th>RPE&lt;sub&gt;avg&lt;/sub&gt;</th>
<th>RER&lt;sub&gt;avg&lt;/sub&gt;</th>
<th>95%&lt;sub&gt;V&lt;sub&gt;T&lt;/sub&gt;&lt;/sub&gt; (ml/kg/min)</th>
<th>98%&lt;sub&gt;V&lt;sub&gt;T&lt;/sub&gt;&lt;/sub&gt; (mL/kg/min)</th>
<th>Watts&lt;sub&gt;avg&lt;/sub&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>152</td>
<td>12.5</td>
<td>0.90</td>
<td>48.3</td>
<td>49.8</td>
<td>242</td>
</tr>
<tr>
<td>2</td>
<td>146</td>
<td>13.4</td>
<td>0.82</td>
<td>41.3</td>
<td>42.6</td>
<td>211</td>
</tr>
<tr>
<td>3</td>
<td>144</td>
<td>15.8</td>
<td>0.84</td>
<td>50.0</td>
<td>51.6</td>
<td>217</td>
</tr>
<tr>
<td>4</td>
<td>154</td>
<td>14.1</td>
<td>0.87</td>
<td>51.3</td>
<td>52.8</td>
<td>227</td>
</tr>
<tr>
<td>5</td>
<td>161</td>
<td>15.0</td>
<td>0.91</td>
<td>48.9</td>
<td>51.4</td>
<td>266</td>
</tr>
<tr>
<td>6</td>
<td>164</td>
<td>12.9</td>
<td>0.94</td>
<td>49.8</td>
<td>51.3</td>
<td>220</td>
</tr>
<tr>
<td>Mean</td>
<td>153 (±8)</td>
<td>13.9 (±1.3)</td>
<td>0.86 (±0.04)</td>
<td>48.3 (±3.6)</td>
<td>49.9 (±3.7)</td>
<td>223 (±11.9)</td>
</tr>
</tbody>
</table>

HR<sub>avg</sub> = Heart rate average during trial. RPE<sub>avg</sub> = Rate of Perceived Exertion average during trial; RER<sub>avg</sub> = Respiratory Exchange Ration average during trial; Watts<sub>avg</sub> = average watts produced while exercising between 95-98% of V<sub>T</sub> during the 30 km trial 3.
CHAPTER V

DISCUSSION

The purpose of this study was to investigate the effects of a 10 km run and 30 km cycling time-trial on the final run performance during an ITU Duathlon. Specifically, the goal of this study was to improve upon previous ITU Duathlon simulation research by more effectively controlling for exercise intensity, resulting in a more accurately examination of the compounding effects of combined run, cycle efforts on final run performance. The primary findings of this study provided some interesting insight into the physiological response associated within an ITU Duathlon. While there was no change within the $V_T$ (%$\text{VO}_{2\text{max}}$) between Trial-1 and Trial-3, the decrease in $\text{VO}_{2\text{max}}$ from Trial-1 to Trial-3 approaches significance ($P=0.06$).

Before proceeding with any part of this discussion, it should be pointed out that this analysis is underpowered with only 6 subjects. Unfortunately, for the purpose of time and resources we were unable to test any additional subjects for this study, which was supposed to be completed with 8 subjects. While there were no significant results found amongst the stated hypotheses, there were several additional exploratory analyses performed which presented some interesting and applicable findings.

While there was no change in $V_T$ (%$\text{VO}_{2\text{max}}$), the downward trend in $\text{VO}_{2\text{max}}$ meant that a change in relative $\text{VO}_2$ (ml/kg/min) at $V_T$ did occur ($P=0.01$). This observation posed several interesting observations and offers increasingly applicable information to coaches and athletes alike. The change in running speed at $V_T$ between the two trials fell from 15.5 km/h during Trial-1 to 13.9 km/h during Trial-3. Ultimately, this decline in running speed would
result in an average increase of 2 min 14 sec to complete the final 5 km running leg of an ITU Duathlon race.

The results of the current study contradict the results of the only other similar study available in the current literature, performed by Vallier and colleagues in 2003. Vallier et al. (2003) investigated the variability in energy cost of running and an outdoor duathlon simulation. While they found no significant change in physiological parameters (such as metabolic and respiratory alterations) from the first run the last run, there are several limitations that may be explained by environmental factors and terrain.

While the duathlon and triathlon are separate events, consisting of different physical demands, both multi-sport events share similar qualities and require athletes to perform three endurance events in immediate and consecutive order. The compounding effects of the first two exercise bouts on the final run performance have become an increasingly popular subject within the research field. De Vito et al. (1995) conducted a triathlon simulation and did not find any significant difference in VO$_{2\text{max}}$ or $V_T\%\text{VO}_{2\text{max}}$ between the single-bout maximal exercise and triathlon simulation but did observe a difference in relative oxygen uptake (mL/kg/min) at $V_T$. Similar to Vallier et al., De Vito et al. also conducted the cycling time-trial outside on a closed loop circuit, thus raising similar concerns made about the methodology used by Vallier et al.

*Environmental Factors Influencing Performance in Triathlon and Duathlon races*

While performing these trials outside may add to the applicability to training and competition, the environmental factors and terrain associated with performing these trials outside limits the ability to adequately conclude that the first two bouts of a duathlon or
triathlon event do or do-not have an effect on the final run performance. When performing a cycling time-trial outside, the terrain may allow an individual to “rest” on certain sections of the course while maintaining speed (a downhill for example) while being able to exercise above their $V_T$ in shorter bouts on other sections of the course. Essentially, this would become an intermittent exercise bout which would have potentially alter the effects of the cycling bout on the subsequent run performance; additional information and discussion on this topic will be made later. Factors such as temperature, humidity, and pressure may also affect performance. For example, within a hyperthermic and/or a humid environment, the body will elicit an irregular thermoregulatory response in order to maintain core temperature. As exercise duration increases and temperature increases, the need to thermoregulate will result in various physiological responses observed through various cardiovascular, metabolic, respiratory, and endocrine responses. During exercise, the body thermoregulates through increasing blood flow to the skin and increasing sweat rate. Nevertheless, these responses result in a decreased blood flow to the working muscle and a loss of plasma volume. Elevated blood pressure during exercise will result in the increased filtration of plasma through the vascular space. Coupled with the loss of plasma through elevated sweat rate, this will result in a less venous return to the heart during exercise. In order to maintain cardiac output, HR must increase due to the decrease in stroke volume. In order to increase HR, the sympathetic nervous system will be stimulated and epinephrine release will increase. This increase in HR will create a desensitization of the adrenergic receptors resulting in a decreased contractility of the heart. Ventilation will also increase in an attempt to facilitate venous return through the action of the respiratory pump blood flow to working muscle will decrease at a given intensity – allowing for increased blood flow to the skin and increased
sweat rate. Additionally, the increased epinephrine (EPI) release over the course of time will have various metabolic consequences. Increased EPI will result in the increased stimulation of a muscle phosphorylase to breakdown glycogen into glucose 6 phosphate. Consequently, this will result in increased lactate production and a decrease in pH which will inhibit lipolysis and the mobilization of free fatty acids (FFA).

Through the interpretation of the data presented within the current study, the decrease in glycogen can be interpreted through the decline in maximal RER values and decrease in blood lactate following the treadmill VO$_{2\text{max}}$ tests in Trial-3 compared to Trial-1. There are several factors that could affect performance during a race simulation, some of which were discussed above, however, in order to combat these variables, the intensities throughout the 10 km run and 30 km cycling time trial were intensely monitored and controlled (Table 9). Performing the 10 km run and 30 km cycling time-trial at 95-98% of $V_T$ results in a depletion of glycogen stores.

The RER$_{\text{max}}$ and maximal blood lactate values observed during the treadmill max test in Trial-3 are indicative of this decrease. While each of these highly-trained athletes would utilize a higher concentration of fats for fuel when compared to an average individual, exercising at these intensities for 2+ hours will deplete glycogen stores regardless of fitness level.

Each of the subjects were instructed to prepare themselves for these sessions as though they would an actual competition and were required to consume a caloric beverage and/or food during Trial-3. Future research studies should also be directed toward developing a better dietary strategy during multi-sport endurance events such as the ITU Duathlon.
While each of these trials were performed in a thermo-neutral environment, it is important to note the potential effects of plasma volume lost through sweat. While blood pressure falls, anti-diuretic hormone (ADH) and aldosterone release will be stimulated in order to help maintain plasma volume. ADH is part of the hypothalamic pituitary adrenal system and is stimulated through decreases in blood volume (10-20%) (Brooks et al. 2005). Decreased blood volume signals the hypothalamus to signal the posterior pituitary to release ADH, increasing water reabsorption within the kidneys. This is important from a thermoregulative standpoint and because it helps to maintain stroke volume. Maintaining stroke volume means that cardiac output can be maintained and an individual can continue working at a particular intensity. Low sodium and high potassium also stimulate the secretion of aldosterone. Additionally, the kidneys release renin which reacts with angiotensinogen, forming angiotensin II and stimulating the release of aldosterone from the adrenal cortex. This results in the reabsorption of sodium and increased secretion of potassium.

*Sport Specific Factors Influencing Performance in Triathlon and Duathlon Races*

Coaches and athletes must cautiously interpret the results of the current study as one of the most important factors to affect performance within International Olympic Committee (IOC) events was the rule change to allow drafting during the cycling leg of certain triathlon and duathlon events. Specifically, drafting during a cycling event can result in up to 39% energy reduction (McCole et al. 1990). Similarly, drafting during the swimming bout has been shown to significantly reduce oxygen uptake, heart rate, and drag (Bassett et al. 1991). While the applicability of the current study is more in line with athletes competing in non-
draft legal races, it is important to consider the effects of drafting during competition and consider these effects when developing/considering race strategy.

Other factors to consider are the effects of cycling cadence on run performance (Bernard et al. 2003, Gottschall and Palmer 2000, Vercruyssen et al. 2002, Vercruyssen et al. 2005, Suriano et al. 2007), the effects of swimming on cycling performance (Delextrat et al. 2005), dietary/hydration strategy (McMurray et al. 2006), clothing (Trappe et al. 1996, Lowden et al. 1992) as well as race strategy (Lehenaff et al. 1998).

Gottschall and Palmer (2000) investigated the effects of a cycling bout on a subsequent run, finding that participants ran with a smaller stride length and higher stride frequency immediately following the cycle-run transition. As the run progressed, they observed a longer stride length and lower stride frequency. Vercruyssen et al. (2002) began their investigation into the effects of cycling cadence on run performance by investigating the effects of cycling cadence on the metabolic and kinematic parameters during a run following a cycling bout. In conclusion, Vercruyssen et al. (2002) found that both mechanically optimal cadence (90rpm) (Neptune and Hull, 1999) and freely chosen cadence resulted in an increased energy cost, whereas the lower economically chosen cadence resulted in a stable energy cost during a subsequent running bout. Vercruyssen et al. (2005) investigated various strategies associated with the cycle-run transition. Subjects elicited an improved maximal run time when performing the last minutes of a cycling bout at 20% less than their freely chosen cadence when compared to a cycling bout completed at their freely chosen cadence. Nevertheless, Vercruyssen et al. did not observe any variation in metabolic response or stride length during the subsequent run within any of their trials, suggesting that alternative mechanisms are responsible for the variability in maximal run time following a cycling bout.
Suriano et al. (2007) further expanded the exploration of cycling strategy on subsequent run performance by examining the effects of variable cycling power output on maximal run time – finding that variable power output during a 30 minutes cycling bout improved maximal run time.

In the current study, cadence was not controlled, however, an electronically braked cycle ergometer was used in order to control power output regardless of any change self-selected cadence throughout the trial. While a change in cadence throughout the trial could alter the oxygen uptake, the researchers assumed that maintaining a constant and steady power output was adequate for this particular study. Methodologically, this approach was used to control the intermittent nature of cycling bouts observed in DeVito et al. (1995) and Vallier et al. (2003) – a major limitation to each of these studies.

Study Limitations

It is important to note that there were several limitations to this study. The use of a cycle ergometer could have resulted in-optimal performance during either the cycle ergometer max test or the 30 km cycling time-trial performed in Trial-3. Ideally, subjects would have used their own bikes in order to allow each individual to exercise on the equipment and in the position that they train and compete. Similarly, it would have been advantageous to add controls for diet prior to and during the trial in order to rule out any effects of diet on glycogen availability, ultimately affecting performance. While each individual was asked to prepare for and complete Trial-3 as though the subject was preparing for an actual race, the variable diets between each individual may confound the observed results. Similarly, each individual’s training phase was not accounted for at the time of
recruitment. Each coach has his or her own training methodology and each methodology must be modified to best suit the individual athlete. Recruitment for this study spanned over a course of four months which would have certainly resulted in a variation of training phases between each subject.

While glycogen depletion has been discussed as the primary reason behind the observed decline in relative oxygen uptake at ventilatory threshold and downward trend in maximal oxygen uptake, this could be confirmed by performing blood draws throughout the trials in order to quantify glucose uptake.

In conclusion, this study did not result in any significant findings in either of the listed hypotheses, however, a downward trend in VO$_{2\text{max}}$ and a significant decrease in relative VO$_2$ at ventilatory threshold during a maximal treadmill test following a 10 km run and 30 km cycling time-trial compared to a lone single-bout maximal treadmill protocol was observed. These findings suggest that an individual cannot perform the final 5 km run during an ITU Duathlon at the same intensity at which one performs the initial 10 km run. One key physiological factor associated with this includes, but is not limited to glycogen depletion.

**Recommendations for Future Research**

While none of these studies have focused specifically on the ITU Duathlon, each of these studies pose interesting questions related to race strategy and duathlon performance. Future research should also begin to investigate:

- **Cadence** – The specific effects of cadence on run performance, including both the effects of marinating a steady cadence and intermittent cadence
- *Nutrition and Diet* – Future research should not only control for diet during similar studies, but also examine the effects of various dietary strategies both before and during competition.

- *Training Phases* – Future research should attempt to control for the current training phase of each athlete in order to try and control for the current fitness level of each individual and the type of training they have been performing in recent weeks. Ideally, subjects would be tested as they peak for competition.

- *Equipment* – Specifically, the cycle ergometer was a major limitation to this study as the variation in bike fit between the cycle ergometer and each athlete’s personal bike could limit performance and efficiency throughout the trials.

- *Sample Size* – Unfortunately, time and resources limited the results of this study. Future research should aim to include a larger sample size in order to increase power.
APPENDIX I

Examination status:  Approved Disapproved

Department of Exercise & Sport Science
Physical Examination Screening

Name: ______________________  ID: _________  Age: _______  Gender: ____________

Please respond to each of the following in writing.

Pulse rate and regularity: _______________  ECG Interpretation: _______________

Blood Pressure:
   Supine: _______  Sitting: _____________  Standing (Left side): _______
   Squat: ___________  Standing (Right side): ___________

Marfan Syndrome evaluation: (Δ BP, Physical Char.) __________________________

Palpation of Pulses:
   Carotid: ___________  Radial: ___________  Pedal: ___________

Auscultation of the Lungs:
   Back:  Lower: ___________  Middle: ___________  Upper: ___________
   Front:  Middle: ___________  Upper: ___________

Auscultation of Heart Sounds:(Supine, Standing, Squatting)
   Non-Specific HS: _____ / _____ / _____
   Murmur: _____  Gallop: _____ Click: _____ Rub: _____  Click w/ Murmur: _____

Bruits:
   Carotid: ___________  Abdominal: ___________

Edema:
   Abdominal: _______  Calf: ___________  Pedal: ___________
Tenderness: Abdominal: __________  Other: __________

Xanthoma or xanthelasm: __________

Medical / Family History:

   High Blood Pressure: _____  Diabetes: _______  CHD/CAD: __________

   Last examination w/ physician: __________

   Medications (prescription / counter): ________________________________

Examiner: ________________________________  Date: __________________
PAR-Q & YOU
(A Questionnaire for People Aged 15 to 69)

Regular physical activity is fun and healthy, and increasingly more people are starting to become more active every day. Being more active is very safe for most people. However, some people should check with their doctor before they start becoming more physically active.

If you are planning to become much more physically active than you are now, start by answering the seven questions in the box below. If you are between the ages of 15 and 69, the PAR-Q will tell you if you should check with your doctor before you start. If you are over 69 years of age, and you are not used to being very active, check with your doctor.

Common sense is your best guide when you answer these questions. Please read the questions carefully and answer each one honestly: check YES or NO.

YES NO
☐ ☐ 1. Has your doctor ever said that you have a heart condition and that you should only do physical activity recommended by a doctor?
☐ ☐ 2. Do you feel pain in your chest when you do physical activity?
☐ ☐ 3. In the past month, have you had chest pain when you were not doing physical activity?
☐ ☐ 4. Do you lose your balance because of dizziness or do you ever lose consciousness?
☐ ☐ 5. Do you have a bone or joint problem (for example, back, knee or hip) that could be made worse by a change in your physical activity?
☐ ☐ 6. Is your doctor currently prescribing drugs (for example, water pills) for your blood pressure or heart condition?
☐ ☐ 7. Do you know of any other reason why you should not do physical activity?

If you answered YES to one or more questions
Talk with your doctor by phone or in person BEFORE you start becoming much more physically active or BEFORE you have a fitness appraisal. Tell your doctor about the PAR-Q and which questions you answered YES.

• You may be able to do any activity you want — as long as you start slowly and build up gradually. Or you may need to restrict your activities to those which are safe for you. Talk with your doctor about the kind of activities you wish to participate in and follow his/her advice.
• Find out which community programs are safe and helpful for you.

If you answered NO to all questions

DELAY BECOMING MUCH MORE ACTIVE:
• If you are not feeling well because of a temporary illness such as a cold or a fever — wait until you feel better; or
• If you are or may be pregnant — talk to your doctor before you start becoming more active.

PLEASE NOTE: If your health changes so that you then answer YES to any of the above questions, tell your fitness or health professional. Ask whether you should change your physical activity plan.

No changes permitted. You are encouraged to photocopy the PAR-Q but only if you use the entire form.

I have read, understood and competed this questionnaire. Any questions I had were answered to my full satisfaction.

NAME ____________________________ SIGNATURE ____________________________ DATE ____________________________

SIGNATURE OF PARENT ____________________________ DATE ____________________________

Note: This physical activity clearance is valid for a maximum of 12 months from the date it is completed and becomes invalid if your condition changes so that you would answer YES to any of the seven questions.
Get Active Your Way. Every Day—For Life!

Safest way to accumulate 60 minutes of physical activity every day is to do moderate activity 3 days a week, add 2 days of vigorous activity. As you progress to moderate activities you can cut down to 10 minutes, 4 days a week. And it’s okay to have some in portion of at least 10 minutes each. Start slowly and build-up.

Time needed depends on effort

Endurance

Moderate effort

Vigorous effort

Strength

- Walking
- Jogging
- Bicycling
- Mowing the lawn
- Cleaning the house
- Lifting 30-lb weight
- Lifting 50-lb weight

-2 1/2 1/2
-4 2 1/2
-6 1 1/2
-7 7 1/2

- 15 15 1/2
- 20 20 1/2
- 25 25 1/2
- 30 30 1/2

-1 1/2
-2

- 0.5 0.5
- 1 1

-2.5 2.5
-5 5

Sitting is very safe for most people. Not much stress on your health professionals.

A close of the Guide backdrop and more Information: 8-888-839-3194 or www.saguide.ca

Fitness and Health Professionals may be interested in the information below:

The following companion forms are available for doctors use by contacting the Canadian Society for Exercise Physiology (address below):

The Physical Activity Readiness Medical Examination (PARmed-X) – to be used by doctors with people who answer YES to one or more questions on the PAR-Q

The Physical Activity Readiness Medical Examination for Pregnancy (PARmed-X for Pregnancy) – to be used by doctors with pregnant patients who wish to become more active.

References:


For more information, please contact the:

Canadian Society for Exercise Physiology

202-185 Somerset Street West

Ottawa, ON K2P 0Z

Tel: 1-877-651-3755 • Fax (613) 234-3565

Online: www.csep.ca

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Supported by: Health Canada

Sante Canada

The original PAR-Q was developed by the British Columbia Ministry of Health. It has been revised by an Expert Advisory Committee of the Canadian Society for Exercise Physiology chaired by Dr. N. Geelhuij (2002).

APPENDIX III

Department of Exercise and Sport Science
Medical History

Subject:__________________________ ID: ___________ Telephone:______________

Address:________________________________________________________________________

Occupation:__________________________ Age:________________________

YES   NO

Patient History
1. How would you describe your general health at present? 
   Excellent_____ Good_____ Fair_____ Poor_____
2. Do you have any health problems at the present time? ______
3. If yes, please describe:________________________________________________________________________
4. Have you ever been told you have heart trouble? ______
5. If yes, please describe:________________________________________________________________________
6. Do you ever get pain in your chest? ______
7. Do you ever feel light-headed or have you ever fainted? ______
8. If yes, please describe:________________________________________________________________________
9. Have you ever been told that your blood pressure has been elevated? ______
10. If yes, please describe:________________________________________________________________________
11. Have you ever had difficulty breathing either at rest or with exertion? ______
   12. If yes, please describe:________________________________________________________________________
13. Are you now, or have you been in the past 5 years, under a doctor’s care for any reason? ______
   14. If yes for what reason?________________________________________________________________________
15. Have you been in the hospital in the past 5 years? ______
   16. If yes, for what reason?________________________________________________________________________
17. Have you ever experienced an epileptic seizure or been informed that you have epilepsy? ______
18. Have you ever been treated for infectious mononucleosis, hepatitis, pneumonia, or another infectious disease during the past year? ______
   19. If yes, name the disease:________________________________________________________________________
20. Have you ever been treated for or told you might have diabetes? ______
21. Have you ever been treated for or told you might or low blood sugar? ______
22. Do you have any known allergies? ______
23. If so, what?

24. Have you ever been “knocked-out” or experienced a concussion? _____ _____
25. If yes, have you been “knocked-out” more than once? _____ _____
26. Have you ever experienced heat stroke or heat exhaustion? _____ _____
27. If yes, when? __________________________________________

28. Have you ever had any additional illnesses or operations? (Other than childhood diseases)
29. If yes, please indicate specific illness or operations:________________________

30. Are you now taking any pills or medications? _____ _____
31. If yes, please list:_________________________________________

32. Have you had any recent (within 1 year) difficulties with your:
   a. Feet _____ _____
   b. Legs _____ _____
   c. Back _____ _____

Family History
33. Has anyone in your family (grandparent, father, mother, and/or sibling) experienced any of the following?
   a. Sudden death _____ _____
   b. Cardiac disease _____ _____
   c. Marfan’s syndrome _____ _____

Mental History
34. Have you ever experienced depression? _____ _____
35. If yes, did you seek the advice of a doctor? _____ _____
36. Have you ever been told you have or has a doctor diagnosed you with panic disorder, obsessive-compulsive disorder, clinical depression, bipolar disorder, or any other psychological disease? _____ _____
37. If yes, please list condition and if you are currently taking any medication.
   Condition ________ Medication ________

Bone and Joint History
34. Have you ever been treated for Osgood-Schlatter’s disease? _____ _____
35. Have you ever had any injury to your neck involving nerves or vertebrae? _____ _____
36. Have you ever had a shoulder dislocation, separation, or other injury of the shoulder that incapacitated you for a week or longer? _____ _____
37. Have you ever been advised to or have you had surgery to correct a shoulder condition? _____ _____
38. Have you ever experienced any injury to your arms, elbows, or wrists? _____ _____
39. If yes, indicate location and type of injury: ________________________________

40. Do you experience pain in your back? _____ _____
41. Have you ever had an injury to your back? _____ _____
42. If yes, did you seek the advice of a doctor? _____ _____
43. Have you ever been told that you injured the ligaments or cartilage of either knee joint? _____ _____
44. Do you think you have a trick knee? _____ _____
45. Do you have a pin, screw, or plate somewhere in your body as the result of bone or joint surgery that presently limits your physical capacity? _____ _____
46. If yes, indicate where: ________________________________

47. Have you ever had a bone graft or spinal fusion? _____ _____

Activity History
48. During your early childhood (to age 12) would you say you were:
   Very active _____ Quite active_____ Moderately active_____ Seldom active_____
49. During your adolescent years (age 13-18) would you say you were:
   Very active _____ Quite active_____ Moderately active_____ Seldom active_____
50. Did you participate in:
   a. Intramural school sports? _____ _____
   b. Community sponsored sports? _____ _____
   c. Varsity school sports? _____ _____
   d. Active family recreation? _____ _____
51. Since leaving high school, how active have you been?
   Very active _____ Quite active_____ Active_____ Inactive_____  
52. Do you participate in any vigorous activity at present? _____ _____
53. If yes, please list:
   Activity | Frequency | Duration | Intensity
   __________________________________________
   __________________________________________

54. How would you describe your present state of fitness?
   Excellent_____ Good_____ Fair_____ Poor_____
55. Please list the type(s) of work you have been doing for the previous ten years:
   Year | Work | Indoor/Outdoor | Location (city/state)
   __________________________________________
   __________________________________________
   __________________________________________

56. Whom shall we notify in case of emergency?
   Name: __________________________________________
   Phone: (Home)______________________ (Work)______________________
Address:______________________________________________________________

57. Name and address of personal physician:________________________________
______________________________________________________________

All of the above questions have been answered completely and truthfully to the best of my knowledge.

Signature:________________________________________ Date:________
APPENDIX IV

BASELINE MEASUREMENTS/TRAINING HISTORY QUESTIONNAIRE

Subject ID: _____________________________

DEMOGRAPHICS & ANTHROPOMETRICS

Age: _____________ years
Height: ______________ cm Body Mass: ____________ kg

EATING & SLEEPING PATTERNS

Normal Bed Time: ______________ AM / PM
Normal # Hours of Sleep: ______________
Normal # Meals per Day: ______________

TRAINING HISTORY

1) In the past six months, how many hours per week (on average) have you swum?
   < 1  2-3  4-6  7+
   Estimation____________

2) In the past six months, how many hours per week (on average) have you cycled?
   < 4  5-7  8-10  11+
   Estimation____________

3) In the past six months, how many hours per week (on average) have you run?
   < 3  4-5  5-7  8+
   Estimation____________

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APPENDIX V

THE UNIVERSITY OF NORTH CAROLINA AT CHAPEL HILL
Claudio Battaglini, Ph.D.
Department of Exercise and Sport Sciences
125 Fetzer Gym, CB # 8700
(919) 843-6045 / Email: Claudio@email.unc.edu

Pre-Test Guidelines

1. No eating 4 hours prior to testing.
2. Void completely before testing.
3. Maintain proper hydration prior to testing.
4. Please wear appropriate clothing/shoes for testing (running shorts/shirt/shoes)
5. No exercise 12 hours prior to testing.
6. No alcohol consumption 48 hours prior to testing.
7. No diuretic medications 7 days prior to testing.

Source: Advanced Fitness Assessment and Exercise Prescription – Third Edition – Vivian H. Heyward
APPENDIX VI

PRE-TRIAL TESTING QUESTIONNAIRE

TRIAL-1 | TRIAL-2 | TRIAL-3

SUBJECT ID: __________________

DATE: ________________ TIME: ________________ AM / PM

EATING AND SLEEPING PATTERNS

BEDTIME: ________________ AM / PM

HOURS OF SLEEP: ________________

LAST MEAL: ________________ AM / PM

NUMBER OF MEALS TODAY: ________________

PHYSICAL ACTIVITY PREPAREDNESS

PERCEIVED FATIGUE: (none) 0 1 2 3 4 5 (wanting to sleep)

MUSCLE SORENESS: (none) 0 1 2 3 4 5 (unbearable)

SPECIFIC GRAVITY EVALUATION: ________________
REFERENCES:


