Physiological responses to various durations and intensities of warmup

Susan J. Hanson
University of Nebraska at Omaha

PHYSIOLOGICAL RESPONSES TO VARIOUS DURATIONS AND INTENSITIES OF WARMUP

A Thesis

Presented to the

School of Health, Physical Education and Recreation

and the

Faculty of the Graduate College

of the

University of Nebraska

In Partial Fulfillment

of the Requirements for the Degree

Master of Science

University of Nebraska at Omaha

by

Susan J. Hanson

April 1996

THESIS ACCEPTANCE

Acceptance for the faculty of the Graduate College,
University of Nebraska, in partial fulfillment of the
requirements for the degree Masters of Science,
University of Nebraska at Omaha

Committee

Name	Department/School
William A. deGraw	Biology
Richard D. Latin	HPER

Chairperson Kris Berg

Date 4/10/96

ABSTRACT

Warmup has been a general practice for most athletes to engage in prior to a practice or competitive race. However, there has been little scientific evidence, specifically for the endurance athlete concerning the appropriate duration, intensity, or a combination of duration and intensity needed to enhance performance. Therefore, the purpose of this study was to determine how different combinations of durations and intensities of warmup affect heart rate (HR), lactic acid (LA), minute ventilation (VE), respiratory exchange ratio (R) and rating of perceived exertion (RPE) during a 5 minute treadmill run at 80% VO_2 max. Subjects included four male and four female trained (male mean VO_2 max = 55.3; female mean VO_2 max = 48.6) endurance athletes (mean age = 30.6 yr, SD = $\pm$ 4.4). Subjects randomly participated in one of the warmup conditions, followed by a 5 minute run at 80% VO_2 max. The four warmup conditions were low intensity, short duration (LISD), low intensity, long duration (LILD), high intensity, short duration (HISD) and high intensity, long duration (HILD). The low and high intensities were set at 40% VO_2 max and 80% VO_2 max, and the short and long durations were set at 5 and 20 minutes, respectively. Results of the 2 x 2 ANOVA showed significant ($p<.01$) main effects for duration for RPE, with 20 minutes significantly higher than 5 minutes, and intensity for HR ($p<.01$), with 70% VO_2 max significantly greater than 40% VO_2 max. There was no significance found

for LA, R and VE. The omega squared analysis showed that for RPE and HR 68.7% and 39.6% of the variance among the conditions was due to the duration and intensity of the warmup, respectively. In summary, no particular warmup produced optimal effects on all of the physiological factors associated with performance. Therefore, it is recommended that warmup within the range of 40% to 70% VO_2 max for 5 or 20 minutes produced equivalent effects for most of the physiological variables studied.

ACKNOWLEDGMENTS

I would like to thank all of my committee members for all of their hard work and assistance to me during this past year. I would like to especially thank Dr. Berg for being my advisor and committee chair, for without him I wouldn't be where I am today. I would also like to thank my fellow graduate assistants for all of their time, patience, encouragement, and most of all for not complaining when I needed their help on numerous occasions to collect data.

I would also like to thank my family for all of their support and encouragement. I know I am a better person for having such a great family behind me. Finally, I would like to thank my wonderful husband Mitchell. He has been there every step of the way with me, even through the stressful times. I am forever grateful for his love and support.

TABLE OF CONTENTS

Chapter I

Introduction

Warmup has been a general practice for most coaches and athletes to engage in prior to a practice or competitive race. However, for endurance athletes, there has been little scientific evidence to the appropriate duration, intensity, or combination of duration and intensity that is needed in order for the warmup to enhance performance, which is the primary objective many runners. Warmup by an athlete is usually based on either prior experience or the latest techniques Olympic athletes are using.

In 1991 the American College of Sports Medicine (ACSM) recommended that a warmup should last between five and ten minutes at the appropriate intensity for the individual. However, in the 1995 edition, ACSM offered no recommendations for warmup. McArdle, Katch and Katch (1991) have recommended that the warmup should be individualized to the specific needs of the athlete; however, no specific guidelines are given for reference. Due to the limited recommendations, many researchers have investigated the effects of warmup. Most studies investigating the effects of warmup used relatively short test distances ranging from 8 pedal revolutions for cycling (Skubic & Hodgkins, 1957), a 30 yd sprint for swimming (Thompson, 1958) to a 50 yd dash for running (Hipple, 1951). Across many studies, the longest test distances used were a one mile run (Grodjinovsky & Magel, 1970) and a 40 minute run at 67% VO_2 max (Hetzler, Knowlton, Kaminsky & Kamimori, 1986).

Warmup has been shown to increase muscle temperature, thus decreasing intramuscular resistance, increasing range of motion, increasing circulation, increasing oxygen availability, thus delaying fatigue, and increasing speed of contraction and relaxation (Miller, 1951). Barcroft and King (1909) found that warmup caused a shift in the oxygen dissociation curve, resulting in a greater oxygen extraction at the same PO_2. Also, warmup has been shown to allow individuals to achieve a higher level of aerobic metabolism more quickly (Gutin, Stewart, Lewis & Kruper, 1976; Andzel, 1978) and eliminate ECG ischemic responses during high intensity exercise (Barnard, Gardner, Diaco, MacAlpin & Kattus, 1973a). Warmup may further affect the fat utilization during exercise and decrease lactate production (Hetzler et al., 1986).

Warmup has been investigated in cycling, swimming and running studies, with a variety of durations, intensities, and results. In cycling studies, Skubic and Hodgkins (1957), Karpovich and Hale (1956) and Massey, Johnson and Kramer (1960) all found a nonsignificant difference in performance due to warmup. However, Gutin et al. (1976) and Robergs et al. (1991) found significant enhancement in physiological responses in cycling due to warmup. Reasons for discrepancies in cycling studies finding no significance for warmup may include overly short warmups or rest intervals between the warmup and test condition that were too long.

In swimming, Muido (1946), Carlile (1956), deVries (1957) and Thompson (1958) found significant enhancement in performance due to warmup. In contrast, Robergs et al. (1990) found no significant difference in swimming performance due to warmup. However, Houmard et al.(1991) and Mitchell and Huston (1993) found significant increases in HR, but nonsignificant differences in VO_2 max.

Significant enhancement in performance in running studies include studies by Blank (1955), Grodjinovsky and Magel (1970) and Andzel (1978). Matthews and Snyder (1958), Hipple (1955) and Andzel and Busuttil (1982) found no significant difference in performance due to warmup. The range of times for warmup in the running studies showing significance was 5-18 minutes, with a mean warmup time of 9.6 minutes.

Most studies that found significant differences, whether cycling, swimming, or running, used relatively short criterion performance tests. Few studies have examined the influence of various warmup combinations of intensity and duration. Also, only until recently, performance has been used as the only dependent variable, and only one study (Houmard et al., 1991) has yet to examine perceived exertion in relation to the influence of warmup. Therefore, the purpose of this study was to determine how different combinations of durations and intensities of warmup affect the physiological variables such as heart rate (HR), blood lactate levels (LA), minute ventilation (VE), respiratory exchange ratio (R) and ratings of perceived exertion (RPE) during a treadmill run foe 5 minutes at 80% VO_2 max.

Chapter II

The Problem

Purpose

The purpose of this study was to determine how different combinations of durations and intensities of warmup affect heart rate (HR), blood lactate levels (LA), minute ventilation (VE), respiratory exchange ratio (R) and ratings of perceived exertion (RPE) during a treadmill endurance run at 80% VO_2 max.

Hypotheses

The following hypotheses were tested:

1. The low intensity, long duration warmup (LILD) will produce optimal effects on the physiological variables associated with warmup on endurance runners compared to the high intensity, short duration warmup (HISD), high intensity, long duration warmup (HILD) and the low intensity, short duration warmup (LISD).
2. The HISD will produce the next best effects on the physiological variables associated with warmup on endurance runners compared to the HILD warmup and LISD warmup.
3. The HILD warmup will produce adverse effects on the physiological variables associated with warmup on endurance runners.

4. The LISD warmup will not be able to produce sufficient responses on the physiological variables associated with warmup to cause an impact for endurance runners.

Delimitations

Subjects consisted of four female and four male distance runners from the Omaha, Nebraska area. Subjects ranged in age from 24 to 35 years. Subjects were required to run an average of 25 miles per week in the previous 4 months and a 10 km time $\leq$ 50 minutes. Also, subjects were actively competing in road races in the previous six months.

Limitations

A limitation to this study was the adherence of the subjects to not engage in intense exercise the day before and the day of testing. Also, compliance of the subjects regarding the dietary guidelines of no food intake prior to testing may have been a limitation.

Definition of Terms

For clarity, the following terms are defined.

Oxygen Uptake: The rate at which oxygen can be consumed per minute.

Maximal Oxygen Uptake: The maximum rate at which oxygen can be consumed per minute; the power or capacity of the aerobic or oxygen system. This provides a quantitative index of an individual's aerobic capacity and is expressed in ml/kg/min.

Respiratory Exchange Ratio: The respiratory exchange ratio indicates the ratio of the amount of carbon dioxide produced to the amount of oxygen consumed; provides an index as to the percentage of energy being oxidized from fat and carbohydrate.

Lactic Acid: A metabolite resulting from the incomplete breakdown of glucose.

Minute Ventilation: The volume of air expired per minute.

Ratings of Perceived Exertion: A 15 point scale from 6 to 20 with verbal descriptions at the odd numbers. The ratings are well correlated with VO_2, HR, VE and blood lactate.

Significance of the Study

The practice of warming up is a very common habit among competitive as well as recreational athletes; however, there are very few guidelines regarding duration and intensity. The ACSM provides no guidelines for warmup in the new 1995 edition and only general guidelines in their 1991 edition without supporting documentation. Research about the effect of various durations and intensities on the physiological parameters associated with distance running is lacking. Therefore, further investigation of warmup is warranted. The information and observations obtained from this study may give runners and coaches guidelines for warmup that may enhance performance and comfort.

Chapter III

Review of Literature

Many theoretical benefits of warmup exist, such as injury prevention, decreased muscle viscosity, increased muscle elasticity and increased blood circulation. However, there is little evidence identifying the appropriate duration and intensity of warmup that exists for the endurance athlete. Consequently, few specific recommendations can be made. The review of literature will address these issues and provide general information about the topic.

Recommendations for Warmup

There are very few recommendations for the appropriate amount of warmup needed prior to a recreational activity or competitive race. The American College of Sports Medicine (ACSM) (1991) has recommended that an exercise session should include a warmup of 5 to 10 minutes in duration. The warmup may include walking or slow jogging, light stretching, and calisthenics. The ACSM (1991) has also stated that the duration and intensity of the warmup period depends on environmental conditions, functional capacity, symptomatology and preferences of the participant.

McArdle, Katch and Katch (1991) suggested that the warmup should be gradual without producing fatigue. However, they identified no specific duration or intensity for the warmup. They considered warmup to be individualized and that it should mimic the activity through a full range of motion (ROM). Also, they suggested that the activity the participant was warming up for should begin within several minutes after the warmup period in order to receive the greatest benefits from the increase in body temperature.

Types of Warmup

Warmup has been classified as either general or specific. General or informal warmup has included exercises such as calisthenics or stretching unrelated to the activity. Specific or formal warmup includes exercises that are related to the activity, which should provide a type of skill rehearsal. Some examples of specific warmup include throwing a baseball before a game and shooting a basketball before a game.

Warmup may also be classified as active or passive warmup. Active warmup is considered to be any type of exercise, such as calisthenics or walking, in which the body is actually moved in order to raise the body temperature. Passive warmup is used to raise the body temperature through an outside or external means, such as heating pads or hot showers. Karpovich & Hale (1953) used heating pads and hot showers as a means of warmup, although they included these methods under the category of general warmup and did not formally introduce them as passive warmup. Active formal warmup has been suggested to be more beneficial than general or passive warmup (Thompson, 1958; McArdle Katch & Katch, 1991; Shellock, 1983). Most researchers consider active warmup as the most effective type of warmup (Thompson, 1958; McArdle, Katch & Katch, 1991; Shellock, 1983).

Injury Prevention

Bixler and Jones (1992) studied high school football players and the effects of post half-time warmup and stretching routines on injury rates. They felt that fatigue and lack of an adequate warmup and stretching routine may be two of the underlying reasons for injuries seen in these athletes. The study observed five high school football teams during the course of the regular season. During this season, two teams conducted their usual half-time activities, while three teams participated in a three minute routine of warmup and stretching at the end of the half-time break. The results of the study showed that the warmup and stretching significantly ($p<.05$) reduced certain types of third quarter injuries, such as ligament sprains and muscle strains. Moreover, ligament sprains and muscle strains are the most commonly seen injury in the third quarter of high school football games (Bixler & Jones, 1992). An adequate warmup not only reduces injuries to muscles and ligaments, but also to tendons and other connective tissue, due to the increased tissue elasticity, which is temperature dependent. Therefore, athletes are urged to stretch only after warming up (Shellock, 1983).

Physiological Mechanisms

The benefits of warmup may be attributed to several physiological mechanisms including increased range of motion in the joints, increased circulation, increased body and muscle temperature, and neural facilitation (Rochelle, Skubic & Michael, 1960; Miller, 1951). Miller (1951) suggested four advantages of warming up, which include: 1) greater safety, 2) increased physiological economy, 3) improved mental readiness, and 4) more effective coordination. Warmup not only prepares the muscle for the upcoming activity, but also reduces the chance for injury. The facilitating effects of warmup are produced by increasing blood flow to selected tissues which also raises intramuscular temperature. Increasing intramuscular temperature decreases intramuscular resistance and provides an increase in the availability of oxygen to the muscle, delaying the onset of fatigue. Warming up before competition aids in relieving the body of tension, especially before competition. Also, warmup benefits intramuscular coordination and reminding the body of the appropriate neuromuscular responses (Miller, 1951).

McArdle, Katch and Katch (1991) suggested several physiological benefits of warmup: 1) increased speed of contraction and relaxation of muscles, 2) greater mechanical efficiency because of lowered viscous resistance within the muscles, 3) facilitated oxygen utilization by the muscles because hemoglobin releases oxygen more readily at higher temperatures, 4) facilitated nerve transmission and muscle metabolism at higher temperatures, and 5) increased blood flow through active tissues due to higher temperatures causing an increase in vascular dilation.

Most researchers used to believe that the rise in body temperature was a sign of an impaired heat regulation within the body. Asmussen and Boje (1945) showed that the importance in the amount of work that could be performed was mainly due to a higher muscle temperature. The muscle temperature was thought to improve performance considerably. Mechanically, a higher temperature in the working muscles may be an advantage by influencing the viscous and elastic properties which results in a reduced oxygen cost. Also, performance and even a higher oxygen uptake may be enhanced through the more rapid movement of the muscles (Asmussen & Boje, 1945). Also, it was thought that with a higher muscle temperature, less energy may be lost and more energy may be utilized to perform external activities (Andzel, 1987; Asmussen & Boje, 1945). When muscles are warm, a higher VO_2 max may be elicited as compared to when the muscles are cold (Asmussen & Boje, 1945). Temperature also affects the dissociation curve of hemoglobin, so that more oxygen is extracted at a constant PO_2 (Barcroft & King, 1909).

Warmup allows reaching a higher level of aerobic metabolism more quickly, thus producing a mobilizing effect and enhancing the performance of the endurance activity

(Gutin et al., 1976; Andzel, 1978). By producing a mobilization effect, the initial oxygen deficit is reduced, and the subject will be allowed to start the endurance task with a higher heart rate, oxygen consumption, ventilation and oxygen pulse (Andzel & Gutin, 1976; Gutin, et al., 1976). The warmup phenomenon has been attributed to a reduction of regional myocardial oxygen consumption, which is not caused by changes in the systemic hemodynamic variables (Okazaki et al., 1993).

Barnard et al. (1973a) studied six healthy men who were firemen in Los Angeles, California, ranging in age from 21 to 52 years old. Subjects performed a strenuous treadmill test with and without a warmup. In more than half the subjects, the effect of warmup on blood pressure (BP) and electrocardiogram (ECG) recordings showed completely normal ECG responses. However, warmup had little effect on diastolic blood pressure (DBP). They concluded that warmup performed immediately before or 10 to 15 minutes prior to the sudden burst of high intensity exercise can eliminate or reduce the ischemic ECG response (Barnard, Gardner et al., 1973a). Similar results were seen in a similar study by Barnard, MacAlpin, Kattus & Buckberg (1973b).

Barnard et al. (1973b) investigated the Los Angeles, California firemen with university students performing a criterion task with and without prior exercise. The criterion test without warmup consisted of running 20 s at 10 mph at 24% grade. Once blood pressure was at resting level, subjects performed a multistage treadmill test. Subjects ran for 2 minutes at each workload until a max HR was attained. Twenty minutes after the test, the men ran 20 s at 10 mph at 24% grade again. The ECG results showed six abnormal ECGs with three ST Segment Depression and three with minor ST and T wave changes. However, following a warmup eight subjects had a normal ECG, while only two had minor ST and T wave changes. The HR was significantly ($p<.05$) higher (164.8 bpm) with warmup as compared to when no warmup (158.3 bpm) was used. The findings were similar to those of Barnard, Gardner et al. (1973a) such that warmup preceding sudden exertion reduces ischemic ECG responses.

Warmup and Cycling Performance

A summary of the studies regarding warmup and cycling performance can be found in Table 1. Skubic and Hodgkins (1957) investigated the difference between a cycle ergometer speed test when it was preceded by either no warmup, a general warmup of jumping jacks, or a specific warmup consisting of a cycle ergometer ride of eight revolutions at a modest speed. The test consisted riding one tenth of a mile as fast as possible. The results showed a slight, but nonsignificant tendency toward better scores with the related warmup. The warmup was relatively light and of a very short duration, which may have affected the results.

Table 1

Warmup and Cycling Performance

Study	Subjects	Warmup	Test Distance	Results	Comments
Skubic & Hodgkins (1957)	31 F collegiate volunteers	1. no warmup 2. jumping jacks 3. 8 rev cycle ride	cycle 1/10 mile as fast as possible	NSD	Low I, short D warmup to cause any effect on performance
Karpovich & Hale (1956)	7 volunteers	1. no warmup 2. cycle at 60 rpm @ 5.5# for 5 min	cycle 35 pedal rev. as fast as possible	NSD	Short D warmup to cause any effect on performance
Massey et al. (1960)	15 M volunteers	1. no warmup 2. jogging, running & hopping on one foot 7 min. under hypnosis	cycle 100 rev. as fast as possible	NSD	Did not use cycle warmup with cycle test; warmup psychological
Gutin et al. (1976)	6 M volunteers	1. no warmup 2. cycle at 60 rpm @ HR of 140 bpm for 10 min.	cycle at 68 rpm @ 4 kg for 2 min.	sig ($p<.05$) inc. in HR, VE & VO2	Mobilization effect produced, dec. initial oxygen deficit
DeBruyn-Prevost (1980)	1. 7 M/F Phys. Ed. students 2. 6 M/F Phys. Ed. students	1. cycle 5 or 20 min. @ HR's 105, 120 & 135 (bpm) with no RI 2. cycle 5 or 20 min. @ HR's 105, 120 & 135 (bpm) with 5 or 10 min. RI	working capacity of 170 (WC170) for 5 min. of cycling	1. VO2 & HR values inc., LA dec., but not sig after 4th min 2. VO2, HR values NSD, LA dec. throughout, but not sig.	Possibly too short (o min) or too long (5 & 10 min.) of RI, so can't show warmup was effective
Robergs et al. (1991)	6 M active volunteers	1. no warmup 2. cycle at 60% VO2max 10 min. with 1 min. RI, plus 4, 30 s at 100% PO2max with 15 min. RI	sprint ride for 2 min. at 120% PO2max	sig. ($p<.05$) dec. in LA; NSD in VO2, RER & VE	LA dec. due to the intense warmup thus increasing oxidative metabolism

M = male; F = female
I = intensity; D = duration
rev. = revolutions; # = pounds
sig. = significance; NSD = nonsignificant difference
RI = rest intervals

HR = heart rate; LA = lactic acid
VE = ventilation exchange
VO2 = oxygen consumption
RER = respiratory exchange ratio

Karpovich and Hale (1956) studied the effect of warmup on physical performance. Subjects cycled at 60 rpm for 5 minutes with a load of 5.5 pounds. The test consisted of riding for 35 pedal revolutions in the shortest amount of time possible. Warming up did not significantly enhance performance. The results were in agreement with those of Skubic and Hodgkins (1957), who also used a short duration of warmup.

Massey et al. (1960) tested the effect of warmup consisting of jogging, running and hopping in one position alternately for seven minutes. The test consisted of riding a cycle ergometer for 100 revolutions as fast as possible. Hypnosis was used to control the psychological variables thought to be associated with warmup. However, they used walking, jogging and hopping exercises for warmup, even though a cycle test was performed. They found no significant enhancement in performance due to warmup just like Skubic and Hodgkins (1957) and Karpovich and Hale (1956). However, since psychological variables were controlled, the researchers concluded that it would seem that warmup was primarily of psychological value.

Gutin, et al. (1976) studied oxygen consumption in the first stages of strenuous work as a function of prior exercise. The warmup and criterion task (CT) were performed on a Monark cycle ergometer. The duration of the warmup was 10 minutes of pedaling at 60 rpm with increasing resistance to a HR of 140 bpm. The criterion task consisted of pedaling 68 rpm at 4 kg for 2 minutes. VO_2 was significantly ($p<.05$) higher under every stage with warmup except the 30 s period of the criterion task and 60 s recovery period. VE was also significantly ($p<.05$) higher following warmup at every stage except the last 30 s and 60 s of post exercise. Heart rate was significantly higher ($p<.05$) at every stage of the criterion task and during recovery. Warmup shortened the adjustment period to exercise, thus producing a mobilization effect and reducing the initial oxygen deficit enabling the subjects to achieve a higher peak VO_2. One reason for the significant responses may have been that Gutin et al. (1976) used a longer duration of warmup than the previous researchers.

DeBruyn-Prevost (1980) investigated the effects of different warmup intensities and durations while using a working capacity of 170 (WC_{170}) on a cycle ergometer. The WC_{170} was defined as the load the subject was able to maintain for at least five minutes with a heart rate of 170 bpm without warming up. Warmup durations of 5 or 20 minutes were used at intensities of 105, 120, and 135 bpm. There were two series of tests. Series I was cycling 5 or 20 minutes at intensities of 105, 120 & 135 bpm with no rest intervals. Series II used the same protocol as series I, with 5 or 10 minute rest intervals. The results showed that when the exercise test immediately followed warmup (series I), HR and oxygen consumption were higher, but not significantly and LA levels did not vary. However, when there were 5 or 10 minute rest intervals (series II) HR and oxygen consumption were no different compared to when there was no warmup. Also in series II, LA decreased throughout, but not significantly. Reasons for the findings of this study may be due to no rest intervals or too long of a rest interval (5 or 10 minutes). Warmup was not found to alter physiological responses to exercise, which refutes the findings of Gutin et al. (1976).

Robergs et al. (1991) studied the effects of warmup on intense cycle ergometer exercise. The warmup consisted of cycling 10 minutes at 60% VO_2 max, followed by a one minute rest interval and four 30 second bouts of cycling at 100% of their power output at VO_2 max (PO_2 max) with 15 minute rest intervals. The sprint ride consisted of two minutes of cycling at 120% PO_2 max. The results of this study showed that the extensive warmup significantly ($p<.05$) decreased the accumulation of blood and muscle lactate, with a difference of 6.5 mM $\pm$ .9 mM for the warmup trial and 10.7 mM $\pm$ .8 mM for the no warmup trial, thereby increasing oxidative energy metabolism. Also, VO_2, RER and VE did not show significant change. The results for VO_2, RER & VE refute the study by Gutin et al. (1976), but are in agreement with DeBruyn-Prevost (1980).

Warmup and Swimming Performance

A summary of the studies regarding warmup and swimming performance can be found in Table 2. Muido (1946) performed various experiments using both active and passive warmup on untrained swimmers. For passive warming, a hot bath at 40^0 to 43^0 C was used for 15 to 18 minutes. Active warmup consisted of light jogging for 10 minutes. Later in the experiment, the light jogging was replaced by riding a cycle for 10 minutes at a work rate of 1,080 mkg/min. The criterion task consisted of the 50 m and 400 m front crawl and 200 m breast stroke. The results of this experiment showed that warmup significantly ($p<.05$) enhanced performance within a range of 1.4 to 2.6%. However, active warmup was no better than passive warmup. One reason the researcher gave for the enhanced performance was the increase in temperature, although rectal temperature seemed to be more essential than muscle temperature. Also, Muido suggested that the beneficial effect of the higher body temperature may have been attributed to the increase in the velocity of chemical reactions.

Carlile (1956) investigated the effects of passive warmup on swimming performance. He tested at distances of 40 yards and 220 yards, which was preceded by an 8 minute hot shower. In both the 40 and 220 yard swim, there was a statistically significant ($p<.05$) improvement in performance when the swim followed the 8 minute hot shower. There was a

Table 2
Warmup and Swimming Performance

Study	Subjects	Warmup	Test Distance	Results	Comments
Muido (1946)	3 healthy untrained individuals	1. hot bath (40-43 C) 15-18 min. 2. light jogging 10 min. or 3. cycling 10 min. @ 1080 mkg/min	50 m & 400 m front crawl; 200 m breast stroke	sig. (p<.05) inc. in performance (1.4 - 2.6% inc.)	Active warmup was no better than passive warmup on performance
Carlile (1956)	11 ss (1-26yrs.; 10-13-20 yrs.) off-season training	1. no warmup 2. 8 min. hot shower	1. 40 yd swim 2. 220 yd. swim	sig. (p<.05) inc. in performance (1.4-2.6% inc.)	A 1% improvement is beneficial for elite competitors
deVries (1957)	13 M trained swimmers	1. 50 yd active swimming 2. 6 min. hot shower 3. 10 min. massage 4. calisthenics - >300 reps	15 trials of 100 yd active swimming	active swim warmup sig (p<.05) dec. 100 yd time; NSD for hot showers, massage & calithenics	Active, specific warmup was most beneficial for performance
Thompson (1958)	85 M collegiate students	1. no warmup 2. calisthenics 3. active swimming	1. 30 yd sprint swim (sp) 2. 5 min. endurance swim (end)	1. sp - sig (p<.05) inc. in perf. between #3 wup & #2 wup; not between #2 & #1. 2. end - sig (p<.05) inc in perf. in #2 & #3, but not within #1	Active formal warmup improves performance in sprint and endurance swimming
Robergs et al. (1990)	8 M trained collegiate swimmers	1. no warmup 2. 400 m flutter kick @ 45% VO2max; 4 - 50 m front crawls @ 111% VO2max with 15 s RI	200 m front crawl @ 120% VO2max	sig. (p<.05) inc. in metabolic acidosis & LA; no change in performance	Itensity level of warmup was between 45-111% VO2max, yet LA levels significantly decreased
Houmard et al (1993)	8 trained collegiate swimmers	1. no warmup 2. mild I long D (20min/65% VO2max) 3. intensity specific (4x45.7m swim with 1 min RI) 4. swim 1188.7m at 65% VO2max plus warmup #3	high I swim at 95% VO2max for 365.8 m	post-ex.-sig (p<.05) dec. LA & inc. in HR; NSD for perf., VO2, VO2max &RPE in mild I, long D warmup, NSD in intensity specific warmuup	The important concept when warming up is to use a mild I long D exercise
Mitchell & Huston (1993)	10 collegiate swimmers	1. no warmup 2. low I - 365 m sw @ 70% VO2max 3. hi I - 4 - 46 m sw @ 110% VO2max @ 1 min. RI	1. standardized sw - 183 m (SS) 2. tethered sw - 2 min. (TS)	1. SS-sig (p<.05) inc. in HR in #3 than #2; sig (p<.05) inc. LA in #3 than #2 or #1 2. TS-sig (p<.05) inc. HR in #3 & #2 than #1; NSD in VO2max & LA	Do not need event (intensity) specific warmup for the beneficial effects on the physiological responses and performance

HR - heart rate; LA = lactic acid
VE - ventilation exchange
VO2 - oxygen consumption

HR = heart rate; LA = lactic acid
VE = ventilation exchange
VO2 = oxygen consumption

sw = swim; m = meters; yd = yards
sig. = significance; NSD = nonsignificant difference
RER = respiratory exchange ratio

significant ($p<.05$) improvement of approximately 1 - 1.5% when the 220 yard swim was preceded by a passive warmup. Although a small improvement, Carlile pointed out that at the competitive level even a 1% improvement is beneficial. Therefore, Carlile concluded that some type of passive warmup, in addition to some active work, should be used prior to swimming.

deVries (1957) studied four different types of warmup, active swimming, hot showers, calisthenics, and massage on five different swimming groups/strokes: 4 freestyle sprinters, 3 freestyle distance specialists, 1 backstroker, 2 breaststrokers, and 3 dolphin specialists. The swimming warmup was 500 yards, the calisthenics were over 300 repetitions, the hot shower was for 6 minutes, and the massage was for 10 minutes. Each swimmer performed 15 separate trials incorporating all types of warmup for a distance of 100 yards. When swimmers were grouped together for analysis, regardless of which stroke they swam, it was found that the 500 yd warmup was significantly ($p<.05$) better for decreasing 100 yd time. The mean difference was .44 s. Also, when swimmers were grouped together, it was shown that the 6 minute hot shower, calisthenics and massage had no significant effect on trial time. The results showed that swimming performance can be enhanced with proper warmup, as well as even being hindered with improper warmup, which are in agreement with Muido (1946) and Carlile (1956). Thompson

(1958) investigated whether warmup affected speed in swimming a 30 yard sprint and endurance in swimming 5 minutes. The warmups were either using no warmup, formal warmup of active swimming or informal warmup of calisthenics. The sprint swimmers were tested on a 30 yard sprint, and the endurance swimmers were tested on a five minute endurance swim. For sprint swimming, the results showed a significant ($p<.05$) difference in performance between formal warmup and no warmup; however, there was no significant difference in performance between informal and no warmup. Moreover, in endurance swimming, there was a significant ($p<.05$) difference in performance in both the formal and informal warmup groups compared to the no warmup group. These results were similar to Muido (1946), Carlile (1956) and deVries (1957).

In a study by Robergs et al. (1990) warmup during sprint swimming was investigated. The test consisted of a 200 meter front crawl swim at 120% VO_2 max following either a warmup or no warmup. The warmup involved a 400 meter front crawl swim at 82% VO_2 max, a 400 meter flutter kick at 45% VO_2 max and four 50 meter front crawl sprints at 111% VO_2 max with 15 second rest intervals. The results indicated that when the sprint test was preceded by warmup there were significantly ($p<.05$) reduced levels of metabolic acidosis and accumulation of blood LA. Also, there was no change in performance, which contradicted the findings of Muido (1946), Carlile (1956), deVries (1957) and Thompson (1958).

Houmard et al. (1991) studied high intensity swimming of approximately 95% VO_2 max when it was preceded by no warmup, mild intensity, long duration warmup and/or intensity specific exercise. The mild intensity, long duration warmup consisted of a 1371.6 m swim at 65% VO_2 max, the intensity specific swim was swimming four 45.7 m swims with 1 minute rest intervals, and the final swim was 1188.7 m at 65% VO_2 max plus the intensity specific warmup combined. The test was a paced 365.8 meter swim at 95% VO_2 max. The results indicated that stroke distance was improved and there was a significant ($p<.05$) decrease in LA accumulation with a mild intensity warmup when compared to no warmup. The reduction in LA levels was similar to those found by Robergs et al. (1990). There were no significant differences among trials with regard to performance, VO_2, VO_2 max and RPE. Intensity specific exercise warmup showed no significant difference on performance. The authors suggested a mild intensity. long duration warmup prior to exercise.

Mitchell and Huston (1993) recently investigated three warmup conditions: no warmup, low intensity warmup and high intensity warmup on well trained swimmers. The low intensity warmup consisted of a 365 meter swim at 70% VO_2 max, while the high intensity warmup involved four 46 meter swims at one minute intervals at 110% VO_2 max. Performance measures were a standardized swim of 183 meters and a tethered swim of two minutes. The changes for the standardized swim included a significantly ($p<.05$) higher HR in the high intensity warmup (177.0 bpm ± 7.4) compared to the no warmup trial (170.4 bpm ± 8.7) trial. Also, lactate was significantly ($p<.05$) higher in the high intensity warmup (13.55 mM ± 2.66) compared to the low intensity warmup (9.53 mM ± 2.22) and no warmup (10.04 mM ± 2.15) trials. The results for the tethered swim showed a significantly ($p<.05$) higher HR for the high intensity warmup (173.8 bpm ± 9.0) trial and low intensity warmup (173.2 bpm ± 7.2) trial compared to the no warmup (162.5 bpm ± 4.5) trial. However, there were no significant differences for VO_2 max and lactate between trials. Although there were changes which occurred with high intensity warmup that did not with low intensity or no warmup, there were no effects on performance. An interesting finding of this study was that the test swim was of short duration and high intensity, yet the short duration high intensity warmup showed no greater effects on performance. Therefore, this showed that event specific warmup may not always needed.

Warmup and Running Performance

A summary regarding warmup and running performance can be found in Table 3. Blank (1955) studied the effects of warmup on speed. Each subject participated in either a cold or minimal warmup condition, or an optimum or warm condition. The warm condition involved running, walking and other

Table 3

Warmup and Running Performance

Study	Subjects	Warmup	Test Distance	Results	Comments
Blank (1955)	1. 16 trained track & field athletes 2. 38 untrained subjects	1. no warmup 2 running, walking or calisthenics	1. trained runners - 120 yd run 2. untrained runners - 100 yd run	for both groups, warmup sig. (p<.05) inc. performance than no warmup	Enhanced performance seen when an optimum warmup routine is peformed
Matthew & Snyder (1958)	54 untrained high school students	1. no warmup 2. walking, jogging & calisthenics with 5 to 10 minutes of rest	440 yd run	NSD	Used a relatively light warmup with long RI
Hipple (1951)	28 8th grade boys	each run was the warmup for the next run	5 - 50 yd runs with 5 min RI	NSD	Age and training status of the subjects may have an effect on the results
Grodjinovsky & Magel (1970)	13 M volunteers	1. no warmup 2. reg. = 5 min. jog plus set of 8 calisthenics 3. vig. = reg. plus 176 yd sprint	1. 60 yd sprint 2. 440 yd. run 3. one mile run	Perf. sig inc. with 60 yd (p<.05) & 440 yd (p<.01) with #2 & #3 wup, perf. sig (p<.01) inc. with #3 than #2 or #1 in 1 mile run	Vigorous warmup is best suited for longer distances
Ingjer & Stromme (1979)	6 M trained endurance runners	1. no warmup 2. active - run at 50-60% VO2max 3. passive - hot bath at 40 C	running uphill 3 @ 100% VO2max for 4 min.	sig (p<.05) inc. in O2 uptake after #2 than #1 or #3; HR sig (p<.05) inc. 10 bpm with #3 and #3 than #1; NSD with RQ	Active warmup provides beneficial effects to physiological resonses
Andzel (1978)	20 F collegiate athletes from various sports	1. no PE 2. Pe+30s 3. PE+60s 4. PE+90s 5. PE+120s; run 2mph/0%gr, inc. speed to HR 140 bpm	5 mph at %gr to 95-100% HRmax for 4-6 min.	perf. sig (p<.05) better with PE+30s and PE+60s than no PEm PE+90s, or PE+120s	Use RI of 30-60 seconds
Andzel & Busuttil (1982)	8 collegiate females	1 no warmup 2. PE+30s 3. PE+90s run 2.0mph/0% gr for 1 min., inc. speed to a HR of 140 bpm	running to exhaustion at 95-100% VO2max	NSD for VO2max, HR, O2 pulse, VE & perf. @ no warmup & PE+30s; perf. sig. (p<.05) worse at PE+90s	Use RI of 30s
Hetzler et al. (1986)	6 M trained distance runners	1. no warmup 2. walking at speed & grade of 30% VO2max	40 min run at 67% VO2max	sig. (p<.05) inc. in fat util. & sig. (p<.05) dec. in CHO util with warmup	Enhancement of fat met. lead to preservation of CHO

M = male; F = female; I = intensity; D = duration; RI = rest intervals

HR = heart rate; LA = lactic acid; VE = ventilation exchange; VO2 = oxygen consumption

mph = miles per hour; % gr = percent elevation; sig. = significance, NSD = nonsignificant difference; RER = respiratory exchange ratio calisthenic type of activities. Two different groups were used, a trained group of track athletes and an untrained group of individuals running 120 yards and 100 yards, respectively. In the 120 yd group, times were significantly ($p<.05$) faster (.64 s to .815 s) under the optimum (warm) condition compared to the minimal (cold) condition. The results were similar for the 100 yd group, such that the optimum group ran significantly ($p<.05$) faster (.39 s to .94 s) compared to the minimum condition. Blank found that performances were enhanced significantly when the optimum warmup preceded the run at both the 120 and 100 yard distances.

Mathews and Snyder (1958) studied the effects of warmup on the 440 yard dash. The warmup group walked, jogged and performed light calisthenics with 5 to 10 minute rest intervals, while the control group did no warmup. The warmup performed prior to the 440 yard dash showed no significant enhancement on performance. However, they used a relatively light warmup with long rest intervals. These results contradict those of Blank (1955).

Hipple (1951) investigated the effects of warmup and fatigue on sprint performance in junior high school boys. Each subject ran five 50 yard dashes with five minute rest intervals. Each subsequent run acted as the warmup for the next race. Fatigue set in after three 50 yard runs, and showed that warmup had no effect on the performance of the race. These results were in direct agreement with Matthews and Snyder (1958), but the age and training status of the subjects may have been a contributing factor in finding no significance.

Grodjinovsky and Magel (1970) investigated the effects of a regular and vigorous warmup on running performance in the 60 yard, 440 yard, and one mile runs. Regular warmup consisted of 5 minutes of jogging and a set of eight calisthenic exercises. Vigorous warmup consisted of the regular warmup plus a 176 yard sprint at maximum speed. The results showed that performance was significantly enhanced in the 60 yd ($p<.05$) and 440 yd ($p<.01$) runs with both regular and vigorous warmup, with mean times of 6.96 s and 6.93 s and 63.73 s and 63.62 s , respectively. Vigorous warmup showed no additional benefits. However, vigorous warmup appeared to be more beneficial, such that performance was significantly ($p<.01$) greater using vigorous warmup (371.18 s) than the regular (379.66 s) or no (379.28 s) warmup conditions in the one mile run. Therefore, the researchers concluded that the vigorous warmup would be best suited for distances beyond 440 yds.

Ingjer and Stromme (1979) investigated the effects of active, passive or no warmup. Active warmup consisted of treadmill running at 50 to 60% VO_2 max, while passive warmup consisted of sitting in a tank of hot water at approximately 40^0 C. The test involved running uphill at 3^0 at 100% VO_2 max for 4 minutes. The results showed that there was a significantly ($p<.05$) higher oxygen uptake after active warmup (16.41 ml/kg/min) compared to after passive (15.6 ml/kg/min) or no (15.7 ml/kg/min) warmup. Heart rate was significantly ($p<.005$) higher by 10 bpm with active and passive warmup than during the no warmup condition. Also, there was no significant difference among the three conditions regarding the respiratory quotient (RQ). Therefore, the researchers concluded that active warmup provided beneficial effect to physiological responses.

In 1978, Andzel conducted a study on the effects of prior exercise (PE) with various rest intervals on endurance performance. There were five experimental conditions: 1) no PE, 2) PE + 30 s rest, 3) PE + 60 s rest, 4) PE + 90 s rest, and 5) PE + 120 s rest. The PE consisted of a treadmill walk beginning at 2.0 mph/0% grade, with an increasing speed of 1 mph until a HR of 140 bpm was attained. After attaining a HR of 140 bpm, this workload was maintained for 2 minutes, which was then preceded by one of the rest interval experimental conditions. The test consisted of a treadmill run at 5 mph and a % grade which corresponded to a 95 to 100% max HR, for approximately 4 to 6 minutes. The performance means (seconds) following the test conditions No PE, PE + 30 s, PE + 60 s, PE + 90 s, and PE + 120 s were 365.9, 404.4, 399.8, 348.4 and 363.8, respectively. The results indicated that performance was significantly ($p<.05$) better when it was preceded by PE + 30 s rest than no PE, PE + 90 s rest, and PE + 120 s rest. PE + 60 s rest just missed being significantly better than no PE, but was significantly better than PE + 90 s rest. The mean HR (bpm) prior to the criterion task for no PE, PE + 60 s, PE + 90 s and PE + 120 s were 78, 120, 110, 99 and 89, respectively. This showed that with PE + 30 s and PE + 60 s, HRs in subjects were substantially mobilized. The poorer performance following the longer rest intervals (90-120 seconds) indicated that the mobilization effect was probably lost during this period of time, and it seemed to be enhanced during the 30-60 second rest intervals.

Andzel and Busuttil (1983) investigated the metabolic and physiological responses to prior exercise with varied rest intervals in an endurance criterion task. The prior exercise consisted of walking for one minute on a treadmill at 2.0 mph at 0% grade. This was followed by an increase in speed of 1 mph each minute thereafter to a HR of 140 bpm. The criterion task involved running to exhaustion at 95-100% VO_2 max, which was previously determined. The criterion task followed either no PE, PE + 30 s or PE + 90 s. The results showed no significant difference for VO_2 max, HR, VE and oxygen pulse. Furthermore, there was no significant difference on performance between no PE (402 s run time) and PE + 30 s (401 s run time). Performance was significantly ($p<.05$) worse (379 s run time) in the PE + 90 s trial. These results were similar to those of Andzel (1978). The study showed support for modest prior exercise and short rest intervals (30 s) in order to mobilize the cardiorespiratory system.

Hetzler et al. (1986) investigated the effects of warmup on substrate utilization on well trained distance runners. The warmup consisted of walking on a treadmill at a speed and grade which corresponded to 30% VO_2 max. The test condition was a 40 minute run at a speed and grade which was approximately 67% of their VO_2 max. The R value between test conditions were significantly ($p<.001$) different. An analysis of the results showed a significant difference between the warmup and no warmup conditions for both fat ($p<.05$) and CHO ($p<.05$). A mean of 40 g and 25.7 g of fat and a mean of 64.5 g and 87.6 g CHO were metabolized in the warmup and no warmup trials, respectively. The most significant finding was that warmup affected fat metabolism, such that FFA were utilized more extensively during the early portion of the run. The enhancement of fat metabolism lead to the preservation of carbohydrate.

Summary

Scientific evidence regarding the appropriate intensities and durations of warmup has been lacking in the area of endurance running. Active, specific warmup has been shown to have the most beneficial effects (Thompson, 1958; Shellock, 1983). In previous studies, relatively short warmup periods and test distances were used, with the exception of one study that used a 40 minute treadmill test distance (Hetzler et al., 1986). Although many studies have explored different warmup procedures on different activities, no studies have explored the appropriate duration and intensity of warmup in endurance running. It would appear that a warmup longer than that recommended by the ACSM (1991) would be beneficial for endurance runners, because there is an increase in FFA utilization plus a decrease in the amount of lactic acid produced. However, the appropriate duration and intensity of warmup has not been investigated in endurance running.

Chapter IV

Methods

Subjects

The subjects consisted of four female and four male distance runners from the local Omaha, Nebraska area. The descriptive characteristics of the subjects can be found in Table 4. The subjects ranged in age between 24 and 35 yr and were actively competing in road races. Because of the vigorous test protocol to be completed, subjects had to meet the following participation criteria: running an average of 25 miles per week and a 10 km run time ≤ 50 minutes in the previous 4 months.

Table 4. Description of Subjects

Gender	Wt (kg)	Height (cm)	%BF	running miles/ wk	10 km time (min)	VO_2max (ml/kg/min)
Male						
Subj. 1	73.6	178	12.9	25	38.00	49.2
Subj. 2	80.9	180.5	8.0	40	41.30	59.8
Subj. 3	77.9	182	19.2	20	43.05	49.7
Subj. 4	83.2	188.5	5.6	20	37.42	62.6
Mean	78.9	182.3	11.4	25	39.9	55.3
SD	3.6	3.9	5.2	9.4	2.3	6.0
Female						
Subj. 5	62.2	169	18.0	50	40.00	45.1
Subj. 6	49.1	154	17.1	40	39.33	51.0
Subj. 7	50.0	152.5	17.1	40	43.50	53.9
Subj. 8	56.4	163	20.5	20	47.50	44.3
MEAN	54.4	159.6	18.2	37.5	42.58	48.6
SD	5.3	6.7	1.4	10.9	3.3	4.0

Subjects were well trained, which was demonstrated by the low percent body fat (male mean = 11.4, SD = 5.2; female mean = 18.2, SD = 1.4), the large number of miles each of them ran each week (male mean = 25.0, SD = 9.4; female mean = 37.5, SD = 10.9), and the above average aerobic capacities
(male mean = 55.3, SD = 6.0; female mean = 48.6, SD = 4.0).Each subject completed a training history and medical form prior to participating (see Appendix B). All subjects indicated an absence of smoking, cardiovascular disease, hypertension, diabetes mellitus, epilepsy, use of medications known to alter heart rate and orthopedic or muscular problems that could compromise their ability to run without pain. Also, an informed consent written in accordance to the University of Nebraska Institutional Review Board was read and signed by all subjects (see Appendix A).

VO_2 max Test

All subjects performed a graded exercise test to determine their maximum aerobic capacity. Before the test, the subject's height and weight were measured. The test consisted of subjects walking at 3 mph for 3 minutes, after which the speed was increased to 6 mph. After 6 mph was reached, the speed was increased by 1 mph every two minutes until 9 mph was attained. Thereafter, speed was kept constant at 9 mph and the grade was increased by 2% every minute until the subject reached voluntary exhaustion. The

VO_2 max was based on attainment of two of the three following criteria: R>1.05, HR ± 10 bpm of 220-age, and the plateauing of VO_2, i.e., increase of less than 150 ml/min in the last two minutes. Subjects performed a walk recovery at the completion of the test until a HR of 120 bpm was attained. The test was performed on a Quinton treadmill Model 644 and used in conjunction with a SensorMedics MMC Horizon System metabolic cart. Prior to each test, the metabolic cart was calibrated using gases of known concentration. HR was monitored using a Polar Vantage XL heart rate monitor (model number 145900). Subjects were also introduced and familiarized with the RPE scale which was used in the subsequent tests.

Ratings of Perceived Exertion

The rating of perceived exertion (RPE) is a 15 point scale ranging from 6 to 20, with verbal descriptions at the odd numbers (Borg, 1982). The ratings are well correlated with VO_2, HR, VE and blood lactate. Subjects were familiarized with assessing their RPE during the initial VO_2 max test. Thereafter, subjects were asked to elicit an RPE during the final minute of the 5 minute criterion test at 80% of their VO_2 max.

Blood Pressure

Blood pressure was taken prior to and following the treadmill test protocol. The blood pressure was taken in the supine position using a standard sphygmomanometer and stethoscope, utilizing the auscultatory method. Proper cuff size was used, with those whose arm circumference was over 34 cm being assessed with a large cuff.

Blood Lactate

Blood was collected during the warmup and treadmill run at 80% VO_2 max and analyzed for lactate using a Yellow Springs Instrument 2300 Stat lactate/glucose analyzer. Whole blood samples were taken at pre and post warmup, as well as at 5 minutes of the criterion test. During the treadmill run, the subjects stopped running just long enough for the finger to be sterilized and punctured for the blood sample. Each sample was collected in a heparinized pipette. To avoid contamination with sweat and interstitial fluid, the first drop was wiped away before collecting the blood sample. Lactate values were corrected for the shift of plasma volume from the blood during exercise using the method of Dill and Costill (1974). This procedure involved measurement of hematocrit and hemoglobin before and after exercise to calculate the percent loss of plasma volume in the blood. A B-Hemoglobin Photometer Hemocue AB (model number 9526011304) and Adams Readacrit micro-hematocrit centrifuge (model number CT-3400) were used to measure hemoglobin and hematocrit, respectively. Lactate values were then be corrected accordingly.

Body Composition

Body composition was used for the descriptive purposes. The Jackson and Pollock (1978) or Jackson, Pollock and Ward (1980) method for the estimation of percent body fat was used for assessing body composition of males and females, respectively.

Treadmill Test Protocol

Subjects were asked to run at 80% VO_2 max for 5 minutes during the treadmill criterion test. Subjects performed four treadmill runs while being monitored on the treadmill and metabolic cart, wearing a noseclip and mouthpiece. Subjects performed four different warmups in random order: low intensity, short duration (LISD), low intensity, long duration (LILD), high intensity, short duration (HISD), or high intensity, long duration (HILD). The LISD warmup consisted of running on the treadmill for 5 minutes at 40% VO_2 max. The LILD warmup consisted of running on the treadmill for 20 minutes at 40% VO_2 max. The HISD warmup consisted of running on the treadmill at 70% VO_2 max for 5 minutes. The HILD warmup involved running on the treadmill at 70% VO_2 max for 20 minutes (see Appendix C). The rest interval between each protocol and the performance run was 60 seconds, since it has been found to produce optimal performance (Andzel, 1978; Andzel & Busuttil, 1983).

The test protocol consisted of running on the treadmill for 20 minutes at 80% VO_2 max. Treadmill speed and grade were altered if necessary to elicit the designated VO_2, i.e. to control for the cardiovascular drift. The treadmill speed was calibrated daily to ensure that all trials were conducted at identical speeds. Subjects were tested $\pm$ 2 hours of the initial testing time to minimize possible circadian effects. Subjects were instructed not to eat or drink two hours before testing and to avoid alkaline and antacid substances, as well as intense exercise each day prior to testing. They were also encouraged to avoid strenuous or lengthy exercise in the two days prior to testing to minimize muscle fatigue. Subjects had at least a two to three day rest interval between each session (see Appendix D).

Data Analysis

The data was analyzed using descriptive statistics and a 2 (duration) by 2 (intensity) ANOVA with repeated measures for each dependent variable, with the data taken at the end of the fifth minute of the criterion test for HR, VE, R, LA and RPE for both the warmup and treadmill test. Omega squared was used to estimate the amount of variance explained by the independent variable. Significance was set at $p<.05$.

Chapter V

Results

The results of the data analysis showed significant main effects (F with 1,21(df) = 24.46; p<.01) for duration in RPE with 20 minutes eliciting a higher RPE than 5 minutes and for intensity in HR (F with 1,21(df) = 8.10; p<.01) with 70% VO_2 max producing a higher HR than 40% VO_2 max for the 5 minute criterion test run. There were no significant main effects found for the dependent variables LA (intensity, F=1.15; duration, F=.34; with no interaction, F=1.26), RER (intensity, F=.31; duration, F=1.60; with no interaction, F=.225) and VE (intensity, F=1.98; duration, F=.57; with no interaction, F=.03).

The ANOVA results for RPE and HR can be found in tables 5 and 6, respectively. The omega squared analysis showed that for RPE, 68.7% of the variance among the conditions was due to the duration of the warmup. For HR, the omega squared analysis showed that 39.6% of the variance among the conditions was due to the intensity of the warmup.

All of the proposed hypotheses were rejected, such that no particular warmup produced optimal effects in the physiological variables associated with performance. Therefore, warmups within the ranges of 40% to 70% VO_2 max for 5 or 20 minutes produce equivalent effects on most of the physiological variables studied.

Table 5. Summary ANOVA for RPE

Source of Variance	SS	df	MS	F ratio
Intensity	.125	1	.125	.38
Duration	8.0	1	8.0	24.46**
Interaction	.125	1	.125	.38
Error	6.875	21	.327	

* $p \leq .05$

** $p \leq .01$

Table 6. Summary ANOVA for HR

Source of Variance	SS	df	MS	F ratio
Intensity	496.1	1	496.1	8.10**
Duration	21.1	1	21.1	.34
Interaction	105.1	1	105.1	1.72
Error	1286.75	21	61.27	

* $p \leq .05$

** $p \leq .01$

Chapter VI

Discussion

The results of this study showed significant main effects for duration in RPE ($p<.01$) and intensity in HR ($p<.01$). Further analysis revealed that a 5 minute warmup would elicit a lower RPE compared to a 20 minute warmup, and that a 40% VO_2 max intensity warmup produced a lower HR compared to a warmup at 70% VO_2 max. Few running studies have looked at the physiological variables associated with warmup, although not many more cycling and swimming studies observed these variables either.

Houmard et al. (1993) was the only study which investigated the role of RPE in response to various warmups upon a high intensity swim at 95% VO_2 max. A 20 minute warmup at 65% VO_2 max was not significantly different than the other durations used by in that study. Interestingly, their warmup of 65% VO_2 max was similar to one of the warmups used in this study. However, this study found that a 5 minute warmup elicited a lower RPE compared to a 20 minute warmup. Therefore, the results of this study refute those of Houmard et al. Reasons for dissimilar results may have been the test intensities. Although Houmard et al. tested swimmers, they were well-trained collegiate swimmers, similar to the trained endurance runners used in this study. The intensities in the criterion tasks in the studies were quite different. The study by Houmard et al. used a test intensity and distance of 95% VO_2 max to maximal exhaustion compared to 5 minute run at 80% VO_2 max used in this study.

Many of the studies investigating physiological variables used HR to determine the effects of warmup on performance. Some studies have found a significant increase in HR (Ingjer & Stromme, 1979; Gutin et al., 1976; DeBruyn-Prevost, 1980; Houmard et al., 1993; Mitchell & Huston, 1993), while Debruyn-Prevost (1980) and Andzel and Busuttil (1982) found no significant HR response of warmup on performance.

Ingjer and Stromme (1979) found a significant ($p<.05$) increase in HR in performance following warmup, which is similar to the results of Houmard et al. (1993), Mitchell and Huston (1993), Gutin et al. (1976) and Debruyn-Prevost (1980). One similarity in the studies is that the intensity used for the warmup was between 50-65% VO_2 max or a HR between 105-140 beats per minute (bpm). The intensity is similar to the high intensity protocol design used in this study, which also found a significant ($p<.01$) HR response. The exception to this is found in the study by Mitchell and Huston (1993), who used high intensity warmups between 70-110% VO_2 max.

In the second part of the study by Debruyn-Prevost (1980), he added a rest interval of 5 or 10 minutes between the warmup and the criterion task. This may have been the reason he found no significant HR responses on performance due to warmup. These results are similar to those of Andzel and Busuttil, (1982). The study by Andzel and Busuttil however, used 8 collegiate females with a warmup of 1 minute at a HR of 140 bpm with a criterion test at 95-100% VO_2 max to exhaustion. Therefore, too long a rest interval or too short of a warmup could have lead to these nonsignificant results.

Although most of the warmups used relatively the same intensities, the test distances were quite different. With the exception of the study by Debruyn-Prevost (1980) where rest intervals of 5 or 10 minutes were used, the study by Andzel and Busuttil (1982) used a criterion test of 95-100% VO_2 max until exhaustion was reached, and found non-significant results. However, those studies that found significant results of an increase in HR due to warmup(Gutin et al., 1976; Ingjer & Stromme, 1979 and Mitchell & Huston, 1993) used criterion test times between 2-6 minutes in a 365.8 m swim. Therefore, running to maximal exhaustion instead of a shorter more defined criterion test, such as the one used in this study (5 minutes), may not produce a significant HR response.

The results of this study showed a nonsignificant LA response, similar to the study by Debruyn-Prevost (1980) in which a 5 or 10 minute rest interval was used, but refutes the studies of Robergs et al. (1990), Houmard et al. (1993), Debruyn-Prevost (1980) (no rest interval), Mitchell and Huston (1993) and Robergs et al. (1991). However, the results of these studies are somewhat conflicting. Houmard, Debruyn-Prevost and Robergs (1991) found a significant decrease in LA. The studies that refute these results and found significant increases in LA are those by Robergs (1990) and Mitchell and Huston. Both of these studies used relatively high warmup intensities (110-111% VO_2 max), compared to those studies that found a decrease in LA who used a milder intensity (~40-60% VO_2 max) with a longer duration (~5-20 minutes). Therefore, it is apparent that a high intensity warmup would produce adverse effects and cause a rise in LA, compared to a decrease in LA concentration with a mild intensity warmup for 5-20 minutes.

The results of this study showed a nonsignificant VE response. Only three studies (Gutin et al., 1976; Robergs et al., 1991 and Andzel and Busuttil, 1982) studied at the effects of VE on performance following warmup. Of the three studies, Gutin et al. was the only one to find a significant ($p<.05$) increase in VE in performance following warmup. The other two studies found a nonsignificant VE response during performance. Reasons for the contradiction between studies may have been the test intensities. Robergs (1991) and Andzel and Busuttil used relatively high intensity criterion tests at 120% PO_2 max and 95-100% VO_2 max, respectively. However, it is hard to speculate as to why there was a discrepancy between studies when there are only three to compare.

As with VE, only a few studies (Robergs et al., 1991 and Ingjer & Stromme, 1979; Hetzler et al., 1986) observed the effects of warmup on R. The studies by Robergs et al. and Ingjer and Stromme found a non significant R response to performance following warmup, similar to the results of this study. However, Hetzler et al. found a significant R response, such that a greater amount of fat was utilized compared to carbohydrate. Reasons for the nonsignificant findings may have been the intensity of warmup, which was consistent with the intensities used in this study; whereas Hetzler et al. used an intensity of 30% VO_2 max. However, it is difficult to say with such a limited group of studies to analyze.

Limitations to this study include the fact that only eight subjects participated. A greater number subjects would raise the likelihood of finding significance. Also, a few mechanical problems with the metabolic cart may have caused incorrect oxygen consumption values to be produced.

In summary, the results of this study show significant main effects for intensity in RPE and duration in HR, but non significant responses for LA, VE and R. No particular warmup produced optimal effects on all of the physiological factors associated with performance. Therefore, warmups within the ranges of 40% to 70% VO_2 max for 5 or 20 minutes produce equivalent effects on most of the physiological variables studied.

Chapter VII

Summary, Recommendation, Conclusions

Summary

The purpose of this study was to determine how different combinations of durations and intensities of warmup affect heart rate (HR), blood lactate levels (LA), minute ventilation (VE), respiratory exchange ratio (R) and ratings of perceived exertion (RPE) during a treadmill run for 5 minutes at 80% VO_2 max. The participants included four male and four female trained endurance runners, who were randomly assigned to each of the four warmup conditions (LISD, LILD, HISD and HILD). Although it was hypothesized that the LILD warmup would produce the most optimal effects on performance, followed by the HISD, and that the HILD would produce adverse effect, while the LISD would not produce sufficient effect on the physiological variables associated with warmup, none of the results supported these hypotheses. A 2 x 2 ANOVA found significant main effects for intensity in RPE ($p<.01$) and duration in HR ($p<.01$).

Recommendations

It is recommended that a greater number subjects be used to raise the likelihood of finding significance. Also, it is recommended that exercise intensities between 40% to 70% VO_2 max and duration between 5 to 20 minutes should be examined to see if there are additional levels of warmup that would produce beneficial effects on performance. In addition, it is recommended that a performance test, such as an actual competitive race, be added to the protocol in order to better understand how warmup affects performance.

Conclusions

From the results of this study it can be concluded that warmup at 40% to 70% VO_2 max lasting between 5 to 20 minutes produces the similar effects on most of the physiological variables studied.

References

American College of Sports Medicine (1991). Guidelines for exercise testing and prescription. Philadelphia: Lea & Febiger.

American College of Sports Medicine (1995). Guidelines for exercise testing and prescription. Baltimore: Williams & Wilkins .

Andzel, W. (1987). The effect of prior exercise and varied rest intervals upon cardiorespiratory endurance performance. Journal of Sports Medicine and Physical Fitness, 18, 245-252.

Andzel, W. & Busuttill, C. (1982). Metabolic and physiological responses of college females to prior exercise, varied rest intervals and a strenuous endurance task. Journal of Sports Medicine, 22, 113-119.

Asmussen, E. & Boje, O. (1945). Body temperature and capacity for work. Acta Physiologica Scandinavica, 10, 1-22.

Barcroft, J. & King, W. (1909). The effect of temperature on the dissociation curve of blood. The Journal of Physiology, 39, 374-384.

Barnard, R., Gardner, G., Diaco, N., MacAlpin, R. & Kattus, A.(1973a). Cardiovascular responses to sudden strenuous exercise heart rate, blood pressure, and ECG. Journal of Applied Physiology, 34, 833-837.

Barnard, R., MacAlpin, R., Kattus, A. & Buckberg, G. (1973b). Ischemic response to sudden strenuous exercise in healthy men. Circulation, 33, 936-942.

Bixler, B. & Jones, R. (1972). High-school football injuries: Effects of a post-halftime warmup and stretching routine. The Family Practice Research Journal, 12(2), 131-139.

Blank, L. (1955). Effects of warm-up on speed. The Athletic Journal, 35, 10,45-46.

Borg, G. (1982). Ratings of perceived exertion. Medicine and Science in Sport and Exercise, 14, 377-387.

Carlile, F. (1956). Effect of preliminary passive warming on swimming performance. Research Quarterly, 27, 143-151.

DeBruyn-Prevost, P. (1980). The effects of varying warming up intensities and duration upon some physiological variables during an exercise corresponding to the WC_{170}. European Journal of Applied Physiology and Occupational Physiology, 43, 93-100.

deVries, H. (1959). Effects of various warm-up procedures on 100-yard times of competitive swimmers. Research Quarterly, 30, 11-20.

Dill, D. & Costill, D. (1974). Calculation of percentage changes in volumes of blood, plasma, and red cell in dehydration. Journal of Applied Physiology, 37, 247-248.

Grodjinovsky, A. & Magel, J. (1970). Effect of warm-up on running performance. Research Quarterly, 41, 116-119.

Gutin, B., Stewart, K., Lewis, S. & Kruper, J. (1976). Oxygen consumption in the first stages of strenuous work as a function of prior exercise. Journal of Sports Medicine, 16, 60-65.

Hetzler, R., Knowlton, R., Kaminsky, L. & Kamimori, G. (1986). Effect of warm-up on plasma free fatty acid responses and substrate utilization during submaximal exercise. Research Quarterly for Exercise and Sport, 57(3), 223-228.

Hipple, J. (1955). Warm-up and fatigue in junior high school sprints. Research Quarterly, 26, 246-247.

Houmard, J., Johns, R., Smith, L., Wells, J., Kobe, R. & McGoogan, S. (1991). The effect of warm-up on responses to intense exercise. International Journal of Sports Medicine, 12, 480-483.

Ingjer, F. & Stromme, S. (1977). Effects of active, passive or no warm-up on the physiological response to heavy exercise. European Journal of Applied Physiology and Occupational Physiology, 40, 273-282.

Jackson, A. & Pollock, M. (1978). Generalized equations for predicting body density of men. British Journal of Nutrition, 40, 497-504

Jackson, A., Pollock, M. & Ward, A. (1980). Generalized equations for predicting body density of women, Medicine and Science in Sport and Exercise, 12, 175-182.

Karpovich, P. & Hale, C. (1956). Effect of warming-up upon physical performance. Journal of the American Medical Association, 162, 1117-1119.

Massey, B., Johnson, W. & Kramer, G. (1960) Effect of warm-up exercise upon muscular performance using hypnosis to control the psychological variable. Research Quarterly, 32, 63-71.

Matthews, D. & Snyder, H. (1959). Effect of warm-up on the 440-yard dash. Research Quarterly, 30, 446-451.

McArdle, W., Katch, F. & Katch, V. (1991). Exercise physiology, energy, nutrition, and human performance (3rd ed.).Philadelphia: Lea & Febiger.

Miller, R. (1951). The science and practice of warming-up. The Athletic Journal, 25, 46-47.

Mitchell, J. & Huston, J. (1993). The effect of high and low-intensity warm-up on the physiological responses to a standardized swim and tethered swimming performance. Journal of Sports Sciences, 11, 159-165.

Muido, L. (1946). The influence of body temperature on performance on swimming. Acta Physiologica Scandinavica, 12, 102-109.

Robergs, R., Costill, D., Fink, W., Williams, C., Pascoe, D., Chwalbinska-Moneta, J. & Davis, J. (1990). Effects of warm-up on blood gases, lactate and acid-base status during sprint swimming. International Journal of Sports Medicine, 11, 273- 278.

Robergs, R., Pascoe, D., Costill, D., Fink, W., Chwalbinska-Moneta, J., Davis, J. & Hickner, R. (1991). Effects of warm-up on muscle glycogenolysis during intense exercise. Medicine and Science in Sports and Exercise, 23, 37-43.

Rochelle, R., Skubic, V. & Michael, E. (1960). Performance as affected by incentive and preliminary warmup. Research Quarterly, 31, 499-504.

Shellock, F. (1983). Physiological benefits of warm-up. The Physician and Sportsmedicine, 11(10), 134-139.

Skubic, V. & Hodgkins, J. (1957). Effect of warm-up activities on speed, strength, and accuracy. Research Quarterly, 28, 147- 152.

Thompson, H. (1958). Effect of warm-up upon physical performance in selected activities. Research Quarterly, 29, 231-246.

APPENDIX A

INFORMED CONSENT FORM

IRB PROTOCOL NUMBER 109-96

ADULT INFORMED CONSENT FORM

PHYSIOLOGICAL RESPONSES TO VARIOUS DURATIONS AND INTENSITIES OF WARMUP

INVITATION TO PARTICIPATION

You are invited to participate in this research study. The following information is provided in order to help you to make an informed decision whether or not to participate. If you have any questions please do not hesitate to ask.

BASIS FOR SUBJECT SELECTION

You are being asked to participate in this study because you are a healthy male or female 19 to 35 years old. You are also being asked to participate because you are a competing distance runner. You may participate only if you are a nonsmoker free from any heart, lung, muscle or joint risk factors and medications known to alter normal heart rate.

PURPOSE OF THE STUDY

The purpose of this investigation will be to determine how different combinations of durations and intensities of warmup affect heart rate (HR), oxygen uptake (VO_2), blood lactate levels (LA), minute ventilation (VE), respiratory exchange ratio (R) and ratings of perceived exertion (RPE) during a 20 minute treadmill endurance run at 80% VO_2max. An attempt will be made to show which combination of intensity and duration of warmup will produce the best effects for distance runners.

EXPLANATION OF PROCEDURES

You will be asked to come to the Exercise Physiology Laboratory at the University of Nebraska at Omaha to participate in five separate sessions on different days: a maximal fitness test, a low intensity, high duration (LIHD) warmup condition, a low intensity, low duration (LILD) warmup condition, a high intensity, low duration (HILD) warmup condition and a high intensity, high duration (HIHD) warmup condition. You will have at least a three day rest interval between each session. The LIHD warmup condition will be at 40% of your maximal exercise ability. The LILD warmup condition will be at 40% of your maximal work effort. The speed of the treadmill at 40% of maximal exercise capacity will be a brisk walk or slow jog, depending on your exercise capacity. The HILD warmup condition will be at 70% of you maximal exercise ability. The HIHD warmup condition will be at 70% of your maximal exercise ability. The speed of the treadmill at 70% of maximal exercise capacity is typical of trained runners running a bit slower than 10 km race pace. The test condition will consist of running for 20 minutes at 80% VO_2max. You will be tested within ± 2 hours of the initial testing period and asked to avoid antacids the day prior and day of testing and to refrain

______ Initials

from eating for 2 hours before a scheduled session. Prior to any testing, you will be asked to complete a medical and training history and read and sign an informed consent form. Also, you will be asked to refrain from intense or lengthy exercise two days prior to any testing.

The purpose of the initial session will be to estimate your maximal aerobic capacity using a treadmill test in order to standardize the workload for all subjects during the warmup and exercise conditions. After measuring your height and weight, you will be instructed in how you will rate work effort during each run. Next, you will be asked to perform a treadmill test to assess you maximal work ability, during which you will signal the appropriate work effort score in order to become accustomed to the rating scale. Heart rates will be measured from a belt worn around your chest and physiological variables which will be collected from a tube connected to a mouthpiece you will be wearing, along with a noseclip.

During the treadmill test you will walk slowly at first and every several minutes speed and/or the grade of the treadmill will be increased. This will continue until you reach voluntary exhaustion. You will perform a walk recovery at the completion of the test until a HR of 120 bpm is attained. Blood pressure will be taken prior to and following the treadmill test protocol.

You will be asked to perform the four warmup conditions in random order. Upon assignment to the warmup condition, you will warmup at the appropriate intensity and duration. You will be asked to run for 20 minutes at 80% of your maximal work effort.

Blood will be collected during the warmup and treadmill run at 80% of your maximal aerobic ability and analyzed for a chemical in your blood called lactate. Blood samples will be taken at pre and post warmup, as well as at 5, 10 and 20 minutes. During the treadmill run, you will stop running just long enough for you finger to be sterilized and punctured for the blood sample.

Your body fatness will be determined using skinfold measurements. Thickness of skin at locations will be measured and used to calculate fatness.

POTENTIAL RISKS AND DISCOMFORTS

The following are the risks and discomforts you could potentially experience during this study:

Maximal Treadmill Test: As a result of the maximal treadmill test you may experience, for a short time, some breathing discomfort and/or muscle soreness similar to what you may have experienced during or following intense runs. The mouthpiece may be uncomfortable during the test and may cause some muscle soreness in the mouth. You should be aware that these tests involve the possible risk of falls and/or muscle-joint injuries. Some muscle soreness may also be experienced following the test. Sudden death is also a possible risk. However, considering your age and fitness level sudden death is unlikely.

Submaximal Test: The submaximal treadmill tests should not cause any undue discomfort, except for some muscle fatigue towards the

______ Initials

end of the test. Other risks such as muscle-joint injuries and sudden death are existent but are considered highly unlikely.

POTENTIAL BENEFITS TO THE SUBJECT

Subjects will obtain information regarding their maximal aerobic capacity (VO_2max), which is important for endurance athletes. Also, subjects will learn how various types of warmup affect their own running performance.

POTENTIAL BENEFITS TO SOCIETY

Scientific evidence regarding the appropriate intensity and duration of warmup needed by the endurance athlete is lacking. Therefore, both coaches and athletes will benefit by learning how different types of warmup affect the physiological variables associated with performance.

FINANCIAL OBLIGATIONS

No fee will be charged for participation in the study.

ASSURANCE OF CONFIDENTIALITY

Information obtained from you in this study will be treated confidentially. Your name will not be used in the publishing of the results of this study. Only group data will be reported.

VOLUNTARY PARTICIPATION AND WITHDRAWAL

You are free to decide not to participate in this study or to withdraw at any time without adversely affecting your relationship with the investigators or the University of Nebraska at Omaha. Your decision will not result in loss of benefits to which you are otherwise entitled. If any information develops or changes occur during the course of this study may affect you willingness to continue participating you will be informed immediately.

RIGHTS OF RESEARCH SUBJECTS

Your rights as research subjects have been explained to you. If you have any additional questions concerning the rights of research subjects, you may contact the University of Nebraska Institutional Review Board (IRB), telephone (402) 559-6463.

DOCUMENTATION OF INFORMED CONSENT

YOU ARE VOLUNTARILY MAKING A DECISION WHETHER OR NOT TO PARTICIPATE IN THIS RESEARCH STUDY. YOU SIGNATURE CERTIFIES THAT THE CONTENT AND MEANING OF THE INFORMATION ON THIS CONSENT FORM HAVE BEEN FULLY EXPLAINED TO YOU AND THAT YOU HAVE DECIDED TO PARTICIPATE HAVING READ AND UNDERSTOOD THE INFORMATION PRESENTED. YOUR SIGNATURE ALSO CERTIFIES THAT YOU HAVE HAD ALL YOUR QUESTIONS ANSWERED TO YOU SATISFACTION. IF YOU THINK OF ANY ADDITIONAL QUESTIONS DURING THIS STUDY, PLEASE CONTACT THE INVESTIGATORS. YOU WILL BE GIVEN A COPY OF THIS CONSENT FORM TO KEEP.

______________________________ ____________________

Signature of Subject **Date**

MY SIGNATURE AS WITNESS CERTIFIED THAT THE SUBJECT SIGNED THIS CONSENT FORM IN MY PRESENCE AND HIS/HER VOLUNTARY ACT AND DEED.

______________________________ ____________________

Signature of Witness Date

IN MY JUDGMENT THE SUBJECT IS VOLUNTARILY AND KNOWINGLY GIVING INFORMED CONSENT AND POSSESSES THE LEGAL CAPACITY TO GIVE INFORMED CONSENT TO PARTICIPATE IN THIS RESEARCH STUDY.

______________________________ ____________________

Signature of Investigator Date

Primary Investigator:

Susan J. Hanson
Master's Candidate, School of HPER
(Home) 597-8676
(Work) 554-2670

Secondary Investigators:

Kris Berg, Ed.D.
Professor, School of HPER
(Home) 391-4516
(Work) 554-2670

Richard Latin, Ph.D.
Professor, School of HPER
(Home) 399-8305
(Work) 554-2670

APPENDIX B

TRAINING HISTORY FORM

Training History Form

NAME: ______________________________

DATE: ____________________

AGE (yr): __________

SEX: __________

*** Please answer the following questions to the best of your knowledge regarding your running in the previous four months***

1. Are you actively competing at this time?

__________Yes __________No

2. If you answered "YES" to #1 at what distance did you compete at?

__________5 km __________marathon

__________10 km __________other (please list)

3. How many miles a week do you consistently run?

__________miles/week

4. How many days a week do you consistently run?

__________days/week

5. How many minutes long in duration do you consistently run?

__________minutes

6. How many days per week do you use any of the following types of training?

__________Interval Training
__________Hill Work
__________Anaerobic Threshold
__________Sprinting

7. What is your best time for the following races?

__________5 km __________marathon

__________10 km __________other (please list)

APPENDIX C

TESTING DATA CHECKLIST

High Intensity Long Duration (HILD) Warmup
70% VO2max for 20 min

1. VO2max =___________

2. Go over RPE scale and how to score during test

3. Take hematrocrit and hemoglobin measurements pre-test

4. Attach to Metabolic Cart

5. Review "thumbs up and thumbs down" plus "OK"

6. Review treadmill protocol

7. Review the moving of hands/arms before taking blood work

Date: ______________________ Weight (kg): ___________
Name: ______________________ Height (cm): ___________
Age (yr): ___________ VO2max: ___________
RHR: ___________ 70% VO2max: ___________
BP: ___________ 80% VO2max ___________

Pre-test Hematocrit: ___________
Pre-test Hemoglobin: ___________
Pre-warmup lactate: ___________
Post-warmup lactate: ___________

**Remember to change workload on the metabolic cart

Criterion Test

Minute	mph/grade	HR	RPE	Lactate	Comments
5					
10					
20					

Post-test HR: ___________
Post-test BP: ___________
Post-test Hematocrit: ___________
Post-test Hemoglobin: ___________

APPENDIX D

SUBJECT CHECKLIST

Check Off List

Pre-testing Check List (tester)

1. Make sure supplies are ready and in abundance ____________
2. Get pan of hot water (if needed) ____________
3. Calibrate Lactate machine ____________
4. Calibrate Metabolic Cart ____________
5. Remember to change workloads ____________

Pre-testing Check List (subjects)

1. Fill out and explain Informed Consent ____________
2. Fill out and check over medical history ____________
3. Check over training history ____________
   - 25 miles/wk ____________
   - 10 km time < 50 minutes ____________
4. Get weight and height ____________
5. Get RHR and blood pressure ____________
6. Get body composition ____________

Chest (mm): ____________	Tricep (mm): ____________
AB (mm): ____________	Illiac (mm): ____________
Thigh (mm): ____________	Thigh (mm): ____________

7. Attach Polar watch ____________
8. Go over RPE scale ____________
9. Get pre-test hematocrit and hemoglobin ____________
10. Remind to move arms/hands for blood work ____________

Post-testing Check List

1. Get post-test hematocrit and hemoglobin ____________
2. Add data to recording sheets ____________
3. Confirm next appointment ____________