EFFECT OF COMPRESSION STOCKINGS ON CYCLING PERFORMANCE AND POST EXERCISE MUSCLE SORENESS IN MODERATELY TRAINED FEMALES

by

Korey Kilsdonk

A Thesis Submitted to the Faculty of

The College of Education

in Partial Fulfillment of the Requirements for the Degree of

Master of Science

Florida Atlantic University

Boca Raton, Florida

May 2012

EFFECT OF COMPRESSION STOCKINGS ON CYCLING PERFORMANCE AND POST EXERCISE MUSCLE SORENESS IN MODERATELY TRAINED FEMALES

by

Korey Kilsdonk

This thesis was prepared under the direction of the candidate's thesis advisor, Dr. Michael Whitehurst, Department of Exercise Science and Health Promotion, and has been approved by the members of his supervisory committee. It was submitted to the faculty of the College of Education and was accepted in partial fulfillment of the requirements for the degree of Master of Science.

SUPERVISORY COMMITTEE:

Michael Whitehurst, Ed.D.
Thesis Advisor

Robert Zoeller, Ph.D.

Tina Penhollow, Ph.D.

B. Sue Graves, Ed.D.
Chair, Department of Exercise Science and Health Promotion

Valerie J. Bristor, Ph.D.
Dean, College of Education

Barry T. Rosson, Ph.D.
Dean, Graduate College

April 12, 2012
Date

ACKNOWLEDGEMENTS

The author wishes to express his sincere thanks and love to family and friends for their support and encouragement. The author wishes to express gratitude towards Dr. Michael Whitehurst for his never-ending encouragement. He would additionally like to thank his peers, Trey Andrews and Dara Wittenberg, for their time and commitment.

ABSTRACT

Author:	Korey Kilsdonk
Title:	Effect of Compression Stockings on Cycling Performance in Moderately Trained Females
Institution:	Florida Atlantic University
Thesis Advisor:	Dr. Michael Whitehurst
Degree:	Master of Science
Year:	2012

Purpose: Determine effect of below knee compression stockings on metabolic and perceptual responses to cycling (i.e., BLa, HR, VO_2, and RPE) in moderately-trained female cyclists. **Methods:** Subjects (n=12) performed a graded exercise test (GXT) on a cycle-ergometer to assess VO_{2peak}. Subsequently, and on different days, two graded tests were administered (with, without stockings) with 5 minute warm-up at 50 W followed by 5 minute stages at 60 %, 70%, and 80% of max power output. Following the last sub-maximal stage, participants performed 3 - 5 supramaximal trials. Each lasted 30 seconds at 200% of her peak power output with HR, RPE, and BLa measured at the end of each trial. **Results:** No significant difference was observed between conditions for any metabolic or perceptual measure across workloads while perceived muscle soreness at 24 hours trended towards significance (p=.067). **Conclusion:** Compression socks did not significantly alter metabolic or perceptual responses to cycling.

EFFECT OF COMPRESSION STOCKINGS ON CYCLING PERFORMANCE AND POST EXERCISE MUSCLE SORENESS IN MODERATELY TRAINED FEMALES

LIST OF TABLES

LIST OF FIGURES

INTRODUCTION

Historically, compression garments (CG) have been used in clinical settings for the management of circulatory insufficiencies secondary to vascular pathology (e.g., blood clotting, deep veins thrombosis (DVT), and varicose veins (Morris & Woodcock, 2004; Sajid, Desai, Morris, & Hamilton, 2008). The theory behind CG is that the compression of lower body segments promotes lymphatic and venous return (Agu, Hamilton, & Baker, 1999; Doan et al., 2003; Watanuki & Murata, 1994). For example, Weiss and Duffy (1999) found class II (20 mmHg) compression garments reduced symptoms of lower body venous congestion in patients who stood for more than four hours. Similarly, Kraemer et al. (2000) found wearing various classes of graduated compression garments during the day minimized edema and muscle tissue disruption. Given the simplicity and potential benefits, it would appear that CG offer an effective means of combating circulatory insufficiencies.

Interestingly, in recent years, the use of compression garments has moved from the clinical setting to athletics, particularly endurance sports (Scanlan, Dascombe, Reaburn, & Osborne, 2008). Specifically, endurance athletes have adopted CG in hopes of improving performance, promoting recovery, and decreasing soreness.

Kemmler et al. (2009) evaluated the effect of CG on running performance in moderately trained runners. Subjects completed two stepwise speed-incremented

treadmill tests in a randomized order to voluntary maximum termination with and without below-knee compression stockings. The CG condition resulted in significantly greater work, speed, and higher anaerobic threshold. Similarly, Ali, Caine, and Snow (2007) examined running performance among healthy recreational male runners with and without knee-length graduated compression garments (pressure at ankle 18 – 22 mmHg). The researchers noted that 10 out of 14 runners ran faster with the use of knee-length compression garments. Finally, Scanlan et al. (2008) employed the use of a full length (i.e. hip to ankle) CG in a study using trained cyclists. Results of incremental tests to exhaustion and one hour time trials revealed increased power output at anaerobic threshold while wearing the CG.

Although limited, some data is available suggesting that CG can hasten recovery and reduce post-exercise soreness. In a study of runners, Ali et al. (2007), found that wearing knee-length CG resulted in lower blood lactate (Bla) and lower levels of perceived muscle soreness 24 hours post-exercise. Similarly, wearing CG during and after a high intensity (110% of VO_{2max}) cycling exercise, as compared to wearing CG only post exercise, has been shown to lower blood lactate (Berry, Bailey, Simpkins, & TeWinkle, 1990).

Thus, to date there are only a few studies that have attempted to evaluate the effects of CG on the metabolic responses (e.g. heart rate (HR), minute ventilation (V_E), oxygen uptake (VO_2), lactate threshold (LT)) to submaximal cycling exercise. The question of whether soreness can be alleviated with the use of CG is also explored in only a few studies. Moreover, there is only one published study in which a CG was employed

to determine their effect on cycling performance. Additionally, there is no consistency regarding the types of CG used across these studies, nor their quality. Some studies employ full length CG (i.e., waist to ankle) while others utilize below knee versions. The grade and reliability of the actual compression provided by the CG is inconsistent across studies. Finally, to the best of our knowledge, there are no existing studies that have examined these issues in moderately trained female cyclists.

This study attempts to determine if wearing a below knee, medical grade compression stocking alters the metabolic and perceptual responses to cycling (i.e., BLa, HR, VO_2, and ratings of perceived exertion (RPE)) in moderately trained female cyclists. The secondary purpose of this study is to determine if wearing a below knee compression stocking during exhaustive supramaximal exercise reduces post-exercise soreness.

Research Hypotheses

Wearing a below knee compression stocking will alter the metabolic response to sub-maximal cycling in moderately trained females compared to submaximal cycling without such stockings.

Wearing a below knee compression stocking will alter immediate and post exercise soreness in moderately trained female cyclists compared to soreness experienced without stockings.

LITERATURE REVIEW

To date, a few studies attempted to evaluate the effect of CG on endurance performance. The commonalities in these studies have been the measurement of metabolic responses (e.g. HR, V_E, VO_2, LT), as well as performance indices such as speed and time to complete a prescribed distance. In some of these studies, the question of whether soreness can be alleviated with the use of CS is also asked. There is only one published study in which a CG was employed to determine its effect on cycling performance. Additionally, there is no consistency regarding the types of CG used across these studies. Some studies employ full length CG (i.e., waist to ankle) while others utilize below knee versions. Moreover, the grade and reliability of the actual compression provided by the CG is not consistent across studies. Finally, only a few groups were studied, including novice and recreationally trained subjects. Given the scarcity of data and the varied methodologies employed in these studies, it is difficult to make any definitive statements about the influence of CG on endurance performance.

It is important to understand blood flow, movement of the body, hyperemia, and hemodynamics because each one of these components is influenced by the use of compression garments. Hyperemia is defined as an increased amount of blood flow to particular areas of the body (Sheriff & Van Bibber, 1998), mainly in the lower limbs

during exercise. Hemodynamics is the study of blood flow and the forces which act upon the cardiovascular system (Wray, Donato, Abhimanyu, Merlone, & Richardson, 2005). As the body goes from a supine position to standing erect or rest to exercise there is an amount of venous pooling in the lower limbs due to gravity. Because there are a wide variety of proposed mechanisms to elevate the venous pooling, the muscle pump will be the main focus here. Studies using animals and humans agree that the muscle pump helps to keep blood moving in the vasculature beds of the limbs (Radegran & Saltin, 1998; Sheriff & Bibber, 1998; Wray et al., 2005).

A brief review of the muscle pump will be completed prior to discussing the benefits of compression garments. Sheriff and Van Bibber (1998) conducted a study looking at the flow-generating capability of an isolated skeletal muscle pump. Their study tested whether the mechanical forces produced during muscle action act on the vasculature in a manner to initiate and sustain blood flow or not. Sheriff and Van Bibber used five anesthetized pigs. The hind limb muscle pump was isolated by reversibly connecting the inferior vena cava and terminal aorta with tubing. Following the creations of this short circuit, an electrically evoked contraction sent the venous blood out of the hind limb into the tubing. With the large short stunt offering negligible resistance to flow, the arterial-venous pressure difference across the limbs was at a continuous zero. Thus, the energy to drive flow through the muscle could have only come from the muscle pump. The authors concluded a mechanical force, produced by muscle contraction and relaxation, acts on the vasculature in a manner sufficient to generate blood flow. By creating a short circuit**,** the researchers showed one example of how the muscle pump

was able to send blood out of the hind limb by electrically stimulating the muscle to contract and relax.

Wray et al. (2005) state the predominate mechanisms implicated to increasing blood flow during the first few seconds of exercise remain the muscle pump and rapid vasodilatation. Seven non-smoking men were prescribed four different single leg exercises. These included voluntary exercise in the seated position, passive exercise in the seated position, passive exercise in the supine position with their legs above heart level, and passive exercise using the non-exercised control leg. Subjects were placed in a semirecumbent (~60 degree recline) position for all trials except the supine. The researchers found a contrasting heart rate and leg blood flow response between passive and voluntary exercise onset due to differences in relative contribution of mechanical, vasodilatory, and cardiac mechanisms. The muscle pump was minimized in passive movement but still resulted in a significant case of hyperemia. The studies by Sheriff and Van Bibber (1998) along with Wray et al. (2005) define how the muscle pump is thought to work by sending blood away from the muscles which are working back toward the heart.

The remainder of this literature review will focus on how compression garments were originally used in a clinical setting and how they are being used in endurance sports competition.

Clinical Use of Compression Garments

"Chronic venous insufficiency,**"** CVI, represents a group of disorders characterized by the retrograde flow of blood in the lower extremity (White & Ryjewski, 2005). According to White and Ryjewski (2005), the most common disorders which affect the human condition are varicose veins and venous hypertension. It is theorized that compression of lower body segments promotes lymphatic and venous return (Agu et al., 1999; Doan et al., 2003; Watanuki & Murata, 1994).

The use of compression garments on the legs can be traced back to the mid 1700's (Davison, 1906). According to Davison's book**,** the first elastic garment was developed in Nottingham by John Lombe (1906). Compression garments have been used to treat venous disorders since their development. Several studies look at how CG can help with venous refilling, function, insufficiencies, and congestions (Cornwall, Dore, & Lewis, 1987; Weiss & Duffy, 1999; White & Ryjewski, 2005; Zajkowski, Proctor, Wakefield, Bloom, Blessing, & Greenfield, 2002).

According to the European Classification of Compression Hosiery**,** compression garments are found in four classes, each based on the amount of pressure applied at the ankle, including but not limited to: (I) 14 – 17 mmHg, (II) 18 – 24 mmHg, (III) 25 – 35mmHg, and (IV) above 35 mmHg (Nazarko, 2009; Van Geest, Veraart, Nelemans, & Neumann, 2000). Nazarko states different indications for when each class should be used. Class one is used for a person that has mild varicosos or early lymphedema. They are also used during maintenance therapy. Class two compression garments are

considered to be a medium level of compression used on individuals with pronounced varicosos, post-traumatic swelling, or after thrombophlebitis. Strong compression, class three, is used on post-thrombotic venous insufficiency, severe lymphedema, or recurrent leg ulceration once healed. The fourth class, having very strong compression**,** is used in chronic lymphedema and elephantiasis (Nazarko, 2009; Van Geest et al., 2000). The suggested minimum pressure to improve venous return is 17.3 mmHg at the leg and 15.1 mmHg at the thigh (Watanuki & Murata 1994).

The following studies describe how variations of compression garments are being used to help different chronic insufficiency issues.

White and Ryjewski (2005) investigated chronic venous insufficiency. An impairment of the venous outflow from lower limbs could be due to failure of pumping mechanisms, loss of wall elasticity, or a vein valve incompetency. Patients with chronic venous insufficiency often complain of aching**,** throbbing**,** stinging leg pain, or a combination of the three after a prolonged period of standing or for a brief period of time after assuming the recumbent position. The treatment for chronic venous insufficiency is intended to control the retrograde flow and venous pooling along with the associated symptoms and complications. White and Ryjewski state CG have generally been accepted as the foundation of therapy.

Cornwall, Dore, and Lewis (1987), investigated the use of graduated compression and its relation to venous refilling time. The researchers studied a selection of below knee compression stockings available in hospital practice on patients with venous

diseases and normal subjects. This study was divided into two different research experiments**;** first testing for a significant linear trend with site so graduation and secondly using the satisfactory CG (6 pairs) to measure the effects of varying degree of compression and graduation on venous refilling time. First, they measured the pressure exerted on normal legs by a range of stockings with a Borgnis medical stocking tester. Thirteen normal volunteers were chosen so that each of the manufacturers' standard sizes could be tested at three different sites beneath the stocking. The Borgnis device is a thin tube with four paired electrical contacts on its inner surface, which is connected to a small air pump and an electric pressure transducer. Ankle and calf circumferences were taken before the application of compression garments, which were then tried in randomized orders. After the completion of the first experiment, six CG were selected to measure the effects of varying degrees of compression and graduation on venous refilling time. The same nineteen subjects were used in the second study; nine of which had deep venous insufficiency, ten had superficial vein incompetence. The use of photoplethysmography and Doppler ultrasound were used to help calculate venous refilling time. The calf was squeezed vigorously five times and the refilling time was recorded. This was repeated two additional times after a tourniquet was applied to the calf and then the thigh. The results of the second experiment concluded of the six pairs tested only three helped in venous refilling at a rate either, not significantly different from, or significantly greater than, the lower limit of the normal refilling time of 18 seconds in both superficial and deep vein incompetence. While, on the other hand, the

three unsatisfactory garments produced refilling times significantly below normal patients with deep vein incompetence.

In 1994, Watanuki and Murata conducted a study to determine the effects of CG on cardiovascular responses; heart rate, cardiac output measured by CO_2 rebreathing method, and oxygen intake. The measurements were taken at rest in a supine position for 40 minutes and standing position for 120 minutes. Resting in the supine position for 40 minutes is needed to stabilize the plasma volume when changing the body position from standing to supine. While in the standing position, subjects set their arms on a stand to help maintain their standing position with minimal movement. Six female subjects wore CG after twenty minutes of rest at the supine position. In the standing position, cardiac output and stroke volume were significantly larger when wearing GC than the control, while the heart rate was significantly lower than the control. While no significance was found, there was a remarkable difference in thigh girth with the use of compression and prolonged standing. The effects of CG on females in prolonged standing found to help venous return.

Compression garment studies conducted by Ibegbuna, Delis, Nicoladies, & Aina (2003) compared the effects of CG on venous hemodynamics during walking. Using ten limbs of nine women with primary chronic venous insufficiency, the residual volume fraction (RVF) was monitored during treadmill walking with air-plethysmography (APG). They used four speeds with and without compression garments having 21 mmHg of compression at the ankle. The walking program started with the subject lying supine with the APG cuff around the ankle, while the leg being examined was elevated.

Subjects were asked to stand still on the level treadmill waiting until the venous filling was complete, as determined with APG. Initially, the subjects walked at 1.0 km/h for two minutes, then 1.5, 2.0, and 2.5 km/h for one minute each. Once the five minutes of walking was complete, subjects stood still until venous refilling was completed and then resumed the supine position. The same protocol was used while wearing the compression garment. During walking, there was an initial rapid increase in venous volume followed by steady-state which is why RVF was measured after the first minute. All RVF measurements were taken during the last 15 to 30 seconds of each speed. The compression garment helped to improve RVF when walking at all speeds between 1.0 – 2.5 km/h. Residual volume fraction decreased by 19-20% at speeds of 1 – 2 km/h and by 14.2% at 2.5 km/h. These results were linearly correlated with the amount of reflux. Significant improvement was found in venous hemodynamics through the reduction in RVF in limbs with primary chronic venous insufficiencies at various walking speeds when CG were worn.

In 1999, Weiss and Duffy investigated the clinical benefits of light weight compression. This study evaluated the effects of ready-to-wear CG on the symptoms of patients with standing occupations over a four week period. The subjects used were active flight attendants assigned to international flights. A total of nineteen females completed the study which consisted of wearing the CG, along with completing and returning a questionnaire. The subjects were involved in a prospective crossover design and acted as their own controls. There were three phases to this study. In phase one they used no compression, phase two used 8 – 15 mmHg compression, and phase three used a

compression of 15 – 20 mmHg. Weiss and Duffy found all attendants reported symptoms of leg fatigue when no compression was used. During phase two, using the 8 – 15 mmHg CG, several responses were found. Aching, tightness, and fatigue in the legs all improved by wearing the lightweight CG. Only ten flight attendants wore the 15 – 20 mmHg compression garments. Just as with the previous results, a reduction in swelling, fatigue, and tightness were reported. Even with a small sample size and the subjective nature of the data, the conclusions are evident; wearing lightweight CG can help to improve various venous symptoms if worn consecutively for four weeks.

In 2004, Prandoi et al., studied below-knee CG to prevent the post-thrombotic syndrome. The study was a randomized control trial, in which the CG were worn for two years, trying to prevent the post-thrombotic syndrome in patients with first episode of proximal DVT. The main goal was to compare the five-year cumulative incidences of post-thrombotic syndrome in patients who wore CG to those who did not. A total of 180 subjects took part in the study. Subjects were randomly assigned to wear, or not wear, CG (30 – 40 mmHg at the ankle) for two years. Using a standardized scale, the presence and severity of post-thrombotic syndrome was scored. Within the first two years, post-thrombotic sequel developed in 23 out of 90 subjects wearing compression garments. The results of the study showed that CG are well tolerated and reduce the overall incidence of post-thrombotic syndrome from 49% to 26% and the overall incidence of severe sequel from 12% to 3.5%.

Endurance Sports Use of Compression Garments

Interestingly, in recent years, the use of compression garments moved from clinical settings to athletics, particularly endurance sports (Scanlan et al., 2008). Numerous studies done over the past fifteen years on athletes wearing CG have shown changes in performance, promoting recovery, and decreasing muscle soreness (Ali et al., 2007; Doan et al., 2003; Duffield & Portus, 2007; Kemmler et al., 2009; Rimaud et al., 2007; Scanlan et al., 2008).

In 1987, Berry and McMurray completed a study in which they wanted to see the effects of CG on blood lactate (BLa) following an exhaustive bout of exercise. This study was broken down into two different experiments. The first experiment looked at the effects of CG on maximal oxygen consumption, time to exhaustion during a VO2 max test, and blood lactate levels during recovery from a VO_2 max test. For the second part of the study, Berry and McMurray evaluated the retention of lactate by manipulation of the CG at the end of exercise. A total of six highly fit male college students severed as subjects. Experiment one consisted of a random design in which the subjects completed a VO_2 max test and time to exhaustion, with or without compression garments (18 mmHg at the ankle). The treadmill test was set to elicit a heart rate of 130 beats per minute. After running at this speed for 15 minutes the grade was increased 2.5 percent every 2 minutes until the subject reached exhaustion. Oxygen consumption was measured at various points; at rest, during the last minute of the 15-minute of steady state, during the second minute of every work stage, during the last minute of the test, during minutes one through five of recovery and minutes 15, 30, 45, and 60 of recovery. Along with the

oxygen collection, five milliliter samples of blood were taken during rest and at 5, 15, 30, 45, and 60 minutes post-exercise. The only significance found was the use of CG created a lower level of BLa following exercise. The second part of this study used six healthy male college students who regularly participated in a fitness program. For this study the subjects came 3 times and use a Monarch bike ergometer to determine their VO_2 max. For the remaining visits the subjects would exercise at 110% of their VO_2 for a 3 minute period under one of the following conditions: CG for exercise and recovery, CG just for exercise, or as a control with no CG wore (18 mmHg at the ankle, same CG used in experiment one). Oxygen consumption was measured during a five minute rest period along with the post-exercise recovery in the supine position. Once again they also took a five milliliter blood sample at rest and at minutes 5, 15, and 30 post-exercise. The only significance found through this experiment was in BLa levels when comparing the CG and the non-CG trials, along with CG for exercise and CG for exercise and recovery. Thus the main finding of this study was the recovery lactate values were lower with the use of compression garments. The lower lactate levels suggest there is an inverse gradient created by CG resulting in the lactate being retained in the muscular beds.

Doan et al. (2003) conducted an evaluation of lower body compression garments. The subjects were 20 nationally competitive collegiate track athletes. The CG was custom fit to each individual's specific measurements but was made hyper-compressive (15% smaller than the measurements). The experiment used the CG and regular gym shorts. Each subject performed a series of different tests which included a 60 meter sprint, jump test for power, and muscle oscillations. Doan et al. observed several effects

the CG may have on athletic performance. A rise in skin temperature during warm-ups, muscle oscillation decreased significantly during vertical jump landings, and countermovement jump heights increased. These results show the CG help to generate a performance enhancement by helping the muscle to create more torque reducing the risk for injuries.

Duffield and Portus in 2007 studied the use of full-body compression garments. Ten physically fit, male, club-level cricket players were recruited for the study. The subjects completed 4 randomized exercise sessions. Each session was composed of distance throwing, accuracy throwing, and a 30 minute intermittent repeat sprint protocol consisting of a 20 meter sprint every minute, separated by 45 seconds of submaximal exercise. Several measures were taken over the course of the experiment, which included heart rate, skin temperature, RPE, and muscle soreness (before and 24 hours after). These measures were taken before, after, and 24 hours post-exercise. Blood was taken before and after exercise to examine BLa, pH, partial pressure of oxygen, and creatine kinase. The subjects wore the CG the 24 hours post-exercise when another blood sample was taken to measure creatine kinase, a marker of muscle damage. Duffield and Portus found significant differences in skin temperature during exercise, a reduced creatine kinase level 24 hours after exercise, and a difference in the rating of muscle soreness 24 hours post-exercise. This study concluded the use of CG as a tool for recovery, the same result as Doan et al. (2003).

Also in 2007, Ali et al., examined running performance among fourteen healthy recreational male runners with and without compression garments (18 – 22 mmHg at the

ankle). This study was done in two experiments. The first was an intermittent running program, where the runners performed two multi-stage shuttle tests with and without CG; and the second design was a continuous 10-kilometer road test. The subjects acted as their own controls in a randomized crossover design. The intermittent test consisted of a 20 meter shuttle run at a progressive pace, starting off slowly and adding speed at every audible beep. Subjects were withdrawn from the test by investigators when they failed to keep up with three successive bleeps. The second experiment was a timed 10 kilometer run done outside. The researchers noted that 10 out of 14 runners ran faster with the use of compression garments. Wearing CG resulted in lower BLa and lower levels of perceived exertion 24 hours post exercise, as well.

Another study, Scanlan et al. (2008), employed the use of a full length, i.e. hip to ankle with a pressure of 19.5 mmHg at the ankle, CG in a study using trained cyclists. Twelve well trained cyclists were used as subjects. Each one completed four total tests; two one-hour time trails and two incremental stepwise tests. The stepwise tests were completed to determine anaerobic threshold and VO_2 max with and without compression garments. The test was completed using a Lode bike ergometer. Subjects warmed-up for five minutes then started at 100 watts. The resistance was increased 50 watts every three minutes until any of the following occurred: volitional exhaustion, attainment of age-predicted max heart rate, or a Respiratory Exchange Ratio of greater than 1.15. Subjects in the one-hour time trails warmed-up at 100 watts and then continued to start the time trails at a self-selected power output, maintaining 90 – 100 RPM throughout the test. Results of the incremental tests to exhaustion and one-hour time trials revealed an

increased power output at the anaerobic threshold while wearing the CG. The increase in power output at the anaerobic threshold during the incremental test could be related to an increase in venous return and a higher level of lactate removal. Scanlan et al. show CG may delay the onset of fatigue and prolong optimal performance in well-trained cyclists.

Kemmler et al. (2009) evaluated the effect of CG on running performance in moderately trained runners. Twenty-one moderately trained male runners were the subjects. The subjects completed two stepwise speed-incremented treadmill tests in a randomized order to voluntary maximum termination with and without below-knee CG with a compression of 24 mmHg at the ankle. The protocol setup was based off the known performance of each subject, with an initial starting speed of 9 – 11 kilometers per hour. Every 5 minutes the speed was increased by 1 kilometer per hour. Oxygen uptake, ventilation, and carbon dioxide production were monitored continuously with max values determined from the average of the last minute of exercise. Blood lactate was also taken at rest and at the end of each exercise level. Compression garments covering the calf muscle affected the subjects running performance at various metabolic stages. The CG resulted in greater work, superior speed and a more favorable anaerobic threshold.

These studies show how compression garments are used in sports to enhance performance, promote recovery and reduce muscle soreness. With the variation in CG style (i.e., complete lower body, shorts, below knee) and levels of compression used, shows the need to research the use of below knee compression garments in moderately trained female cyclists.

METHODS

Subjects

Twelve moderately-trained female cyclists were recruited from the Boca Raton community (see Appendix A). To be included, (See criteria in Appendix B) participants must have been 1) cycling (indoor and/or outdoor) 8-12 hours/week for a minimum of 6 consecutive months 2) been between 18 – 45 years of age and 3) possessing a VO_{2max} of less than 50 ml/kg/min. Subjects were excluded, if they had any history of major musculoskeletal or cardiorespiratory disorders that could otherwise affect testing procedures or outcomes. This protocol was approved by the Florida Atlantic University Institutional Review Board for Human Subjects Research, and all subjects provided informed written consent prior to participation.

Study Design and General Testing Procedures

Participants attended three separate laboratory sessions in Fieldhouse 11-A on the FAU Boca Raton campus, at approximately the same time of day, with the first session including familiarization (Informed Consent and Health History; see Appendixes B and C) and an incremental graded cycle-ergometer test to failure to determineVO_{2peak}. The two additional laboratory sessions, each one week apart and randomized, required the participant to perform a graded cycle-ergometer test, one with medical grade below knee

compression stockings and one without. The compression stockings were fitted according to the sizing chart from the company supplying the stockings (CEP, Germany) with sizing based on calf circumference. The calf circumference was taken at the widest point of the muscle by using an elastic measuring tape.

An electrically braked cycle-ergometer (Excalibur Sport V2 cycle ergometer, Lode BV: Groningen, The Netherlands) was used for all three tests. The cycle ergometer was adjusted for proper fit to reflect the measurements on the participant's road bicycle (e.g. saddle position – height and fore/aft, handlebars vertical and fore/aft; (see Appendix D for instructions on bicycle measurements). During testing, an open circuit spirometry system was used to collect and analyze respiratory gases (True One 2400+ Metabolic Measurement System, Parvo-Medics Inc., Provo, UT) with data averaged over 30-second intervals. The metabolic cart was calibrated prior to each test with room air for flow rate and gases (i.e., O_2, CO_2) of known volume and concentration. Calf circumference, HR (Polar HR monitor, Kempele, Finland), RPE (Borg Scale 6-20) and BLa (YSI-2300 Stat Plus Lactate Analyzer, Yellow Springs Instruments, Yellow Springs, OH) were measured throughout testing. Participants were reminded not to deviate from their usual dietary plan and to avoid eating at least three hours prior to testing.

VO_{2peak} Test

After a five-minute warm-up at 25 Watts (W), the VO_{2peak} protocol consisted of three-minute stages with an initial workload of 50 W, which was increased in increments of 25 W per stage. Subjects pedaled at a cadence between 85 - 95 revolutions per minute

(rpm). The test was terminated when cadence could no longer be maintained or due to volitional exhaustion. Criteria for a maximal/peak effort were an attainment of 2 of the following: RER $\geq$ 1.15, plateau in HR and/ or VO_2, or rating of perceived exertion (RPE) of $\geq$ 19 (6 – 20 Borg scale). In addition to HR and respiratory gases, blood lactate was measured at rest, at the end of each exercise stage, and four minutes post-exercise from fingertip capillary blood samples drawn using micro-capillary tubes and analyzed immediately. After the test, subjects were actively cooled-down at 50 W for five minutes.

Submaximal Cycle Ergometry Tests

The two graded tests, with or without compression stockings, began with a five minute warm-up at 50 W followed by five minute stages at 60%, 70%, and 80% of the subject's maximal power output obtained during the VO_{2peak} test. Compression stockings were put on immediately prior to testing and removed immediately following testing. Pedaling rate was maintained between 85 - 95 rpm. Following the last five-minute stage, an active recovery took place at 50 W for five minutes. Participants were then allowed to remove the mouthpiece before performing three to five supramaximal trials. Each trial lasted 30 seconds with a workload of 200% of peak power output (from VO_{2peak} test) at an RPM $\geq$10 revolutions above that achieved during peak testing. There were three minutes of active recovery between supramaximal trials at approximately 25% of their peak power output at a freely chosen RPM. If participants could not maintain the higher RPM at the beginning of the supramaximal test, the test was terminated. The HR, RPE, and BLa were collected at the end of each supramaximal trial with blood lactate samples

also collected at 5, 15, and 30 minutes post exercise. A five minute cool down followed the final supramaximal bout. Immediately following the supramaximal test subjects were asked to rate their soreness level using a 7 point Likert scale of muscle soreness (7 = very sore, Vickers, 2001).

Subjects were not sequestered during the post-exercise period. Rather, participants were instructed not to participate in exercise of any kind or exert themselves for a full 24 hours post exercise. That is, participants returned to the lab 6 hours and 24 hours post exercise to report their level of perceived soreness (1-7 point scale).

Data Analysis

A 2-way repeated measures ANOVA (CG condition by exercise intensity (60, 70, 80 % of peak power output) was performed on the variables of interest from the sub – maximal tests. Two-way repeated measures ANOVA (CG condition by time) were also performed to evaluate post-exercise soreness immediately post, six, and 24 hours. Post-hoc paired t-tests were used when appropriate to probe for statistical significance. A p value <0.05 was accepted as statistically significant. The statistical analysis was performed using the Statistical Package for Social Sciences (SPSS) for Microsoft Windows (Version 17.0, 2006; SPSS, Inc., Chicago, IL).

RESULTS

The results of this study can be seen in the following pages. Table 1 presents participant demographics and fitness data.

Table 1 Participant Demographic and Fitness Data

Age (years)	31.58 ± 8.17 (23 – 45)
Height (cm)	169.62 ± 6.45 (163 – 176)
Weight (kg)	61.08 ± 10.92 (51 – 71)
Body fat %	22.70 ± 6.88 (16 – 28)
Calf Size (cm)	34.87 ± 3.30 (31 – 38)
Heart Rate (bpm)	178.17± 12.47 (160 – 198)
RPE (Borg Scale)	17.51 ± 2.12 (13-20)
VO2peak (ml/kg/min)	44.09 ± 5.44 (39 – 49)
Peak Power Output (Watts)	206.66 ± 18.98 (187 – 225)
Lactate Threshold (bpm)	157.75 ± 11.37 (146 – 168)
Average # of hrs cycling / wk	9.58 ± 2.84 (7 – 11)

Values are means ± SD; Range in parentheses

Physiological and Perceived Exertion

The physiological and perceived data were generated during continuous cycling in three by five minute ascending intervals (i.e. 60, 70 and 80 percent) based on max workload attained during the $VO_{2\ peak}$ test. No significant difference was observed for any physiological or perceived measure across workloads and conditions (see Table 2).

Table 2 Physiological and Perceived Exertion by Condition across Workloads

Physiological Data						
Variable	Sock			No Sock		
	60%	70%	80%	60%	70%	80%
HR (bpm)	143.36 ± 11.82 (132 –154)	157.54 ± 13.90 (143–171)	168.90 ± 13.55 (154 - 181)	143.63 ± 14.24 (129 – 156)	155.63 ± 14.70 (140 – 170)	168.54 ± 14.91 (154 - 183)
Bla (mmol/L)	2.66 ± 1.01 (1.6 – 3.6)	4.43 ± 1.55 (2 – 5)	6.51 ± 2.53 (4 – 9)	2.89 ± 0.88 (2 – 3.6)	3.76 ± 1.04 (2 – 4)	6.33 ± 1.84 (4 – 8)
VO2 (ml/kg/min)	29.7 ± 3.25 (26-33)	33.4 ± 2.90 (30–36)	38.11 ± 3.68 (34 – 41)	29.25 ± 3.32 (25 - 33)	33.88 ± 3.87 (29 - 37)	38.20 ± 4.40 (33 - 43)
RPE (Borg Scale)	10.59 ± 1.71 (8 – 12)	12.68 ± 1.38 (11- 13)	14.63 ± 1.81 (12 – 16)	11.18 ± 1.47 (9 – 13)	13.04 ± 2.10 (11 - 15)	14.86 ± 1.92 (12 - 16)

Values are means ± SD; range in parentheses

Figures 1 and 2 show the CS and no CS (NS) conditions for RPE and HR through the five supramaximal trials. The apparent differences between condition in RPE for trial four (CS 19 ± 0.89443, NS 18.55 ± 1.50923) and trial five (CS 19.3 ± 0.67495, NS 18.875± 0.99103) failed to reach significance. Similarly, although supramaximal HR differed between conditions at trial two (CS 168.636 ± 11.30728, NS 170.4 ± 13.84999), four (CS 167.454 ± 9.83223, NS 168.9 ± 12.16963) and five (CS 167.7 ± 11.35341, NS 170.5 ± 11.10984), they failed to reach significance.

Figure 1 Average RPE

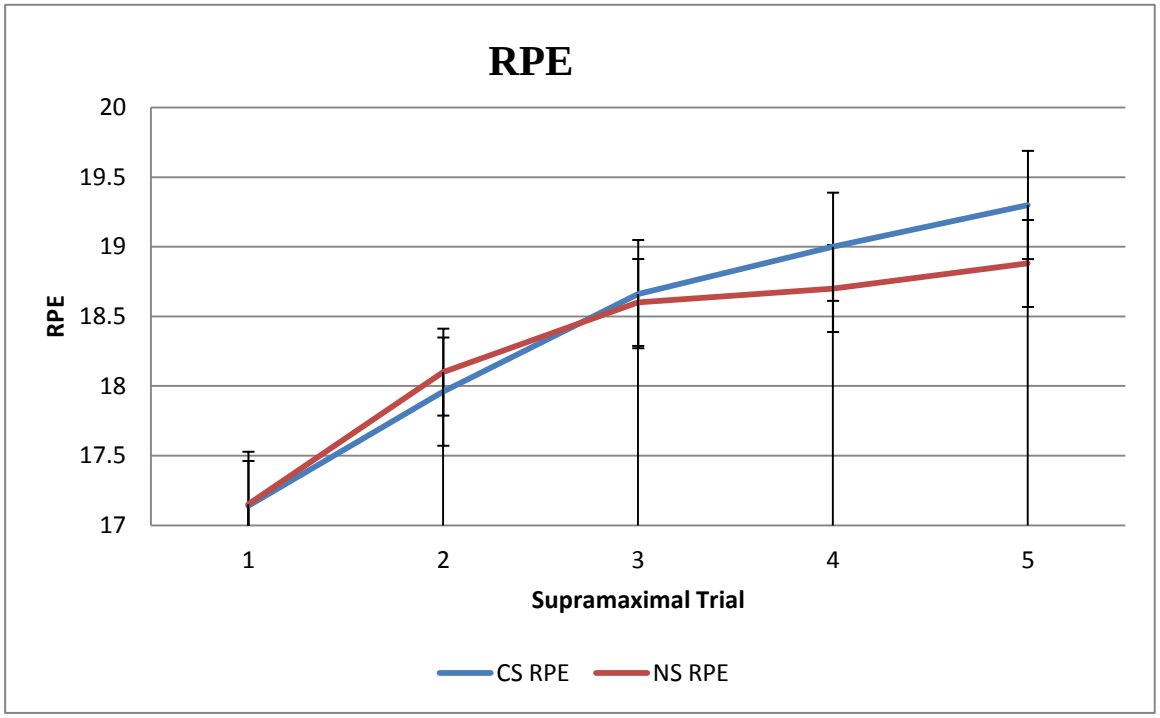
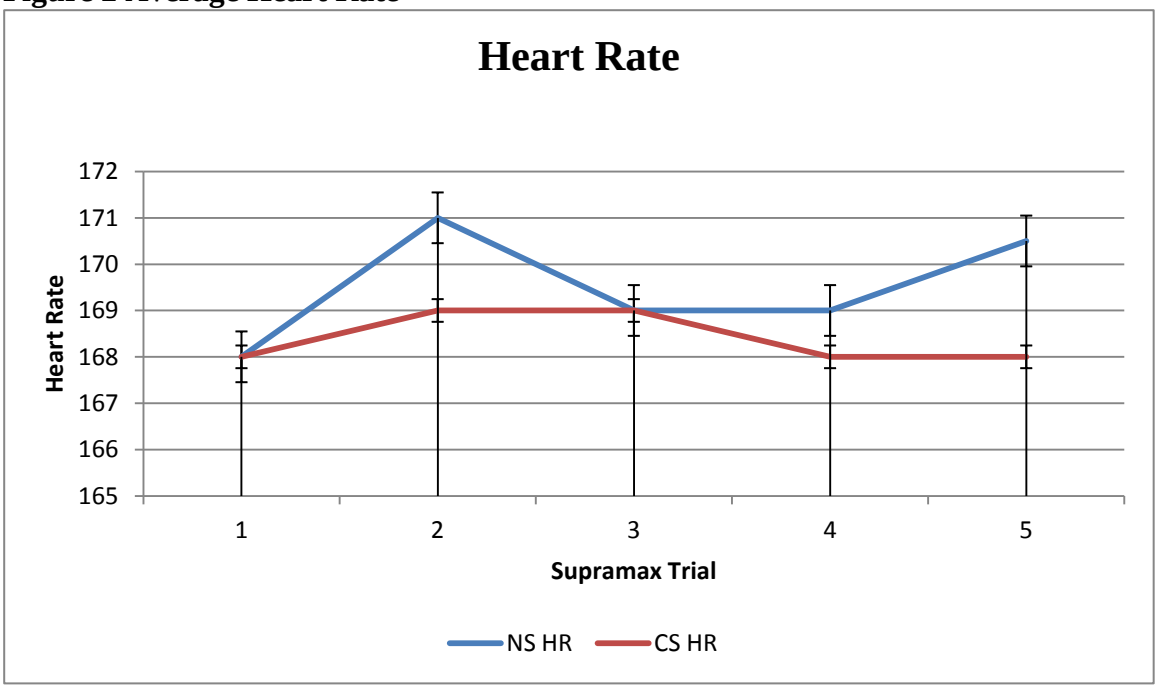


Figure 2 Average Heart Rate



Post Exercise Muscle Soreness

The participants' perception of muscle soreness following the supramaximal testing is shown in Table 3. Although perceived muscle soreness was not significantly different between conditions across any time point, the 24 hour measure trended towards significance (p=.067).

Table 3 Perceptual Data

Perception						
Variable	Socks			No Sock		
	30m	6 h	24 h	30 m	6 h	24 h
Muscle Soreness (7 pt Scale)	1.81± 1.53 (0.3 – 2.3)	1.72±1.48 (0.25-3.25)	.9 ±1.48 (0 – 2.7)	1.9 ±1.62 (0.3–3.5)	1.90±1.62 (0.3 – 3.5)	1.63±1.80 (0 – 3.4)

Values are means ± SD; range in parentheses

DISCUSSION

This study sought to determine if wearing a medical grade below knee compression stocking influenced metabolic and perceptual responses during cycling and post-exercise muscle soreness in moderately trained females. No significant difference was observed between conditions during submaximal and supramaximal cycling nor did the cyclists report a significant difference in perceived muscle soreness while wearing CG for any post exercise time period. To date, only a few studies have attempted to evaluate the effect of compression garments on exercise performance and post exercise muscle soreness. These studies share commonalities across training methods and modes of training, which include running and cycling and performance measures (i.e. HR, V_E, VO_2, LT, time) (Ali et al., 2007; Kemmler et al., 2009; Scanlan et al., 2008). Of these studies, only two actually found significant improvements in performance as a result of employing compression garments (Ali et al., 2007; Kemmler et al., 2009), while three found significantly less post-exercise muscle soreness when compression garments were worn either during (Ali et al., 2007; Scanlan et al., 2008) or after (Duffield & Portus, 2007) exercise. Finally, additional commonalities were the time measurements associated with perceived muscle soreness, including up to 24 hours post-exercise.

Although the present study was unable to demonstrate a significant compression effect, there was a trend ($p=0.067$) for muscle soreness to be reduced 24 hours post-

exercise. Interestingly, perceived muscle soreness peaked in the present study at 6 hours but was lowest (i.e. 0.9 out of 7) at 24 hours under the compression condition. These results may have been influenced by several factors. First and speculatively, the exercise phase of the experiment in which subjects performed consecutive five minute bouts of cycling exercise; representing 60, 70, and 80% of peak power output may have been too short to have challenged the subject enough to reveal any performance advantage via compression. Still, and more importantly, the first question asked in this study was whether compression had any effect on metabolic response. Specifically, there was no advantage from wearing compression socks during cycling in moderately trained females. As such, the original hypothesis stating that there would be a difference in performance between conditions was not supported.

Another factor that was a likely contributor to the lack of significant findings in this study was the type of muscle contraction inherent in the mode of exercise performed in this study, namely, cycling. That is, cycling is predominantly concentric as opposed to eccentric, which by nature, may have been inadequate in inducing soreness. In an attempt to overcome this inherent problem, the second part of the study created an extreme overload condition which was unfamiliar to the subjects. The overload included near all-out supramaximal efforts of 30-second bouts of cycling followed by a brief recovery repeated three to five times. Judging by the perception of effort and extreme fatigue visible on the faces of the subjects, it is likely that the supramaximal bouts of cycling pushed the subject to their maximum capacity. However, it is reasonable to conclude that the cycling, while extremely challenging in terms of work, failed to induce

enough soreness to determine the effects of compression. As such, the results did not support the second hypothesis, i.e., soreness would not differ as a result of compression. Again, given the concentric nature of cycling exercise, inducing soreness is a particular challenge. Future investigations in which presumed benefits of compression garments are evaluated among endurance athletes should attempt to identify protocols that safely induce soreness.

In conclusion, compression stockings did not alter the metabolic and perceptual responses of moderately trained female cyclists.

APPENDIX A

Effect of Compression Stockings on Cycling Performance, Post Exercise Muscle Soreness in Moderately Trained Females

Research Study

Florida Atlantic University

Exercise Science and Health Promotion Lab

Field House 11A

Effects of Compression Stockings on Cycling Performance in Moderately Trained Females

Free for participants:

- VO2 Test
- Body Composition
- Lactate Threshold

Qualifying Criteria:

- Female cyclists
- Min. 6 month of training
- 8 – 12 hours per week of indoor/ outdoor
- 18 – 45 years old

IF INTERESTED, PLEASE CALL

Korey 954.422.2227

APPENDIX B

RESEARCH SUBJECT INFORMATION AND CONSENT FORM

TITLE: **Effect of Compression Stockings on Cycling Performance, Post Exercise Muscle Damage/Soreness in Moderately Trained Females**

PROTOCOL NO.: **10-133**

INVESTIGATOR: **Michael Whitehurst, Korey Kilsdonk, Trey Andrews, Delynox Cortez, Robert Zoeller, Dara Wittenburg, Sarah Rew, Phil Huang**

SITE(S): **Florida Atlantic University, Boca Raton Campus**

STUDY-RELATED PHONE NUMBER(S): For PI: 561.297.2317 (office), 561.302.2674 (cell)

PLEASE READ: This consent form may contain words that you do not understand. Please ask the study doctor or the principal investigator (Dr. Whitehurst) or the study staff to explain any words or information that you do not clearly understand. You may take home an unsigned copy of this consent form to think about or discuss with family or friends before making your decision.

SUMMARY

As a research participant, please know that we are in no way providing ANY form of health assessment or health care. Rather, we are attempting to determine if wearing a compression stocking during exhaustive exercise (cycling) helps you perform better and reduces muscle damage/soreness. As a research participant it is your right to withdraw from the study at any time for any reason or simply decide not to participate in a particular aspect of the study. It is your responsibility (as well as ours) to be vigilant with regard to how you are responding during the exercise and even how you might feel when we draw blood from your arm. That is, if for any reason you don't like the way you feel or how we are administering any aspect of the study, please inform us immediately. Finally, as a research participant in this study please know that we are going to draw blood from your arm(s) 4 times during the course of a 24 hour period ON two occasions separated by approximately seven days.

PURPOSE OF THE STUDY

To determine if wearing a below knee compression stocking during exhaustive exercise improves your cycling performance and reduces muscle damage/soreness. To answer this question we will compare your physical responses when cycling with and without the compression stockings. Additionally, and perhaps most importantly, we will be measuring a protein in your blood that, when elevated, reflects muscle damage. Ultimately, we may get a good idea if wearing a compression stocking during hard workouts can reduce muscle damage.

Initials:_____

PROCEDURES

Assuming that you have met the criteria listed below:

- Participate in endurance training (triathlon), cycling (indoor or outdoor) 8 - 12 hour/wk for at least 6 months
- Between the ages of 18 – 45
- Present veins that are relatively easy to obtain blood from

You will report to the Exercise Science Laboratory directly behind the FAU Field House to complete THREE exercise tests (each about 7 days apart) on a modified laboratory bicycle ergometer (a stationary bike). TWO additional visits per each day of testing for blood draws are required. In all there will be a total of SEVEN visits to the lab. During the first day of testing, you will read and sign a consent form and health history, review with the investigator (s) the purpose of the research, and become familiar with the testing procedure. Following the paperwork and familiarization process, an investigator will measure your calf circumference on the dominant leg (to determine the size of compression stocking you will wear at another test during the experiment) prior to you taking part in what is called a maximum oxygen consumption test (e.g. the max test) on the bicycle, a laboratory contrived way to measure your maximum aerobic capacity. The max test provides the investigators with a baseline from which to start the two remaining tests on the bicycle.

Assuming that the lab bike has been adjusted to reflect the dimensions of your road bike, the test is administered as follows:

- You will place a heart rate strap around your chest (similar to one you use when you train). The strap sends a radio frequency transmission to a receiver which displays your heart rate in beats per minute.

- You then mount the bicycle ergometer in order to be fitted with a one-way breathing valve (like a snorkel used for swimming/diving). The valve allows you to breath-in room air but directs your exhalations into a six foot plastic tube connected to gas analyzers in series with a computer. The analyzers and computer provide information concerning the amount of oxygen you actually consume during the test, a direct measurement of your aerobic power (i.e. the more oxygen you can consume or process the greater your aerobic capacity).

- The test is administered in three minute stages of increasing workloads (resistance you pedal against). The first workload will be light (50 watts – comparable to riding at 10-12 mph) and increasing every three minutes by 25 watts until the test is terminated (approx. 20-30 minutes). The criteria for termination are an inability to maintain YOUR self- selected rpm (typically 85-90) with increasing workload and exhaustion (inability to continue).

- Know that after each stage a few drops of blood will be collected from your finger tip using a disposable lancet. The blood will be collected in a capillary tube and subsequently analyzed for lactic acid content.

Initials:_____

- Additionally, after each stage, you will be asked to select a number between 6-20 (20 = extremely hard - all out) to reflect your total body feeling and the physical demands of each stage.

- Although the max test will take approximately 20 minutes, the entire session including paperwork, familiarization and max test will take about 90 minutes.

The two remaining tests, each administered approximately one week apart, will be very similar to the max test in terms of using the bike and having your heart rate monitored as well as having you wear the mouthpiece so that we can direct your exhalations to the computer to determine how much oxygen you are consuming during the test. However, the two remaining tests differ from the max test as follows:

- On one of the two remaining bike tests (randomly chosen), you will wear a below knee compression stocking (CS). You will be fitted with a CS according to your calf circumference measured on the first day of testing. Know that the CS is of medical grade and is graduated with the compression greatest at the ankle and the least at the calf.

- Each of the two remaining tests includes two parts: part one - five minute stages at your freely chosen rpm with stage one starting at 50 watts, stage two at 60% of the maximum watts you generated during the max test (e.g. 150 watts or about 18 miles per hour on your bike), stage three at 70% of the max watts, and stage four at 80% of your maximum wattage.

- After a five minute recovery (ride at 50 watts at an rpm of 50-70), the investigator will administer part two - what is called a supra-maximal workload consisting of 200% of the maximum workload or watts you produced during the max test on day one. NOTE: the mouthpiece and associated equipment will be removed for this part of the test.

- There will be 3 – 5 supramax trials lasting 30 seconds each at the 200% power output at an rpm that is approximately 10% higher than you achieved during the max test. There will be 3 minutes of active recovery between trials (spin against no resistance).

- As with the max test, you will be asked to rate your level of perceived exertion (6-20) following each stage of the supramax trial.

- You must be no less than 10 rpms of your freely chosen rpm plus 10% value OR the supramax portion of the test will be terminated. It is anticipated that you will complete a minimum of three trials.

PLEASE UNDERSTAND THE SUPRAMAX TRIALS ARE INTRODUCED TO CREATE MUSCLE DAMAGE AND MAKE YOU SORE! GIVEN THAT YOU HABITUALLY EXERCISE, AND ARE LIKELY TO HAVE PERFORMED INTERVAL TRAINING, YOU HAVE PROBABLY EXPERIENCED A SIMILAR KIND OF DAMAGE/SORENESS. The CS and non-CS exercise tests will take approximately 60 minutes each.

Initials:_____

For each of the CS/no CS test days, an investigator experienced in phlebotomy will draw 10 ml (1 ml is 1000th of a liter or quart or in practical terms about 2 teaspoons) of blood from the median cubital vein (inside of arm at the elbow) approximately 30 minutes before testing, immediately post - test, six hours post, and 24 hours post (we will alternate arms). The six hours post and 24 hours post-exercise blood draws require that you return to the lab for a total of 15 minutes each. Since you will not be sequestered during the post-exercise period, it is IMPERATIVE that you DO NOT participate in exercise of any kind or exert yourself during the six hours post exercise or during the following day prior to the 24 hour post-exercise blood draw. Additionally, you will be asked to rate your level of soreness based on a 1-7 point scale (7 = very sore) at the time of each blood draw. Finally, please know that we have created a relatively private area for blood draws wherein we emphasize safety and cleanliness at all times.

The vacutainer into which blood will be drawn from your arm will be coded numerically then spun in a refrigerated centrifuge to separate the large proteins (e.g. RBCs, platelets) from the serum. Your samples will be stored in a -80 degree freezer for analysis, not to exceed six months. Please know we are interested in testing several milliliters of your serum for a marker of muscle damage known as skeletal troponin. It is the skeletal troponin that is central to this study. That is, will wearing CS influence performance and muscle damage/ soreness as expressed by skeletal troponin levels in your blood? Finally, we may also test your serum for inflammatory markers (e.g. C-reactive protein). However, we WILL NOT test your whole blood or serum for anything besides that which is specifically stated in this consent. Moreover, your blood samples, without any form of identification, will be disposed of in hazardous waste containers immediately following the analysis.

RISKS AND DISCOMFORTS

The risks associated with this study include:

- Pain and possible infection from the finger stick method used to obtain several drops of blood in order to measure lactic acid concentration (single use disposable lancets). The investigator is experienced in the finger stick method and will employ standard safety and cleanliness procedures. That is, the investigator uses protective gloves; the fingertip or area will be disinfected with an alcohol swab prior to each stick. All blood collection equipment is single use with used products disposed of immediately in hazardous waste containers
- The obvious risk during venipuncture is the development of infection at the site (i.e. the medial cubital vein - at the inside of elbow) of placement of the needle used to withdraw the blood. There is a slight risk any time the skin is broken. Other risks include excessive bleeding, fainting or feeling light-headed. The formation of a hematoma under the skin (blood accumulating under the skin) and the need to perform multiple punctures to locate the veins are other risks. A hematoma and multiple punctures usually heal with time. The person drawing the blood is well trained and performs the procedures using standard disinfecting procedures. Precautions taken are rather standard - disinfection of the site of needle insertion and use of sterile technique throughout the procedures. We will ascertain if you are taking medication / vitamins or have any conditions that may increase the likelihood of bleeding. You should not give blood if you are anemic.

Initials:_____

- Although you are trained, you WILL experience leg soreness from the two supra-maximal trials (that is the point of the study) with the soreness resolving itself within 24-72 hours. *Please know that the soreness is caused by muscle damage which can be characterized as muscle cells that rupture which allows the cytosol (cell fluid and proteins) to leak out causing localized edema or swelling which in turns puts pressure on sensory nerve endings (this is what we recognize as pain). Again, the pain or soreness should pass in 24-72 hours.*

- Although you are trained and while extremely unlikely, you could experience an unexpected heart rate and/or blood pressure response and/or heart arrhythmia during the exercise test. Should an unexpected event occur during testing, the investigator (s) will initiate standard laboratory procedures to immediately contact EMS by calling 911.

NEW INFORMATION

You will be told about anything new that might change your decision to be in this study. You may be asked to sign a new consent form if this occurs.

BENEFITS

As a result of your participation in this study you can expect:

- the results of your max test which informs you of your aerobic capacity (will compare to age matched norms)
- your lactate threshold - as you know, the LT is widely used in the preparation of endurance training programs.
- Finally, your involvement in this study may provide useful data in the quest for a better understanding of the role of compression garments in endurance performance and post-exercise muscle damage.

COSTS

There are NO costs to you as a research participant.

AUTHORIZATION TO USE AND DISCLOSE INFORMATION FOR RESEARCH PURPOSES

All information we obtain about you or as a direct result of your participation will:

- be stored in the investigators office under lock and key and/or in a password protected computer with ID used rather than your name.
- Your name or any information we may gather will not be released to anyone (except immediate research staff) without your written permission, unless required by law.
- All data pertaining to your involvement in this study will be destroyed after five years.
- Please know that the results of this study, not identifiable to you, may be shared in a public forum such as a professional meeting and published in a scientific journal.
- You may withdraw or take away your permission (by simply telling us to do so) to use any or all data pertaining to participation in this study.

Initials:_____

COMPENSATION FOR INJURY

PLEASE KNOW that FAU is not able to offer financial compensation nor to absorb the costs of medical treatment should you be injured as a result of participating in this research.

VOLUNTARY PARTICIPATION AND WITHDRAWAL
Your participation in this study is voluntary. You may decide not to participate or you may leave the study at any time. Your decision will not result in any penalty or loss of benefits to which you are entitled.

Your participation in this study may be stopped at any time by the principal investigator (Dr. Whitehurst):

- if it is in your best interest or if you miss a testing session

QUESTIONS
Contact Dr. Michael Whitehurst at (561) 297.2713 (office), (561) 302.2674 (cell) for any of the following reasons:

- if you have any questions about this study or your part in it,
- if you feel you have had a research-related injury
- if you have questions, concerns or complaints about the research

If you have questions about your rights as a research subject or if you have questions, concerns or complaints about the research, you may contact: Florida Atlantic University, Division of Research at (561) 297-0777.

Do not sign this consent form unless you have had a chance to ask questions and have gotten satisfactory answers.

CONSENT
I have read this consent form (or it has been read to me). All my questions about the study and my part in it have been answered. I freely consent to be in this research study. I have been provided a copy of this consent form for my records.

By signing this consent form, I have not given up any of my legal rights.

_____

Subject Name (printed)

CONSENT SIGNATURE:

_____ _____

Signature of Subject (18 years and older) Date

_____ _____

Signature of Person Conducting Informed Date

Ver. 12-23-2009 Consent Discussion

APPENDIX C

FAU
FLORIDA ATLANTIC UNIVERSITY

ESHP Department

HEALTH HISTORY

All information you provide is personal and confidential. The information will enable us to better understand your current health status and potential risks associated with your participation in this research study.

PARTICIPANT GENERAL INFORMATION

Date_____
Name_____
Address_____
City State Zip_____
Gender_____ Birthdate _____
Phone (_____) _____
Email _____

Physician's Name _____
Physician phone number (____) _____
Physician fax number (____) _____
Emergency Contact
Name _____
Relationship_____
Home phone _____

HEALTH HISTORY

General

Height _____ft. Weight_____lbs.

Do you currently exercise? YES ☐ NO ☐

If yes, how long have you been exercising regularly?

_____

_____

What exercises do you do and how often?

_____

_____

Medical Diagnosis

Have you ever had any of the followings?

Diabetes	YES ☐	NO ☐
High blood pressure	YES ☐	NO ☐
Stroke	YES ☐	NO ☐
Cancer	YES ☐	NO ☐
Heart disease	YES ☐	NO ☐
Kidney disease	YES ☐	NO ☐
Heart Attack	YES ☐	NO ☐
Angina	YES ☐	NO ☐
Asthma	YES ☐	NO ☐
Anemia	YES ☐	NO ☐
Osteoporosis	YES ☐	NO ☐
Cardiovascular Surgery	YES ☐	NO
Currently Pregnant	YES ☐	NO ☐
Emphysema	YES ☐	NO ☐
Allergies	YES ☐	NO ☐
Emboli - (Blood Clot)	YES ☐	NO ☐
Coronary Artery Disease	YES ☐	NO ☐
Pulmonary Disease	YES ☐	NO ☐
Heart Valve Problems	YES ☐	NO ☐
Rheumatic Fever	YES ☐	NO ☐
Phlebitis (inflammation of vein)	YES ☐	NO ☐
Difficulty Breathing	YES ☐	NO ☐
Poor Circulation	YES ☐	NO ☐
Frequent Colds	YES ☐	NO ☐
Persistent Cough	YES ☐	NO ☐
Ringing in Ears	YES ☐	NO ☐
Rapid/irregular heart beat	YES ☐	NO ☐
Swollen joints	YES ☐	NO ☐
Pain, weakness, numbness in:	YES ☐	NO ☐

☐Arms ☐Hands
☐Legs ☐Feet
☐Neck ☐Shoulders
☐Head ☐Hips

Florida Atlantic University Form HH01

HEALTH HISTORY…CONTINUED

List medications or food supplements you are taking:

Rx Name _____
Reason_____Dosage_____

Rx Name _____
Reason_____Dosage_____

Rx Name _____
Reason_____Dosage_____

Rx Name _____
Reason_____Dosage_____

List any allergies:

_____

_____

_____

_____

List serious illnesses, accidents, surgeries or special condition not listed on page 1:

_____

_____

_____

_____

Major Risk Factors

1. Has your father experience a heart attack before the age of 55 **YES** ☐ **NO** ☐
2. Has your mother or sister experience a heart attack before the age of 65 **YES** ☐ **NO** ☐
3. Has your doctor ever told you that you might have high blood pressure **YES** ☐ **NO** ☐
4. Do you have cholesterol above 200 ml/dl? **YES** ☐ **NO** ☐
   Total Cholesterol _____ HDL _____
   Date tested _____ Unknown _____
5. Do you have impaired fasting glucose (diabetes or pre-diabetes) **YES** ☐ **NO** ☐
   If yes, do you take insulin? **YES** ☐ **NO** ☐
   What year were you diagnosed? _____
6. Are you physically inactive? **YES** ☐ **NO** ☐
   (less than 30 minutes of physical activity on at least 3 days per week)
7. Do you currently smoke or have you quit smoking in the last 6 months? **YES** ☐ **NO** ☐
   a). I smoke (#) _____ cigarettes per day/week (circle one) for _____ years
   b). I smoked (#) _____ cigarettes per day/week (circle one) _____ years ago

SIGNATURE

I understand this Health History has been provided to me for the purpose of helping me better understand any potential risk associated with my participation in this research study. My signature signifies that all the above is true, to the best of my knowledge. Any information left unanswered was done intentionally. If any of the above information changes, I agree to inform the principle investigator.

Participants Signature_____Printed Name _____ Date _____

Investigator Signature_____Printed Name _____ Date _____

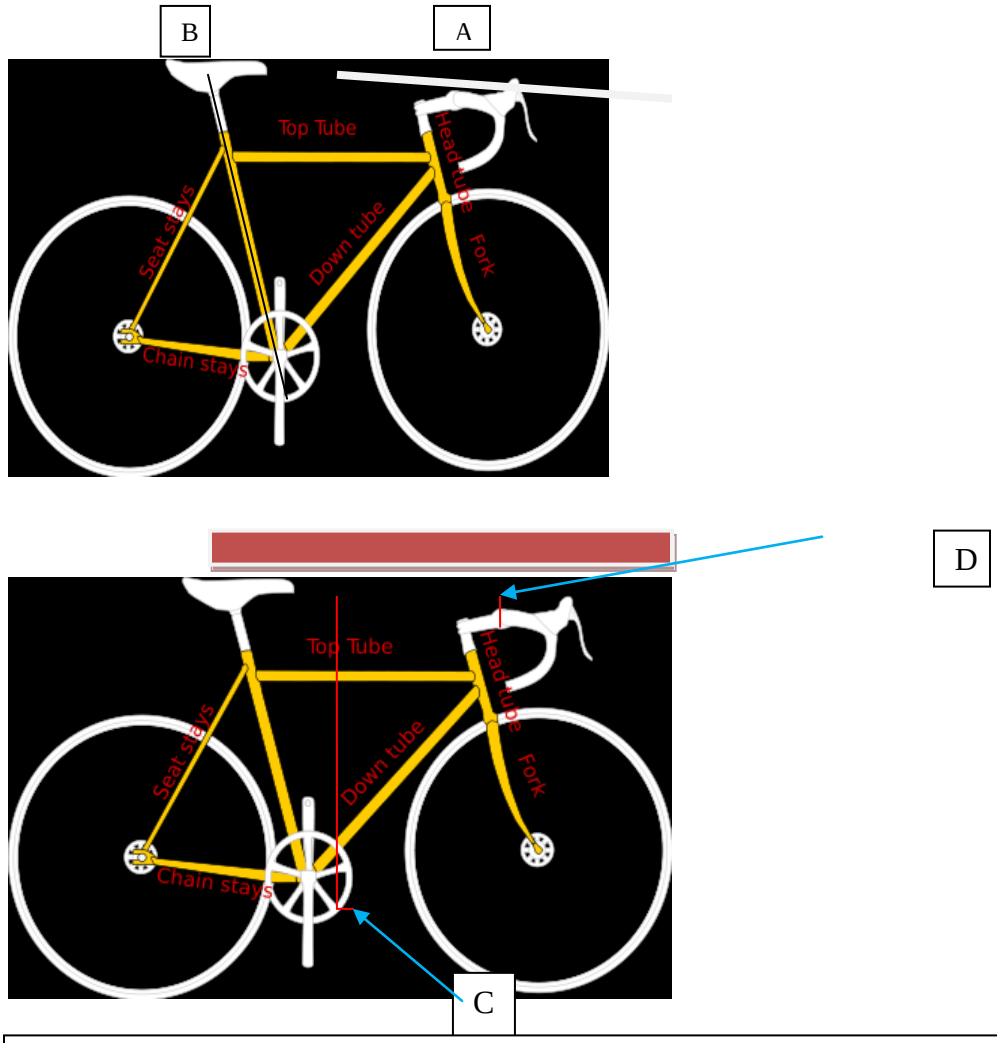
Note: All major risk Factors, Signs & Symptoms classification are taken directly from Whaley, Mitchell H ed. ACSM's Guidelines for Exercise Testing and Prescription. Philadelphia, PA: Lippincott Williams & Wilkins, 2006

OFFICE USE ONLY

Florida Atlantic University Form HH01

APPENDIX D

Measuring Bike Dimensions



Instructions for measuring your bike prior to your first exercise test.

1. Measure distance from tip of seat to center of handle bar (see line labeled A).
2. Measure distance from center of crank to top of seat directly in line with seat tube (see line labeled B).
3. With your bike positioned upright and on level surface, drop a plumb line from tip of seat so that it falls behind the crank. Measure the distance from the plumb line to the center of the crank (see line labeled C).
4. Place a 3' level or board (e.g. 2x4) over the top of your seat so that it reaches at least beyond the steerer tube. Measure the distance from the bottom of the level or board and the top of the steerer tube (see line labeled D).

REFERENCES

Agu, O., Hamilton, G., & Baker, D. (1999). Graduated compression stockings in the prevention of venous thromboembolism. *British Journal of Surgery, 86,* 992 – 1004.

Ali, A., Caine, M.P., & Snow, B.G. (2007). Graduated compression stockings: Physiological and perceptual responses during and after exercise. *Journal of Sports Sciences, 25*(4), 413 - 419.

Berry, M.J., Bailey, S.P., Simpkins, L.S., & TeWinkle, J.A. (1990). The effects of elastic tights on the post-exercise response. *Canadian Journal of Sports Science, 15* (4), 244 – 248.

Berry, M.J., & McMurray, R.G. (1987). Effects of graduated compression stockings on blood lactate following an exhaustive bout of exercise. *American Journal of Physical Medicine, 61*(3), 121 – 132.

Cornwall, J.V., Dore, C.J., & Lewis, J.D. (1987). Graduated compression and its relation to venous refilling time. *British Medical Journal, 295,* 1087 – 1090.

Davison, A.W. (1906). Derby: Its rise and progress. Available from http://books.google.com/books

Doan, B.K., Kwon, Y., Newton, R.U., Shim, J., Popper, E.M., Rogers, R.A., . . . Kraemer, W.J. (2003). Evaluation of a lower-body compression garment. *Journal of Sports Science, 21*, 601 – 610.

Duffield, R., & Portus, M. (2007). Comparison of three types of full-body compression garments on throwing and repeat-sprint performance in cricket players. *British Journal of Sports Medicine, 41*, 409 – 414.

Ibegbuna, V., Delis, K.T., Nicoladies, A.N., & Aina, O. (2003). Effects of elastic compression stockings on venous hemodynamics during walking. *Journal of Vascular Surgery, 37*, 420 – 425.

Kemmler, W., Von Stengle, S., Kockritz, C., Mayhew, J., Wassermann, A., & Zapf, J. (2009). Effect of compression stockings on running performance in men runners. *Journal of Strength and Conditioning Research, 23(1)*, 101 – 105.

Kraemer, W.J., Volek, J.S., Bush, J.A., Gotshalk, L.A., Wagner, P.A., Gomez, A.L., . . . Selle, B.J. (2000). Influence of compression hosiery on physiological responses to standing fatigue in women. *Med Sci Sports Exercise, 32* (11), 1849 – 1858.

Morris, R.J., & Woodcock, J.P. (2004). Evidence-based compression prevention of stasis and deep vein thrombosis. *Annals of Surgery, 239* (2), 162 - 171.

Nazarko, L. (2009). Selecting and using appropriate compression hosiery. *Nursing and Residential Care, 11* (5), 229 – 232.

Prandoi, P., Lensing, A.W., Prins, M.H., Frulla, M., Marchiori, A., Bernardi, E.,. . . Griolami, A. (2004). Below-knee elastic compression stockings to prevent the post-thrombotic syndrome. *Annals of Internal Medicine, 141,* 249 – 256.

Radegran, G., & Saltin, B. (1998). Muscle blood flow at onset of dynamic exercise in humans. *American Journal of Physiology Heart and Circulatory Physiology, 274,* 314 – 322.

Rimaud, D., Calmels P., Roche F., Mongold J.J., Trudeau F., & Devillard, X. (2007). Effects of graduated compression stockings on cardiovascular and metabolic responses to exercise and exercise recovery in person with spinal cord injury. *Arch Phys Med Rehabil, 88,* 703 – 709.

Sajid, M.S., Desai, M., Morris, R., & Hamilton, G. (2008). Knee-length graduated compression stockings for thromoboprophylaxis in air travelers: A meta-analysis. *Int. J Angiol, 17* (3), 119 – 123.

Scanlan, A.T., Dascombe, B.J., Reaburn, P.R., & Osborne, M. (2008). The effects of wearing lower-body compression garments during endurance cycling. *International Journal of Sports Physiology and Performance, 3,* 424 – 428.

Sheriff, D.D., & Van Bibber, R. (1998). Flow-generating capability of the isolated skeletal muscle pump. *Am J Physiol Heart Circ Physiol, 27,* 1502 – 1508.

Van Geest, A.J., Veraart, J.C., Nelemans, P., & Neumann H.A. (2000). The effects of medical elastic compression stockings with different slope values on edema. *Dermatologic Surgery, 26* (3), 244 – 247.

Watanuki, S., & Murata, H. (1994). Effects of wearing compression stockings on cardiovascular responses. *Ann Physiol Anthrop, 13* (3), 121 – 127.

Weiss, R.A., & Duffy D. (1999). Clinical benefits of lightweight compression: Reduction of venous-related symptoms by ready-to-wear lightweight gradient compression hosiery. *Dermatologic Surgery, 25* (9), 701 – 704.

White, J.V., & Ryjewski, C. (2005). Chronic Venous Insufficiency. *Perspectives in Vascular Surgery and Endovascular Therapy, 17* (4), 319 – 327.

Wray, D.W., Donato, A.J., Abhimanyu, U., Merlone, J.P., & Richardson, R.S. (2005). Onset exercise hyperemia in humans: partitioning the contributors. *Journal of Physiology, 563* (3), 1053 – 1060.

Zajkowski, P.J., Proctor, M.C., Wakefield, T.W., Bloom, J., Blessing, B., & Greenfield, L.J. (2002). Compression stockings and venous function. *Arch Surg, 137,* 1064 – 1068.