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Investigation of Sequential Intermittent Pneumatic Compression Effect on Run Performance

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INVESTIGATION OF SEQUENTIAL INTERMITTENT PNEUMATIC COMPRESSION EFFECT ON RUN PERFORMANCE

By

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Abstract page

INVESTIGATION OF SEQUENTIAL INTERMITTENT PNEUMATIC COMPRESSION EFFECT ON RUN PERFORMANCE

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The main aim of this study was to determine if IPC after a 5000 m run influences maximal effort 1600 m run performance. A secondary purpose was to determine if the level of IPC pressure used influences run performance. Nine subjects (6 male and 3 female were included in the study; 30 years±5.19 years; Height 173.72cm±8.25; Weight; 72.54±9.97 kg). These subjects were recruited to be in this study via word of mouth or social media advertisement in the Las Vegas area. Participant inclusion criteria was 18-50 year old apparently healthy, had been running a minimum of 20 miles a week for the last 3 months, and had competed in one race that included running or had a running component to it in the last year, has not had a diagnosed injury in the last 3 months, and were not pregnant. Subjects complete an institutionally reviewed informed consent along with a running questionnaire to give a sense of their running background.

The subjects were ask to perform a 5000-meter competitive run together to induce a competitive atmosphere. After subjects completed the 5000-meter run, subjects returned to the UNLV biomechanics laboratory. The IPC device utilized in this study is the Recovery Pump RPS Complete System (SKU 701A, Pennsylvania, PA) is an FDA approved

intermittent pneumatic compression device that provides sequential pressure. The settings on the IPC were randomly assigned either 80 mmHg of pressure or 20 mmHg of pressure. The duration of recovery time was 60 minutes in duration. During the recovery process there was some measurements collected. Every 10 minutes all subjects had their HR and BP measurements taken. The heart rate monitor utilized was the FT1 Polar heart rate monitor (Polar Electro Oy, Professorintie 5, FIN-90440 KEMPELE). The blood pressure cuff used in this study was the Omron BP710N 3 Series Upper Arm Blood Pressure Monitor (Omron Healthcare, Inc. Lake Forest, IL 60045)

After the 60 minutes of recovery time in the IPC device the boots were removed. After their warm up subjects were asked to perform a maximal 1600-meter effort. After a minimum of 72 hours recovery between the initial test day, subjects returned to UNLV track for day 2 to perform Day 2 tests. Day 2 procedures were identical to Day 1 with the only difference being that they will receive a different pressure setting (i.e., if subject 1 received 80 mmHg on Day 1, they would receive 20 mmHg on Day 2).

There were two sets of dependent variables collected. The performance variables were 1600 m performance and HR_{Avg} during the 1600 m trial. The recovery variables were heart rate and blood pressure. 1600 m performance was not influenced by IPC Pressure ($p = 0.495$). The mean 1600 m run time following IPC pressure 20 mmHg was 366.6±53.59 s. The mean 1600 m run time following IPC pressure 80 mmHg was 364±54.26 s. HR_{Avg} was not influenced by IPC Pressure ($p = 0.063$). HR_{Rec} was not influenced by the interaction of time and pressure ($F(1,8) = 0.205$, $p = 0.925$). HR_{Rec} was not influenced by pressure ($F(1,8) = 0.169$, $p=0.692$) but was influenced by time ($F(4, 32) = 18.000$, $p<0.001$). $BP_{Systolic}$ was not

influenced by the interaction of time and pressure ($F(1,8) = 1.1$, $p = 0.431$). $BP_{Systolic}$ was not influenced by pressure $F(1,8) = 1.8$, $p = 0.215$. $BP_{Systolic}$ was not influenced by time ($F(1,8) = 0.584$, $p=0.689$). $BP_{Diastolic}$ was not influenced by the interaction of time and pressure ($F(1,8) = 0.200$, $p = 0.928$). The current research

differs from the related IPC literature related to performance because it was the first in the reviewed literature to utilize an over ground endurance event to test the efficacy of the IPC product for performance. The performance of the subjects in the current study did not change while using the various IPC pressures, nor did the recovery parameters explored elicit any change during recovery. There seems to be an individual response to the IPC as a recovery modality, as this product becomes more popular in mainstream athletics the amount of literature testing the IPC device must grow if researchers are to better assist coaches and athletes with the practical usage of this product.

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Love you all and thanks again!

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Chapter 1

Introduction

In competition, being able to perform at a high level after subsequent bouts of exertion is paramount to success in sport. Furthermore, being able to recover faster between bouts of exertion is extremely important for endurance training. With a rise in popularity in endurance sports there has been a rise in products associated with improving performance and recovery in endurance athletics.

Currently, there are a multitude of products and techniques to help athletes recover faster such as, but not limited to, massage, active recovery, cryotherapy, contrast temperature water immersion therapy, nonsteroidal anti-inflammatory drugs, compression garments, stretching, and combination modalities (Barnett et al., 2006). These recovery modalities are sought after with the intention of enhancing the rate of blood lactate removal following high-intensity exercise and to reduce the length and intensity of delayed onset muscle soreness (Barnett et al., 2006). However, there is no clear single approach that has been determined to be effective for recovery.

A relatively new product that has risen in popularity with the endurance athlete is the use of intermittent pneumatics compression (IPC) therapy for endurance recovery. Intermittent pneumatic compression has been widely used in patients with deep vein thrombosis and for patients with lymphedema or with patients with overall circulatory issues (Zaleska et al., 2014). However, it is not clear if IPC influences recovery from endurance exercise. Some of the advertised effects of the device in the athletic population is that their legs feel refreshed and recovered. The manufacturers suggest that 60 minutes of IPC boot use will provide the same benefit as 24 hours

of passive recovery. There has been limited research on the efficacy of the IPC as a recovery modality or for athletic performance.

Purpose

The main aim of this study was to determine if IPC after a 5000 m run influences maximal effort 1600 m run performance. A secondary purpose was to determine if the level of IPC pressure used influences run performance.

Research question:

1. Does IPC use after a 5000 m run influence subsequent 1600 m run performance?

2. Does a higher level of IPC use influence 1600 m run performance after a subsequent bout of sub-maximal running in comparison to a lower pressure of IPC use followed by a subsequent bout running?

Significance of the study

To date, Hanson (2013) has been the only published study that utilized the IPC for recovery in-between subsequent bouts of exercise. Specifically, this study measured blood lactate levels using an anaerobic cycling intervention to induce fatigue and compare active recovery to IPC use to passive recovery. The results were that there was no difference in lactic acid levels during the active recovery group and IPC group. Furthermore, lactic acid levels were lower following both recovery protocols vs. passive recovery alone. A limitation of this work is that the experiment was conducted a laboratory setting utilizing an anaerobic intervention to initiate a change in blood

lactate levels above rest. There is no research on the influence of IPC on running performance. The present study will serve to expand the body of literature of regarding using IPC as a recovery modality for athletic populations; in addition this study will be conducted in the field and not in a laboratory setting, which may provide a greater practical application of the efficacy of this product in a real-world setting.

Statistical Hypothesis

Performance variables

H_o Runners using a high pressure IPC protocol in comparison to a low pressure of IPC protocol use will elicit no change in performance during 1600-meter time trial.

H_1 Runners using a high pressure of IPC protocol in comparison to a low pressure of IPC use will elicit a change in performance during 1600-meter time trial.

H_o Runners using a high pressure IPC protocol will have no change in Heart rate in comparison to a lower IPC protocol during 1600-meter time trial.

H_1 Runners using a high pressure IPC protocol will have a change in heart rate in comparison to a lower IPC protocol during a 1600-meter time trial.

Recovery variables

Ho Heart rate during a high pressure IPC use will not change in comparison to a low pressure of IPC use.

H_1 Heart rate during a high pressure IPC use will change in comparison to a low pressure of IPC use.

H_0 Blood pressure during a high pressure IPC use will not change in comparison to a low pressure of IPC use.

H_1 Blood pressure during a high pressure IPC protocol use will change in comparison to a low pressure of IPC use.

Limitations

Number of IPC Recovery Boots available.

Only one model of IPC was tested.

Only 2 different pressures were tested in this study.

Subjects may have unique results from different pressures and duration of treatment time.

A limited number of IPC boot sizes were available and subject leg length was not controlled.

Results can only be applied for populations similar to subject recruitment and may not apply to other sports or age ranges.

Confounding Factors

1) Weather condition variability due to outside study.

2) Athletic motivation during intervention itself.

3) Training stress on subjects outside of study

4) Sickness or fatigue level going into data collection

5) Medication usage

6) Hydration status

7) Prior IPC usage or compression product

8) Adequate rest

Chapter 2

Literature Review

Recovery can be defined as an inter- and intra-individual multilevel process in time for the re-establishment of performance abilities (Jefferys, 2005). Recovery from exercise is an important part of a long-term training program (Barnett, 2006). Although it is not always clear which parameter can be used to represent or measure the factors of recovery. In a literature review, Jefferys (2005) stated that the factors of recovery include but are not limited to: 1) normalization of physiological functions (e.g., blood pressure, cardiac cycle), 2) return to homeostasis (resting cell environment), 3) restoration of energy stores (blood glucose and muscle glycogen), and 4) replenishment of cellular energy enzymes. Muscle recovery occurs primarily after exercise and is characterized by continued removal of metabolites (Jefferys, 2005). During exercise, recovery is needed to reestablish intramuscular blood flow for oxygen delivery, which promotes replenishment of phosphocreatine stores (used to resynthesize ATP), restoration of intramuscular pH (acid/base balance), and regaining of muscle membrane potential (balance between sodium and potassium pump inside and outside of cell) (Weiss, 1991 The stress on the system after exercise may impair the body to reproduce the same exercise intensity for minutes, hours or even multiple days of competition (Westerblad, 2002). Recovery after exercise is dependent on several factors, the restoration of glycogen stores and rehydration and longer lasting impairment may be related to exercise-induced muscle damage and delayed onset muscle soreness (Barnett,

2006). Chronic inadequate rest after exercise can potentially have long-term debilitating effects and result in overtraining (Westerblad,2002).

The purpose of this chapter is to give the reader a sense of the literature related to recovery. Specifically, the literature that will be reviewed will systematically explore various established methods of recovery.

Outline:

Massage

Nonsteroidal anti-inflammatory drug

Active Recovery

Passive Recovery

Cryotherapy

Contrast Therapy

Compression

Intermittent Pneumatic Compression-Medical Overview

Intermittent Pneumatic Compression- Recovery from exercise

Intermittent Pneumatic Compression- Influence on Performance

Intermittent Pneumatic Compression IPC usage as a recovery modality

Massage

Anecdotally massage has been widely used by athletes as a modality for recovery from exercise. Massage is thought to alleviate DOMS, enhance lactate removal, and increase blood muscle flow (Barnett, 2006). Hinds (1994) studied the effects of massage following isokinetic quadriceps exercise on leg and skin blood flow. In this study, 13 male volunteers performed 3 x 2-min bouts of quadriceps exercise the experimental group received deep effeurage massage for 2 x 6-min bouts of massage and the control group was passive recovery. The authors reported that there was no difference in leg blood flow between the experiment and control group; however, skin blood flow was higher in the massage trial.

Tidus and Shoemaker (1998) reported that massage treatments produced a significantly lower delayed onset muscle soreness sensation in the experimental group that consisted of elite boxers, as oppose to the control group of elite boxers who received no massage. Barnett's et al. (2006) review of research on massage found that there is not sufficient empirical evidence to support massage as being a modality that improves recovery and benefit performance.

Vittasalo and Niemela (1995) documented that in elite junior athletes given warm water-jet massage following high-intensity exercise, serum creatine kinase and myoglobin concentrations were significantly higher in athletes given massage than in those given no special recovery treatment. However, the post training decrease in power and increase in ground contact time during continuous jumping were less in athletes treated with massage than those given no special recovery, although massage has no effect on drop jump or successive rebound jump heights.

Nonsteroidal anti-inflammatory drug

Nonsteroidal anti-inflammatory drug (NSAID) are used by millions around the world for its pain relief and anti-inflammatory properties (Lanier, 2003). Because of these properties NSAIDS have been popular modality to athletes as an attempt to enhance recovery between training sessions (Barnett, 2006). Recent evidence has shown that over the counter ibuprofen blunts the protein synthesis response after eccentric exercise in untrained men (Trappe, 2002). The subjects recruited were 24 males who were randomly assigned into one of 3 groups: ibuprofen, acetaminophen, and a placebo group. These groups underwent 10-14 sets of 120% of concentric one-repetition maximum with the knee extensors (Trappe, 2002). The authors reported that serum creatine kinase levels were elevated in all three groups. However, the primary findings were that ibuprofen and acetaminophen blunted the protein synthesis response that is normally seen after this type of exercise used in this study.

Active Recovery/Passive Recovery

Coffey et al. (2004) has stated that active recovery by performing a continuous aerobic movement with the purpose of recovering the body from more intense exercise. Active recovery has a positive effect on blood lactate concentration reduction during repeated standardized exercise (Jemni, 2003). However, it does not appear to be a valid indictor of recovery quality (Barnett, 2006). Passive Recovery can be defined as recovering in non-movement state, this can be accomplished by standing, sitting or lying down (Barnett. 2006). For example, Coffey, Leveritt, and Gill (2004) examined the effects of active recovery on the post-recovery performance following a period of time representative of the duration between training sessions for recovery. They reported that when comparing active recovery, passive recovery and contrast temperature

immersion offers no significant differences in subsequent performance found after four hours of recovery.

Cryotherapy

Cryotherapy has been widely used to treat acute traumatic injury and may be appropriate as a recovery modality after training and competition that causes some level of traumatic injury, such as team and contact sports and the martial arts (Bleakley, 2004). The effects ofpost-exercise cryotherapy have been recently investigated. In one study by Yamane (2006), reported untrained men randomly assigned to either an endurance cycling training or forearm flexor resistance using a handgrip ergometer training over a 6-week period. The training protocols were designed to not induce delayed onset muscle soreness. The cryotherapy group consisted of one 20-minute cold-water immersion for the endurance training experiments and one 20-minute immersion for the resistance training experiments after each training session. The author reported that post-exercise cooling lessens the effects of training in untrained men by retarding the post-training adaptive processes associated with improvement in performance. The dependent variables measured were pre and post exercise tests contraction of the forearm flexor muscles. This was determined by pressing a digital grip strength meter. Local muscular endurance was determined by counting the maximally performed repetitive lifting of the weight-loaded handgrip ergometer in a supine position at a contraction–relaxation duty cycle of 30 contractions per minute and at a workload of 30% of maximum muscle strength determined prior to training, until exhaustion.

Contrast temperature water immersion

Contrast temperature water immersion entails alternating hot water immersion and cold water immersion. (Barnett, 2006). Twenty-three Elite rugby players were divided into four groups

and were monitored post competition contrast water therapy, compression garment, active recovery, and passive recovery. Contrast water immersion therapy has recently been shown to enhance post-match creatine kinase clearance in Rugby players in comparison to passive recovery (Gill, 2006). Coffey (2005) reported no difference in the creatine kinase clearance levels between the active, passive and contrast temperature water immersion interventions. Subjects performed treadmill runs to exhaustion at both 120% and 90% peak running speed pre and post recovery. The therapies were all administered for 15 minutes after the initial exercise bout.

Compression

Barnett's (2006) review of compression garments separates them into three different categories. One being graduated compression for the prevention/management of deep vein thrombosis, the second being compression garments worn over joints and limbs for support and swell reducing properties, the third being elastic tights and tops worn during exercise clothing.

Chatard and Atlaoui (2004) investigated the use of compression therapy in-between two subsequent bouts of cycling. 12 trained elderly cyclists, performed two 5-min maximal exercises, session one and session two, separated by an 80-min recovery period, twice a week with a 2-day rest interval. During the 80-min recovery period, they randomly wore or did not wear grip-top Elastic compression Stockings (ECS). Blood lactate concentrations, hematocrit, and plasma volume were measured after a 60-min rest and every 20 min during recovery. Leg sensations were assessed with a questionnaire. The decrease in maximal power between session one and session two was lower when wearing the ECS during the 80-min recovery period. Blood lactate concentrations, hematocrit, and plasma volume levels were significantly decreased when wearing the ECS in-between session one and session two. In addition to the other measurements the cyclists were given a questionnaire on leg sensation and perceived feeling. Ten of the cyclists thought that

it could have influenced their performance. However, no relationship was found between thegain in performance and the leg pain sensation. It was concluded that wearing ECS during an 80-min recovery period significantly increased subsequentperformance.

Berry (1987) Highly fit male college students who wore gradually compression stockings during both exercise (3 minutes cycling at 100% maximal oxygen uptake) and had lower recovery blood lactate concentrations than when wearing the stockings only during exercise or not at all. Among the 12 twelve subjects that were randomly split into 6 subjects wore gradual compression stockings and the remaining 6 subjects wore no stockings at all. Blood lactate was collected 5, 15, and 30 minutes post exercise. Authors reported that the graduated stockings group resulted in a significantly less lactate when compared to the no stocking group. These lower values may not be ascribable to plasma volume shifts but rather appear to be due to an inverse gradient created by the graduated stockings resulting in the lactate being retained in the muscularbed.

Kramer and Bush (2001) investigated the use of compression therapy on the elbow flexors post eccentric exercise. Twenty women were randomly placed into two groups; both groups performed 2 sets of 50 passive arm curls with the dominant arm on an isokinetic dynamometer. The variables measured were one-repetition maximum elbow flexion, upper arm circumference, relaxed elbow angle, and blood serum cortisol and creatine kinase. The experimental group received upper-arm compression for 5 days post eccentric exercise and the control group did not. Investigators reported that both groups showed significantly elevated creatine kinase levels post exercise but the compression group showed a decreased magnitude of creatine kinase elevation following the eccentric exercise. Compression sleeve use prevented loss of elbow motion, decreased perceived soreness, reduced swelling, and promoted recovery of force production.

Authors stated that these results underline the importance of compression in soft tissue management and recovery.

Intermittent Pneumatic Compression: Medical overview

Intermittent Pneumatic Compression (IPC) use has its origins in the medical world most commonly with venous system conditions such as deep vein thrombosis (DVT), in a key study of 104 patients either going through joint replacement or fracture repairs, the rate of DVT was reduced from 19% in the control group to 2% in the IPC use group (Hartman, 1982). Both the experimental and control groups legs were elevated post-surgery but the experimental group received IPC as well. In addition, IPC use has been utilized in the treatment of lymphatic disorders. In a study of 28 women that were treated for breast cancer IPC use showed a 25% observed reduction in arm volume in comparison to a 20% observed reduction in the control group. (Dini, 1998) These results from these studies show that IPC can be used as medical modality for the treatment of venous and lymphatic disorders.

In theory, intermittent pneumatic compression mimics the anatomical muscle-venous pump to circulate blood from the extremities toward the heart to the lungs, where it is re-oxygenated, and then back to the heart to be re-circulated (Chen, 2001). Intermittent compression is thought to be a mechanical “squeezing” of the limb to push swelling out of the extremity and increase blood flow. This recirculation promotes not only re-absorption of interstitial tissue swelling but also promotes healing due increased blood circulation to injured tissue. (Hanson, 2013)

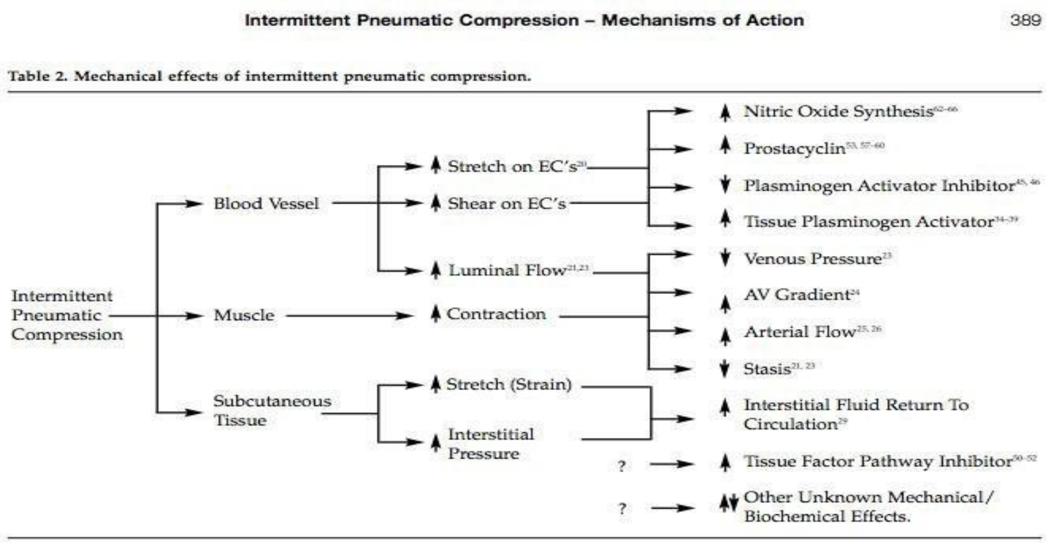

Figure 1: summarizes the current understanding of the mechanism of which IPC works (Chen, 2001).

In another study exploring the mechanism of the IPC, Liu and Chen (1999), this study observed the effects of intermittent pneumatic compression of legs on the microcirculation of distant skeletal muscle. The cremaster muscles of 80 male rats were exposed, a specially designed intermittent pneumatic-compression device was applied to both legs for 60 minutes, and the microcirculation of the muscles was assessed by measurement of the vessel diameter in three categories (10-20, 21-40, and 41-70 microm) for 120 minutes. The results showed significant vasodilation in arterial and venous vessels during the application of intermittent pneumatic compression, which disappeared after termination of the compression. The investigators concluded that the results imply that the production of nitric oxide is involved in the positive influence of intermittent pneumatic compression on circulation. They postulated that the rapid increase in venous velocity induced by intermittent pneumatic compression produces strong shear stress on the vascular endothelium, which stimulates an increased release of nitric oxide and thereby causes systemic vasodilation.

Hanson (2013) stated that consumers have turned to using IPC use for recovering faster after a multitude of competition from Cross-fit competitions, rugby, basketball, soccer, softball, running, cycling, and triathlon. Anecdotal responses have mentioned that athletes legs feel lighter, refreshed and feel performance can be at a higher level after wearing them. Chatard (2004) in addition to quantitative data being presented they also had some qualitative data in the form of questionnaires. This questionnaire asked how the athletes felt after the use of the IPC and how it improved their performance. They investigated the use of compression therapy in-between two subsequent bouts of cycling. Ten out of the twelve cyclists thought that it influenced their performance in a positive manner for the secondary bout of cycling.

Testimonials include statements that there was less perceived soreness in the legs and a feeling that wearing them increases athletic performance. Professional athletes have been sponsored by these products and wear them before and after exercise or in-between daily sessions.

Figure 2: Picture of subjects in Recovery Pump Recovery Boot model RP at UNLV SIRC.

For this thesis, the Recovery Pump Boots were used and in this section a description of the product has been provided. This product encompasses both legs individually like a legging and provides programmable active sequential pressure starting from the feet and proceeding superiorly to the upper thigh and then restarting the process. This product has 4 chambers and as the pressure sets in it fills the most distal compartment by the shank all the way to the most proximal aspectof the lower extremity closer to the pelvis. One full compression from distal to proximal is called a cycle. In a sequential fashion the boots will fill one compartment at a time and hold compression in all the chambers until it reaches that last chamber closest to the pelvis and then decompression of all compartments occurs simultaneously. The control unit has two different dials on it, one

controls the amount of pressure 20 mmHg -80 mmHg, and the other dial is the amount of time between compression of`each cycle which ranges from 15-60 seconds.

Intermittent Pneumatic Compression: Recovery from exercise

There is limited research testing the effectiveness of IPC on recovery and athletic performance. Of the research that does exist, IPC has been used during recovery after a variety of different modes of exercise. The research on IPC can be separated into two distinct categories. The first studies reviewed investigated if IPC improves performance, the secondary set of studies reviewed investigated the use of IPC and its effect on recovery.

IPC Influence on Performance

Zelikovski et al. (1993) investigated if IPC provided accelerated removal of fatigue-causing metabolites by mechanical massage and if it could improve an athlete's performance capacity. The experiment consisted of 11 men who exercised at a constant workload, on a cycle ergometer, until exhaustion. During a 20-min recovery period a new modified pneumatic sequential intermittent device (MISPD) was applied to the subjects' legs. The men then performed a second constant load exercise bout.

The authors reported that after a 20-minute bout of recovery that the intermittent pneumatic compression showed a 45% improvement in time to fatigue in comparison to time to fatigue in the passive recovery that did not receive the IPC device on the secondary bout of cycling. In addition, subjects that had used the IPC device also had a higher mean maximum ventilation and higher mean maximum heart rate. The authors concluded they could not rule psychological reasons for improved performance due to the pleasant sensation that the boots effect on the subjects, meaning they could have felt better prepared for the secondary effort. The type of analysis used was a two-

way analysis of variance and a paired t-test. To date, this is the only study that has investigated using the IPC as recovery modality in-between bouts of exercise.

Waller et al. (2006) utilized the IPC as a recovery modality after a high intensity shuttle run followed by a vertical jump performance test. In this study, 9 subjects were randomly placed into one of three groups: no IPC treatment, graduated low-pressure (20 mmHg) IPC use, and graduated high-pressure (70 mmHg) IPC use. After a 1- hour IPC use, vertical jump assessment was used to identify any changes in performance pre and post-trial. Additionally, all subjects performed all three-recovery interventions with 3 recovery days in-between test days. Vertical jump performance was reduced on all occasions, however the magnitude of reduction was smaller following high and low pressure IPC treatments. The high-pressure treatment produced a significantly smaller mean reduction than both the low-pressure treatment and no treatment. In Waller (2006) study it highlights the effectiveness of IPC as a recovery modality to improve performance after an exhaustive set of exercise.

IPC usage as a recovery modality

To date, Hanson (2013) has been the only been the only study that has compared active recovery, passive recovery, and IPC as recovery modalities in the same study. The aim of this study was to investigate if compression (IPC) unit as a recovery modality by evaluating its effectiveness in clearing blood lactate (BLa) when compared to alternate recovery methods following an anaerobic Wingate cycling test. In this study 21 subjects were college aged student athletes that competed in lower extremity dominant sports. The methods in this particular study incorporated an anaerobic cycling intervention to induce fatigue with blood lactate levels measured and compared between active recovery, IPC use, and passive recovery. All recovery conditions lasted 20 minutes in duration. Blood lactate was collected before and immediately after the Wingate

test, and after the 20 minute recovery session. The subjects of the IPC recovery condition were asked to sit and maintain 90-degree hip flexion and knees in full extension.

The active recovery group maintained 40% of Heart Rate reserve on a stationary ergometer bike. The passive recovery group was asked to sit and maintain 90-degree hip flexion and knees in full extension. The authors reported that blood lactate levels were not different between the active recovery group and the IPC group, however they both yielded a statistically significantly lower blood lactate level than the passive recovery group. The authors noted that more exploration of optimal recovery time was needed considering the recovery protocol used was limited to only 20 minutes. In addition this study was limited to a one-minute intense anaerobic workout followed by a 20-minute recovery period, which limits application of results to athletes who perform in the anaerobic pathway. Further studies exploring recovery for athletes that perform in the aerobic pathway is needed.

Chleboun et al. (1995) induced eccentric elbow flexor muscular damage to subjects exercise used to induce injury consisted of three sets of eccentric exercise performed with weights equal to 90%, 80%, and 70% of the isometric maximal voluntary contraction. IPC use was then applied to the upper body limbs. Pressure intensity was set at 60 mmHg and total treatment time was 20 minutes. The measurements reported after were relative pain measurements and circumference. Subjects were college-aged women that participated in the study. Measurements taken were circumference of upper arm and relative pain on a 1-5 scale. The authors reported that the IPC was effective in reducing circumference and relative pain, most notably on days 2 and 3. In this study they utilized a single chamber IPC device, authors noted, “It is possible that if a sequential unit, which has been shown to be more effective in reducing swelling, had been used the effects would have been more pronounced” (Chleboun, 1995).

In summary, in this literature review it was the goal to review the existing modalities for recovery from exercise. From a systemic point of view the purpose of these recovery modalities is improve the efficiency and time to recovery from exercise. Jefferys (2005) stated that the factors of recoveryinclude but are not limited to: 1) normalization of physiological functions (e.g., blood pressure, cardiac cycle), 2) return to homeostasis (resting cell environment), 3) restoration of energy stores (blood glucose and muscle glycogen), and 4) replenishment of cellular energy enzymes. Muscle recovery occurs primarily after exercise and is characterized by continued removal of metabolites (Jefferys, 2005).

The purpose of this chapter was to give the reader a sense of the literature related to recovery. Specifically, the literature that was reviewed systematically explored the various established methods of recovery. From the above literature these are the modalities reviewed: Massage, Nonsteroidal anti-inflammatory drug, Active Recovery Passive Recovery, Cryotherapy, Contrast Therapy Compression Intermittent Pneumatic Compression-Medical Overview, and Intermittent Pneumatic Compression on Athletic Performance, Intermittent Pneumatic Compression Athletic Recovery, they were reviewed in this order to display a progression of recovery modalities related to athletic recovery. As science and technology progress newer methods of recovery to promote an arena of maximum performance will be further explored. As displayed in this review the IPC was founded for the benefit of assisting the medical population with mainly circulatory issues relating to deep vein thrombosis and lymphedema and then adapted to assisting with athletic recovery.

There is a limited body of research on the efficacy of IPC usage for athletic performance and athletic recovery. One of the major gaps in the literature is a study exploring the IPC as a recovery modality for multiple bouts of performance. To date, Waller (2006) in the

reviewed literature is the only study that used the IPC as a recovery modality for a subsequent bout of exercise. However, their study utilized an anaerobic shuttle run to induce fatigue, then utilized the IPC device for recovery and used a maximal power test the vertical jump to perceive performance. The proposed study purpose is to determine if IPC after a 5000 m run influences maximal effort 1600 m run performance. This study could fill the gap in the literature and provide insight on how IPC can affect the athlete that is more based in aerobic thresholds and performance variables related to that.

Another limited body of research involving IPC is optimal pressure for recovery. Waller (2006) is the only study in the reviewed body of literature to utilize different IPC pressures to investigate if the amount of pressure has an influence on recovery. In their methods they compared two different graduated sets of pressures as well as a control. The independent variables measured were no IPC treatment, graduated low-pressure (20:15:10 mmHg) IPC use, and graduated high-pressure (70:65:60 mmHg) IPC use. The proposed study will be collecting data relevant to recovery from the IPC and could serve to provide information on how IPC affects recovery in-between two subsequent bouts of running.

Chapter 3

Methods: Subject

characteristics

Nine subjects (6 male and 3 female were included in the study; 30 years±5.19 years; Height 173.72cm±8.25; Weight; 72.54±9.97 kg). These subjects were recruited to be in this study via word of mouth or social media advertisement in the Las Vegas area. Participant inclusion criteria was 18-50 year old apparently healthy, had been running a minimum of 20 miles a week for the last 3 months, and had competed in one race that included running or had a running componentto it in the last year, has not had a diagnosed injury in the last 3 months, and were not pregnant.

Instrumentation

The IPC device utilized in this study is the Recovery Pump RPS Complete System is an FDA approved intermittent pneumatic compression device that provides sequential pressure. This product encompasses both legs individually like a legging and provides programmable active sequential pressure starting from the feet and proceeding superiorly to the upper thigh and then restarting the process. This product has four chambers and as the pressure sets in it fills the most distal compartment by the shank all the way to the most proximal aspect of the lower extremity closer to the pelvis. One full compression from distal to proximal is called a cycle. In a sequential fashion the boots will fill one compartment at a time and hold compression in all the chambers until it reaches that last chamber closest to the pelvis and then decompression of all compartments occurs simultaneously. The control unit has two different dials on it, one that controls that amount of pressure 20 mmHg-80 mmHg, and the other dial is the amount of time between compression of` each cycle which ranges from 15-60 seconds. (Mego Afek AC Ltd. SKU 701A, Pennsylvania,

PA). The heart rate monitor utilized was the FT1 Polar heart rate monitor (Polar Electro Oy, Professorintie 5, FIN-90440 KEMPELE). The blood pressure cuff used in this study was the Omron BP710N 3 Series Upper Arm Blood Pressure Monitor (Omron Healthcare, Inc. Lake Forest, IL 60045)

Procedures

Subjects were asked to attend two test sessions held on two different days.

Day 1

Subjects reported to UNLV SIRC for baseline assessments, height, weight, resting HR, and BP. Subjects were instructed to review Informed Consent and gave written informed consent. Subjects were familiarized with how to use and fit into the IPC Recovery pump device. Subjects performed a self-directed warm-up lasting no longer than 10 minutes. Upon volunteering for the study subjects were asked to refrain from rigorous training 24 hours preceding the experiment and the ingestion of caffeine, alcohol and consumption of food 2 hours prior to experiment.

To induce a competitive atmosphere 4 subjects were tested concurrently and completed the conditions together. Following warm up, subjects performed a 5000-meter competitive run. Lap splits were given to subjects to inform them of current pace per lap. After subjects completed the 5000-meter run, subjects returned to the UNLV biomechanics laboratory. The time from subjects completing the 5000-meter run to when they were in boots took no more than 10 minutes to get from the UNLV track to UNLV biomechanics laboratory. Subjects were separated into their own room to commence the IPC usage. The subjects were separated into separate rooms for the purpose of elimination of discussion about the specifics of the study. The settings on the IPC were randomly assigned either 80 mmHg of pressure or 20 mmHg of pressure, with a decompression time of 10

seconds for both pressure amounts. With this model of IPC Recovery Pump, the maximal pressure setting was 80 mmHg and the minimum was 20 mmHg. The IPC control panel was covered so athlete could not review IPC panel to ascertain what their pressure reading was. They had their back to the wall with a neutral spinal position and hips were flexed to 90 degrees and legs extended straight out in front of them. In addition the investigator was blind to what the pressure reading was as well.

The duration of recovery time was 60 minutes in duration. Every 10 minutes all subjects had their HR and BP measurements taken. Hydration was provided for subjects if needed since they were unable to move during recovery process. In addition, the investigator was constantly checking on all subjects and was always within earshot in case the subjects needed assistance at any time. After the 60 minutes of recovery time in the IPC device the boots were removed. The process of removing the IPC device and proceeding back out to track took 10 minutes and then the subjects performed an additional warm up of 10 minutes

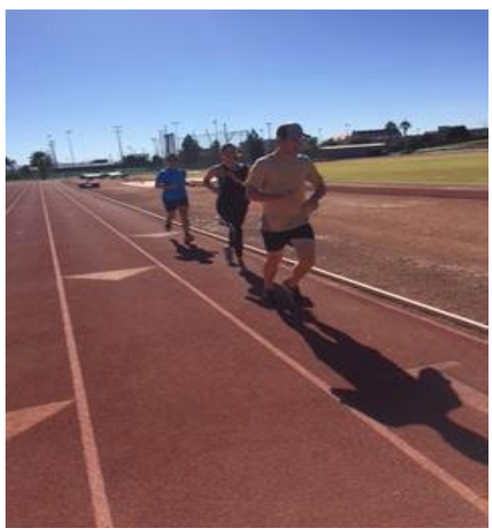

Figure 3: Subjects running 1600 m maximal effort.

After their warm up, subjects were asked to perform a maximal 1600-meter effort. They were instructed to run as fast as possible to produce a maximal effort, lap splits were provided every 400 meter lap. Day 2

After a minimum of 72 hours recovery between the initial test day, subjects returned to UNLV track for day 2 to perform Day 2 tests. Day 2 procedures were identical to Day 1 with the only difference being that they received a different pressure setting (i.e., if subject 1 received 80 mmHg on Day 1, he would receive 20 mmHg on Day2).

Table 1: Example subject outline of IPC pressure

Subjects	Trial 1	Trial 2
S1	80 mmHg	20 mmHg
S2	20 mmHg	80 mmHg
S3	80 mmHg	20 mmHg
S4	20 mmHg	80 mmHg
S5	80 mmHg	20 mmHg
S6	20 mmHg	80 mmHg
S7	80 mmHg	20 mmHg
S8	20 mmHg	80 mmHg
S9	80 mmHg	20 mmHg

A summary of Day 1 tests was as follows; the format for Day 2 tests will be identical.

10 min warm-up

5k time trial

10 min transition to IPC

60 min IPC use

5 measurements of HR/BP every 10 min (alternate based on number of HR/BP cuffs)

10 min transition IPC use back to track

10 min WU

1600 meter

5min cool-down

Figure 4: Map from UNLV Kinesiology lab to Track; Redline indicates walkingpath

Day 2

10 min warm-up

5k time trial

10 min transition to IPC

60 min IPC use

5 measurements of HR/BP every 10 min (alternate based on number of HR/BP cuffs)

10 min transition to IPC use

10 min WU

1600 meter

5min cool-down

Data Reduction

Two different types of data, two performance variables, and two recovery variables were analyzed. The performance variables were the 1600 m run time for Day 1 and Day 2 and was recorded in time as seconds. Heart rate during the 1600 m run was recorded as an average during the entire run; two averaged sets were collected from Day 1 and Day 2. The two recovery variables collected were heart rate and blood pressure measurements. They were collected during IPC use were recorded 5 times over the course of 60 minutes in 10 minute increments.

Statistical analysis

The two performance dependent variables were 1600 m run time on Day and Day 2 in seconds and heart rate averaged during the 1600 m run on Day 1 and Day 2. The independent variable was the two different pressures used in the IPC (20 mmHg, and 80 mmHg). During the 60 min IPC recovery the two recovery dependent variables that were collected was heart rate and blood pressure. During the 60 minutes 5 heart rate measurements were collected in 10-minute increments (10, 20, 30, 40, 50). The second recovery dependent variable was 5 blood pressure measurements taken in 10-minute increments (10, 20, 30, 40, 50). The independent variable was

the two different pressures used in the IPC, 20 mmHg, and 80 mmHg. A Paired T-Test was used to compare all dependent variables with the independent variable IPC Pressure (20 or 80 mmHg) For the Heart rate and Blood Pressure measurements a within-Subjects 2x5 Anova calculation was conducted to see differences. All statistics were run in Excel 2013.

Chapter 4

Results

Group means and standard deviations for all dependent variables are presented in Table2.

Performance Analysis

1600 m performance was not influenced by IPC Pressure (Figure 5; $p = 0.495$). The mean 1600 m run time following IPC pressure 20 mmHg was 366.6±53.59 s. The mean 1600 m run time following IPC pressure 80 mmHg was 364±54.26 s.HR_{Avg} was not influenced by IPC Pressure (Figure 6; $p = 0.063$).

Recovery Analysis

HR_{Rec} was not influenced by the interaction of time and pressure (Figure 7; $F(1,8) = 0.205$, $p = 0.925$). HR_{Rec} was not influenced by pressure ($F(1,8) = 0.169$, $p=0.692$) but was influenced by time ($F(4, 32) = 18.000$, $p<0.001$). $BP_{Systolic}$ was not influenced by the interaction of time and pressure (Figure 8; $F(1,8) = 1.1$, $p = 0.431$). $BP_{Systolic}$ was not influenced by pressure $F(1,8) = 1.8$, $p = 0.215$. $BP_{Systolic}$ was not influenced by time ($F(1,8) = 0.584$, $p=0.689$). $BP_{Diastoli}$c was not influenced by the interaction of time and pressure (Figure 9; $F(1,8) = 0.200$, $p = 0.928$).

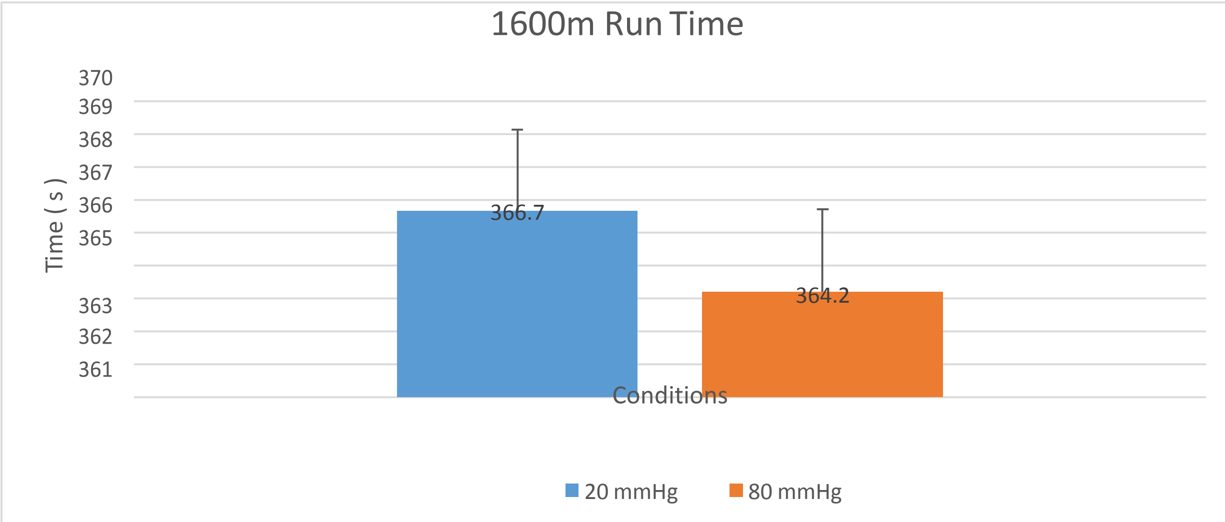

Figure 5: Illustration of group mean and standard error for 1600 m run performance time following use of Intermittent Pressure boots at 20mmHg and 80mmHg. There was no difference in run performance time between pressures ($p = 0.495$).

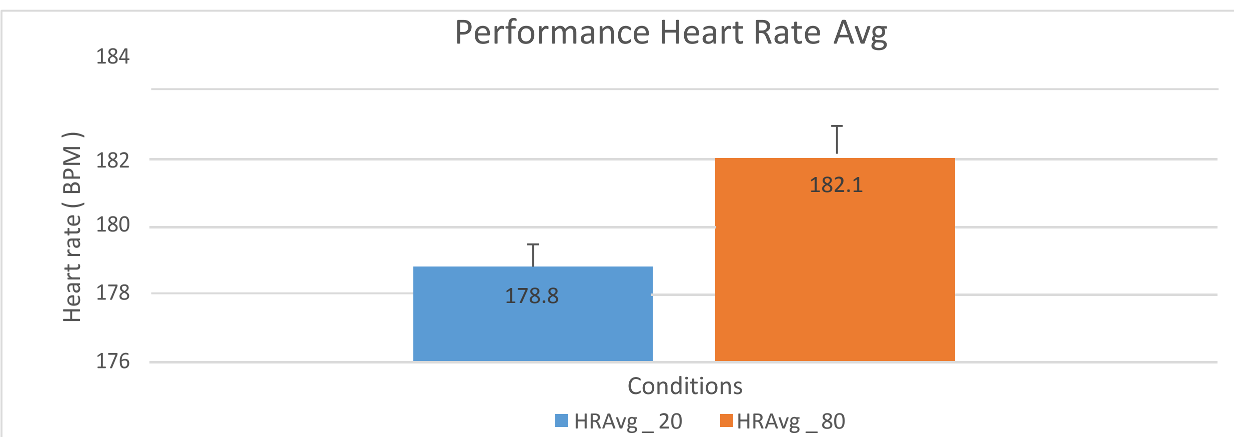

Figure 6: Illustration of group mean and standard error for Heart Rate Average (HR_{Avg}) over the 1600 m run performance following use of Intermittent Pressure Boots at 20 mmHg and 80 mmHg. There was no difference in HR_{Avg} between pressures ($p = 0.063$).

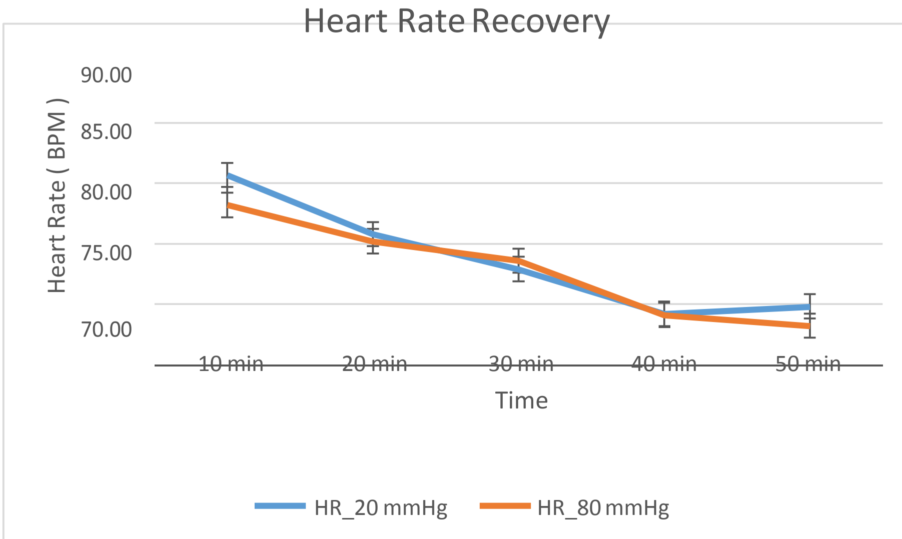

Figure 7: Illustration of group means and standard deviations for Heart Rate recovery (HR_{Rec}) during Intermittent Pressure boot use at 20 mmHg and 80 mmHg. Measurements were recorded at 10 minute intervals. HR_{Rec} was not influenced by the interaction of pressure and time ($p = 0.925$) nor was there a main effect for pressure ($p = 0.692$). HR_{Rec} was influenced by time ($p < 0.001$).

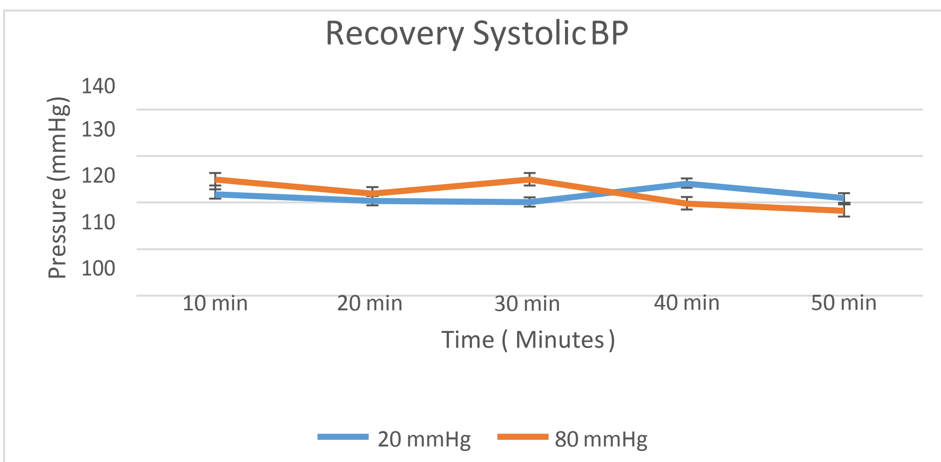

Figure 8: Illustration of group means and standard deviations for Blood Pressure Systolic ($BP_{Systolic}$) during Intermittent Pressure boot use at 20 mmHg and 80 mmHg. Measurements were recorded at 10 minute intervals. $BP_{Systolic}$ was not influenced by the interaction of pressure and time ($p = 0.431$) nor was there a main effect for pressure ($p = 0.215$) or time ($p = 0.689$).

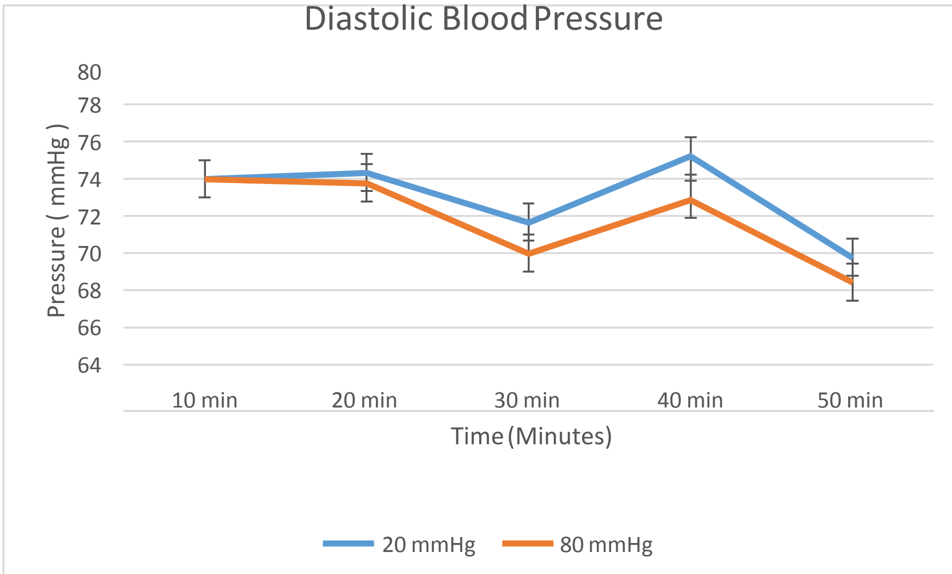

Figure 9: Illustration of group means and standard deviations for Blood Pressure Diastolic ($BP_{Diastolic}$) during Intermittent Pressure boot use at 20 mmHg and 80 mmHg. Measurements were recorded at 10 minute intervals. $BP_{Diastoli}$c was not influenced by the interaction of pressure and time ($p = 0.928$) nor was there a main effect for pressure ($p = 0.519$). $BP_{Diastolic}$ was influenced by time. ($p<0.001$).

	Pressure Used	
	20 mmHg	**80 mmHg**
Performance		
1600 m run time (seconds)	366.7±53.6	364.2±54.26
HR_{avg} BPM	178.8±9.02	182.1±11.2
Recovery		
HR_{Rec} BPM		
10	85.7±7.01	83.2±8.98
20	80.8±5.04	80.2±8.2
30	77.9±4.9	78.6±11.7
40	74 ±6.3	74.1±9.9
50	74.8±6.9	73.2±8.8
$BP_{Systolic}$ mmHg		
10	121.8±13.8	125±12.82
20	120±14.02	122.4±13.82
30	120.1±15.56	125±16.86
40	124.1±9.69	119.8±12.13
50	121±14.26	118.3±13.04
$BP_{Diastolic}$ mmHg		
10	76±6.86	76±4.61
20	76.3±6.2	75.7±5.54
30	73.6±6.14	72±5.59
40	77.2 ±11.33	74.8±5.8
50	71.7±11.2	70.4±6.73

Table 2: Group means and standard deviations for each parameter.

Chapter 5

Discussion

The most important observation of this study was that the level of pressure used during IPC had no influence on 1600 m run time. Based upon the analysis, the null hypothesis was accepted. It was also observed that HR during the 1600 m run was not influenced by IPC pressure usage – and thus, the null hypothesis was accepted.

A secondary purpose of this study was to examine the physiological responses during IPC use. For this aspect of the experiment, there were two recovery variables measured while using IPC: heart rate and blood pressure. It was hypothesized that heart rate during a high pressure IPC was not influenced by level of IPC pressure used. Based upon the results of the experiment, there was no statistical difference in heart rate during the 20 mmHg and 80 mmHg IPC usage. However, there was a decrease in heart rate over time which could be attributed to the natural occurrence of recovery post-exercise and the body returning back to homeostasis. Based upon analysis of the results, that the null hypothesis was retained. Likewise, there was no influence of IPC use on blood pressure (either systolic or diastolic). Therefore, the null hypothesis was retained.

The mean 1600 m run time following IPC pressure 20 mmHg was 366.6±53.59 s, or a 6:06 min/mile±53.59 s. The mean 1600 m run time following IPC pressure 80 mmHg was 364±54.26 s or a 6:04 min/mile±54.26 s. To give a sense of the level of performance in this study, the 1600 m run times were compared with a database for gender and age graded performances as well as with world record performances (Barder, 2015). For the male subjects in this study aged 31.6±6.67 years following IPC pressure 20 mmHg was 356.17±61.01 s or a 5:56±61.01 and the 80 mmHg was 353.8±61.14 s or a 5:53±61.14 s. This would have ranked them in the top 63 percent in relation

to the world record performance. The world record and age world record performance are the same due to the age of the subjects. (3:43.13 Hicham El Guerrouj, 1999) For the female subjects in this study aged 29.67±4.72 years following IPC pressure 20 mmHg was 387.67±34.5 s or a 6:17 min/mile ±34.5 s and the 80 mmHg was 384.3±38.73 or a 6:14±38.73 s. This would have ranked them in the top 68 percent in relation to the world record performance. The world record and age world record performance are the same due to the age of the subjects. (4:12.56, Svetlana Masterkova, 1996)

In addition the same database was utilized to compare 1600m time to predicted 5000m time to demonstrate that the subjects performed at a high level for the corresponding pressures. Note, that when participants ran the 5000 m run they had not had any exposure to the IPC product. For the male subjects in this study aged 31.6±6.67 years the 20 mmHg day was 1257±216 s or a 20:56±216 s and the 80 mmHg was 1248±209 s or a 20:48±209 s. The predicted time for the 5000m for the race equivalent was 20:38 minute. For the female subjects in this study aged 29.67±4.72 years and 20 mmHg was 1374±155.5 s or a 22:53±155.5 s and the 80 mmHg was 1351±118.2 s or a 22:30±118.2 s. The predicted race time for the 5000m for the race equivalent was 22:00. Based on this prediction scale this demonstrates that 5000m effort was a consistent maximal effort on both days.

The heart rates that were recorded during 20 mmHg and 80 mmHg were 178.8±9.02 bpm and 182.1±11.2 bpm, respectively. The average age in this study was 30±5.19 years. American Heart Association suggests based on an age predicted heart rate max of 30 years old the maximum heart rate should be 190 bpm. Based on that calculation, 20 mmHg yielded a 94 percent effort and 80 mmHg yielded a 96 percent effort. Based upon this observation, it seems that the runners exhibited a maximal effort when instructed to do so.

There are no other published data on run performance following IPC usage. However, Zelikovski et al. (1993) investigated the influence of an IPC device on cycling performance. The experiment consisted of 11 subjects (men) who exercised at a constant workload on a cycle ergometer until exhaustion. These groups were split into two groups experimental and control group. During a 20 minute recovery period, a modified pneumatic sequential intermittent device (MISPD) was applied to the subjects' legs. The subjects then performed a second constant load exercise bout.

The authors reported that after a 20 minute bout of recovery with the use of the MISPD, there was a 45 percent improvement in time to exhaustion during cycling in the experimental group in comparison to time to exhaustion in the passive recovery that did not receive the IPC device. However, in contrast to the present study, Zelikovski et al. (1993) used a control group that used passive recovery. The authors stated that psychological factors could not be discounted due to the fact that the control did not receive any physical intervention in comparison to IPC utilization. In the current study, a low pressure IPC setting was used as an attempt to control for a placebo effect. Also, the primary researcher was blind to the level of IPC used. Nevertheless, the work of Zelikovski et al. (1993) suggests possible performance improvement during cycling whereas the current study did not observe a performance improvement during running.

Although there were no data investigating the influence of IPC use on endurance run performance, there has been work investigating the influence of IPC on vertical jump performance. Waller et al. (2006) used the IPC as a recovery modality following a bout of exercise consisting of a shuttle run to induce fatigue. This study used a pre/post maximal vertical jump test to gauge changes in performance. An IPC device was used during recovery with subjects performing a maximal vertical jump test following IPC use. The experiment was a repeated measures design

that included three conditions: no IPC treatment, graduated low-pressure 20:15:10 mmHg IPC use, and graduated high-pressure 70:65:60 mmHg IPC use.

The authors reported that vertical jump performance was reduced compared to pre-experiment maximum vertical jump assessment; however, the magnitude of reduction was smallest following high and low pressure IPC treatments. The high pressure treatment produced a significantly smaller mean reduction than both the low pressure treatment and no treatment (1.9±1.4 vs. 4.4±3.8 and 5.9±3.4cm respectively).

The authors stated the effectiveness of IPC as a recovery modality to improve vertical jump performance after an exhaustive set of exercise. The results of the current study differ from Waller et al. (2006) in that no changes in 1600 m run time were observed between levels of pressures used. Although it was not clear why IPC may influence vertical jump but not 1600 m run time, it may be that a higher volume of exercise to induce fatigue (i.e., 5 K run vs. shuttle run) may influence the outcome of the study. In addition, the pressures of the IPC were different between studies and the application was not consistent across the boot itself. In the study by Waller et al. (2006), a graduated low pressure of 20:15:10 mmHg or a graduated high pressure 70:65:60 mmHg was used, versus the uniform pressure 20 mmHg or 80 mmHg used in this study.

Confounding Factors

There were confounding factors considered due to the nature of this being field study. A confounding factor of this study was weather condition variability between days. According to the National Weather service there was a temperature differential from Day 1 and Day 2. Day 1 of testing had a 57 degree Fahrenheit versus Day 2 was 50 degree Fahrenheit. Day 1 wind speed averaged 8 mph out of the west and the humidity was 36 percent. Day 2 wind speed was 9 mph

out of the northwest and the humidity was 34 percent. However, order of conditions were counterbalanced between subjects. Nevertheless, data were re-analyzed to compare Day 1 1600 m run time to Day 2 (regardless of IPC level used). From that analysis, it was determined that run time was not different between days. Therefore, it does not seem that the variability of weather conditions played a role in the outcome of the study.

Another confounding factor was the training stress on the subject either going into the study or during the time in-between Day 1 and Day 2 of testing. A majority of these athletes were competitive athletes year round and their training program may not have been consistent over the entire test duration. In addition, training stress in between Day 1 and Day 2 was not controlled because these subjects were still in training for various competitions which also could have influenced performance. Nevertheless, based upon average HR during the 1600 m run, the physiological measure of effort was consistent between days and represented a high level of effort when considering the 94 (Day 1) and 96 (Day 2) percent of age predicted HR sustained.

Order of conditions was considered as a potential confounding factor. As noted above, the 1600 m run times were compared between days regardless of pressure level used and it was determined there was no difference in run performance between days. This seems to suggest that there was not an order effect. An interesting note to mention concerning the order of pressures received was that when the 80 mmHg was given on Day 1 and 20 mmHg was given on Day 2, those subjects did audibly exclaim the difference in the tightness or lack thereof on the legs. This was in contrast qualitatively to how they responded when they received 20 mmHg on Day 1 and 80 mmHg on Day 2. As demonstrated in the analysis above this could be a psychological component that could have been a confounding factor on the subject's performance.

Furthermore, the researcher was blind to the pressure level of IPC used by subjects to minimize any potential bias effect. In addition, the individual IPC devices were covered from the subject so they could not read the measurements on the dial and ascertain the pressure they were receiving.

Practical Application

The basis of this study was to simulate a 'real world' situation where an athlete would have to compete at a high level in multiple sessions in one day. Based on the analysis of the result there was no change in mean time between pressures used. However, highly competitive races are won by mere seconds. For example, the 2012 Olympic Final Men's 1500m run (1 metric mile race equivalent) the difference between 1st place and 10th place was 4 seconds. From a coaching or competitive athlete's perspective, a few seconds can mean the difference between success and failure. Therefore, it seems important to inspect the individual responses to IPCuse.

	Subjects	**1600 M _ 80 mmHg (Seconds)**	**1600 M _ 20 mmHg (Seconds)**	**Difference**	**Fast/Slow/No change**
	Subject 1	406	405	1	No change
	Subject 2	277	278	-1	No change
	Subject 3	415	419	-4	Faster
	Subject 4	282	288	-6	Faster
	Subject 5	364	353	11	Slower
	Subject 6	355	352	3	Slower

	Subject 7	388	395	-7	Faster
	Subject 8	429	422	7	Slower
	Subject 9	360	388	-28	Slower
	Mean	364	**366.7**	**-2.7**	

Table 3: An illustration of the individual responses to IPC use.

For each subject, the difference in 1600 m run time following 80 mmHg vs. 20 mmHg use was determined. From this analysis, it seems there were 3 subjects that had a faster 1600 m run time following 80 mmHg vs. 20 mmHg, and 4 subjects that had a slower time, there were 2 subjects that produced no change in time. The investigators took the liberty that a 1 second differential and under was decided as "no change," in performance. This might be an indication that some athletes benefitted from IPC use while others had a reduced or virtually no change in performance following IPC use. However, this experiment was not designed for single subject analysis and it is not known if the subjects that had an improved 1600 m time would continue that trend in future testing.

A very popular racing combination for a competitive endurance athlete in track and field is the 5000 m/1500 m combo. The practicality and usage of a product like this could benefit athletes and could be a very real world technique to improve subsequent run performance. However, since individual responses to the IPC use was varied, it seems important from a coaching perspective to determine which athletes might benefit from this type of treatment.

Limitations

There were several limitations of this study. The number of IPC Recovery boots available limited the number of subjects tested in one trial at a time. This could have affected results because the purpose of this study was to best simulate a field race effort. A lower number of IPC devices limits the number of competitive subjects. A limitation to note was that due to the level of athletic experience, a majority of these subjects could have adopted sub-maximal pacing strategies in the initial 5000 m due to the knowledge of the impending 1600 m maximal effort. Subjects were always encouraged in a similar manner. Based on the analysis of the results the generalizations can only be made to the level of athlete in this study.

Another limitation was that only one model of IPC was tested. This limits the generalizability of the results to other models of IPC. In the present study, the amount of pressure used was a limitation. Specifically, in this study design 20 mmHg and 80 mmHg were the pressures used for 60 minutes. Different results could be observed using other pressures and application time used. Applicability of the current study's results were limited to an athletic population similar to the subjects in this study and may not apply to other sports or activities.

Conclusion

The current research differs from the related IPC literature related to performance because it was the first in the reviewed literature to utilize an over ground endurance event to test the efficacy of the IPC product for performance. The main aim of this study was to determine if IPC after a 5000 m run influences a consecutive maximal effort 1600 m run performance. A secondary purpose was to determine if the level of IPC pressure used influences run performance.

In addition, this literature explored some recovery parameters while subjects were actually recovering with the IPC device. The performance of the subjects in the current study did not change while using the various IPC pressures, nor did the recovery parameters explored elicit any change during recovery. As stated in the analysis there seems to be an individual response to the IPC as a recovery modality, as this product becomes more popular in mainstream athletics the amount of literature testing the IPC device must grow if researchers are to better assist coaches and athletes with the practical usage of this product.

Research recommendations

Further research could explore performance for the endurance athlete by enlisting testing variables that included different distances, speeds, and IPC pressures. In addition, testing the efficacy of the IPC device in other sporting populations would serve to benefit the practical usage of this product. Many sporting events have multiple events that happen in one day or in a back-to-back events. More research that could mimic this amount of volume could expand this body of literature in assisting the athlete in using this product. Lastly, another research recommendation was to use the IPC product to assist with chronic training loads i.e. a runner building their run mileage volume over a period of time.

Appendix 1

IRB Form

INFORMED CONSENT

Department of <u>Kinesiology and Nutrition Sciences</u>

TITLE OF STUDY: Sequential Intermittent Pneumatic Compression effect on run performance.

INVESTIGATOR(S): <u>Mr. Max Jones , Dr. John Mercer, Dr. Navalta, Mr. Tedd Girouard</u>

For questions or concerns about the study, you may contact the Principal investigator Dr. John Mercer (702-895-4672) or Mr. Max Jones (702-985-3785).

For questions regarding the rights of research subjects, any complaints or comments regarding the manner in which the study is being conducted, contact **the UNLV Office of Research Integrity – Human Subjects at 702-895-2794, toll free at 877-895-2794 or via email at IRB@unlv.edu.**

<u>Purpose of the Study</u>

You are invited to participate in a research study. The purpose of this study is to examine the performance in a maximal 1600-meter run after the using Recovery- Boots (see picture at the end

of this document). This product is a ‘intermittent pneumatic compression’ device that applies pressure to your legs while you are resting.

Participants

You are being asked to participate in the study because you fit this criteria: Apparently healthy adult, age 18-50 year old, no injury that would interfere with your ability to run, and are actively training for an endurance event. Also, subjects cannot be pregnant or think they may be pregnant.

We are selecting a group of participants that have similar 5 K performances – it is important to know that even if you are interested in participating in the study, you may not be selected.

Procedures

If you volunteer to participate in this study and are selected, you will be asked to do the following:

Attend two test sessions, held on different days at the UNLV Track and the UNLV Biomechanics laboratory. We will schedule these days prior to your visit.

Day 1

Prior to testing, we will record your height, weight, age, and gender. We will ask you to complete an Endurance training questionnaire (attached) inquiring about experience with the endurance training.

After familiarization with equipment we will proceed to UNLV Track. You will proceed to complete a Self-Selected warm-up no longer than 10 minutes. We will ask you to wear a heart rate transmitter (standard heart rate type monitor).

After the warm-up you will participate in a competitive 5000 meter run on the UNLV Track. Other participants the study will be completing the 5000 m run at the same time with the intent being this will be a race-effort.

Lap splits will be provided to you each 400 meters. Immediately following your run you will have 10 minutes to proceed back UNLV Biomechanics Laboratory and will be directed to your recovery session utilizing Recovery Boots. You will be asked to sit using the Recovery Boots for 60 minutes. During this time your Heart Rate and Blood Pressure will be measured at 5 different time segments in 10-minute intervals. The researchers will be available to assist you and provide hydration if needed. You will be given reading material (related to endurance training) if you choose to read it. After the 60 minutes of Recovery Boot usage you will proceed back out to UNLV track and perform another 10-minute warm-up. After your warm-up you will perform a maximal-effort 1600-meter run, again lap splits will be provided for you each 400 meters. We will measure your time and heart rate during this run.

After the completion of your 1600-meter you can warm down and that concludes the test session.

Day 2

We will repeat the same procedures in the same timely fashion as Day 1. Please wear similar clothing and same running shoes as Day 1.

Benefits of Participation

Individuals may benefit from knowing how a recovery modality can influence performance.

Risks of Participation

There are risks involved in all research studies. This study may include only minimal risks because the activities we want you to perform are ones that you are comfortable doing.

The risks of this study are those that you would experience during any high intensity running efforts (e.g., interval training, race performance). These risks include muscle injury and delayed onset muscle soreness, for example.

In addition, you may feel some uncomfortable pressure using the Recovery Boots. It is important that you let us know if there is any pinching or pain that you are experiencing while using the boots.

Cost/Compensation

There will not be financial cost to you to participate in this study. The entire study will take 3 hours on two separate testing days for a total of 6 hours. You will be compensated with a $5 gift-card for your participation. If you do not have a UNLV parking pass, please let us know and we will provide a day-pass for you.

Confidentiality

All information gathered in this study will be kept as confidential as possible. No reference will be made in written or oral materials that could link you to this study. All records will be stored in a locked facility at UNLV for 3 years. After the storage time the information gathered will be destroyed from all hard drives and storage capacities.

Voluntary Participation

Your participation in this study is voluntary. You may refuse to participate in this study or in any part of this study. You may withdraw at any time without prejudice to your relations with UNLV. You are encouraged to ask questions about this study at the beginning or any time during the research study.

Participant Consent:

I have read the above information and agree to participate in this study. I have been able to ask questions about the research study. I am at least 18 years of age. A copy of this form has been given to me.

Signature of Participant Date

Participant Name (Please Print)

We may want to take some pictures to use during a research presentation or manuscript. Please sign below if it is ok for us to use your image (your face will not be shown in the image).

☐ It is ok to use my image for presentations and/or manuscripts.

☐ It is not ok to use my image.

Signature of Participant Date

Appendix II Runner

Questionnaire

Sequential Intermittent Pneumatic Compression effect on run performance.

Runner Questionnaire

Name:______________________________________

Runner's Questionnaire

1. How long have you been running? ______________________

2. Running interest: (check all that apply):

( )Fitness and fun

( ) Recreational and social

( ) Multisport

( ) Racing for improved performance

( ) Racing for awards (overall, age group, BQ, etc).

3. Would you consider yourself a: Novice or Experienced runner (circle one)

4. Race experience: (circle one) None Novice Experienced

5. What is your most recent race result?_____________

6. Running Personal best: (N/A for unknown)

Distance: Pace:

Mile/1500

5k

10k

Half Marathon

Marathon

7. Have you ever done speed workouts, interval training, or effort sessions? Yes or no

8. What are your training paces for the following: (N/A for unknown)

Distance: Pace:

Mile Repeats

Mid-distance run/tempo run

Long run

Easy run I always run the same pace:

9. What is your normal weekly mileage?______________________________________

10. What is the most mileage you have done in one week?_________________________

11. What is your weekly mileage for the last 3 weeks? _____________________

12. Do you cross train? If so, what type of exercise?

____

13. Are you training for a race? ___________________________

14. What is your goal? ____________________

15. Are you following a plan, if so, from whom/where?? _______________________

16. Have you recently changed running shoes? ___________________________________

Injuries:

Please list any injuries that you have suffered from in the last year:

Running-related musculoskeletal pain in the lower limbs that causes a restriction on or stoppage of running (distance, speed, duration or training) for at least seven days or three consecutive scheduled training sessions, or that requires the runner to consult a physician or other health professional.

____

Recovery:

Do you perform regular recovery work? Yes or no

Please check all that apply:

( ) Foam rolling

( ) Ice bath

( ) Massage

( ) Stretching

( ) Compression garments

( ) Recovery Boots (Pressurized pneumatic boots

( ) Cryo therapy

( ) Contrast baths

( ) NSAIDS

List any others that may apply

Appendix III

Sequential Intermittent Pneumatic Compression effect on run performance.

Data collection sheet

Day

Subject #___________Gender______________Age_____________

Ht____________cm Wt_____________kg

Resting HR/ BP______________bpm __________/__________

5000m_______:________

_______mmhg in Recovery Boots

	10 Minute	20 Minute	30 Minute	40 Minute	50 Minute
HR					
BP	/	/	/	/	/

1600m________:_______

Avg. HR during 1600m_________

Subject # ___________

Day

Resting HR/ BP______________bpm __________/__________

5000m_______:________

_______mmhg in Recovery Boots

	10 Minute	20 Minute	30 Minute	40 Minute	50 Minute
HR					
BP	/	/	/	/	/

1600m________:_______

Avg. HR during 1600m _________

References

Barder, O. (2015, March) Age Graded Performances. Retrieved from http://runningforfitness.org/calc/racepaces/rp

Barnett A (2006) Using recovery modalities between training sessions in elite athletes. Sports Med 36: 781-796.

Berry MJ, McMurray RG. Effects of graduated compression stockings on blood lactate following an exhaustive bout of exercise. Am J Phys Med 1987; 66: 121-32

Boileau RA, Misner JE, Dykstra GL: Blood lacticacid removal during treadmill and bicycle exercise at various intensities. J Sport Med 1983; 23: 159-167.

Chatard J-C, Ataloui D, Farjanel J, et al. Elastic Stockings, performance and leg pain recoveryin 63-year-old sportsmen. Eur J Appl 2004; 93: 347-352

Chen AH, Frangos SG, Kilaru S, Sumpio BE, et al. (2001) Intermittent pneumaticcompression devices -- physiological mechanisms of action. Eur J Vasc Endovasc Surg 21: 383-392.

Chleboun, GS, Howell, JN, Baker, HL, Ballard, TN, Graham, JL, Hallman, HL, et al. Intermittent pneumatic compression effect on eccentric exercise-induced swelling, stiffness, and strength loss. Arch Phys Med Rehabil 76: 744–749, 1995.

Cochrane DJ, Booker HR, Mundel T, Barnes MJ (2013) Does Intermittent Pneumatic Leg Compression Enhance Muscle Recovery after Strenuous Eccentric Exercise? Int J Sports Med.

Coffey V, Leveritt M, Gill N. Effect of recovery modality on 4-hour repeated treadmill running performance and changes in physiological variables. J Sci Med Sport 2004; 7: 1-10

Comerota AJ (2011) Intermittent pneumatic compression: physiologic and clinical basis to improve management of venous leg ulcers. J Vasc Surg 53: 1121-1129.

Dini D, Del Mastro L, Gozza A et al. The role of pneumatic compression in the treatment of postmastectomy lymphedema. A randomized phase III study. Ann Oncol 1998; 9: 187–190.

Flam E, Berry S, Coyle A: Blood-flow augmentation of intermittent pneumatic compression systems used for the prevention of deep vein thrombosis prior surgery.Am J Surg 1996; 171: 312-315.

Gill ND, Beaven CM, Cook C. Effectiveness of post-match recovery strategies in rugbyplayers. Br J Sports Med 2006;40:260-3

Hanson, E, Stetter, K, and Thomas, A. An Intermittent Pneumatic Compression Device Reduces Blood Lactate Concentrations More Effectively Than Passive Recovery after Wingate Testing. J Athl Enhanc 02: 1–4, 2013.

Hartman JT, Pug JL, Smith RD et al. Cyclic sequential compression of the lower lib in prevention of deep venous thrombosis. J Bone Joint Surg 1982; 64: 1059–1063.

Hausswirth, C., Louis, J., Bieuzen, F., et al. (2011). Effects of whole-body cryotherapy vs. far-infrared vs. passive modalities on recovery from exercise-induced muscle damage in highly-trained runners. PloS ONE. 6(12): e27749. Doi:10.1371/journal.pone.0027749

Hemmings, BJ. Physiological, psychological and performance effects of massage therapyin sport: a review of the literature. Phys Ther Sport 2: 165–170, 2001.

Hinds T, McEwan I, Perkes J, et al. Effects of massage on limb and skin blood flow after quadriceps exercise. Med Sci Sports Sci Sports Exerc 1994; 26: 992-6 Exerc 2004; 36: 1308-13

Jeffreys, I. (2005). A multidimensional approach to enhancing recovery. Strength and Conditioning Journal. 27(5): 78-85.

Kraemer, WJ, French, DN, and Spiering, BA. Compression in the treatment of acute muscle injuries in sport. Int SportMed J 5: 200–208, 2004.

Kraemer WJ, Bush JA, Wickham RB, Denegar CR, Gomez AL, et al. (

2001) Continuous compression as an effective therapeutic intervention in treating eccentric-exercise-induced muscle soreness. J Sport Rehabil 10: 11-23

Kraemer WJ, Bush JA, Wickham RB, et al. Influence of compression therapy on symptoms following soft tissue injury from maximal eccentric exercise. J Orthop Sports Phys Therapy 2001; 31: 282-90

Jemni, M.; Sands, W.A.; Friemel, F.; and Delamarche, P. (2003). Effect of active and passive recovery on blood lactate and performance during simulated competition in high level gymnasts. Can. J. Appl. Physiol. 28(2): 240-256. © 2003 Canadian Society for Exercise Physiology

Lanier AB. Use of nonsteroidal anti-inflammatory drugs following exercise-induced muscle injury. Sports Med 2003; 33: 177-86

Tiidus PM, Shoemaker JK. Effleurage massage, muscle blood flow and long-term post-exercise strength recovery. Int J Sports Med 1995; 16: 478-83

Trappe TA, White F, Lambert CP, et al. Effect of ibuprofen on postexercise muscle protein synthesis. Am J Physiol Endocrinol Metab 2002; 282: E551-6

Viitasalo JT,, Niemela K, Kappola R, et al. Warm underwater water jet massage improves recovey from intense physical exercise. Eur J Appl Phsiol 1995;71: 431-8

Waller et. al. (2006) Intermittent Pneumatic Compression Technology for Sports Recovery. Engineering of Sport

Weiss, LW. (1991). The obtuse nature of muscular strength: The contribution of rest to its development and expression. Journal of Applied Sports Science Research. 5: 219-227.

Westerblad H, Allen DG, Lannergren J. Muscle fatigue: lactic acid or inorganic phosphate the major cause? News Physiol Sci 2002; 17: 17-21

Wiener, A, Mizrahi, J, and Verbitsky, O. Enhancement of Tibialis Anterior Recovery by Intermittent Sequential Pneumatic Compression of the Legs. Basic Appl Myol 11: 87–90, 2001.

Yamane M ,Teruya H, Nakano M, et al. Post Exercise leg and forearm flexor muscle cooling in humans attenuates endurance and resistance training effects on muscle performance and on circulatory adaptation. Eur J appl Physiol 2006; 96: 572-80

Zelikovski, A, Kaye, CL, Fink, G, Spitzer, SA, and Shapiro, Y. The effects of the modified intermittent sequential pneumatic device (MISPD) on exercise performance following an exhaustive exercise bout. Br J Sports Med 27: 255–259, 1993.

CURRICULUM VITAE

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Education History

Florida Gulf Coast University, Fort Myers, FL
Bachelor of Science in Human *Performance*, Graduated May 2012
University Of Las Vegas
Masters of Science in Kinesiology, Estimated Graduation Spring 2016
-Concentration in Biomechanics

Work Experience

FGCU Division 1 Athletics Internship August 2011- December 2011
- Completed 500 hours of Special Athletic population training
- Trained Athletes at the Division 1 level

Rockin Runners Running Group Head Coach January 2012- Present
- Downtown Las Vegas Coach of Las Vegas

Las Vegas Athletic Club Personal Trainer January 2012- Present

Las Vegas Athletic Club Group Fitness Instructor
- Aquatic Fitness April 2012- Present

Co-Founder of Extraordinary Trainers March 2012- Present

Anthem Fitness
FMS Tester
Corrective Exercise Specialist **January 2014- Present**

Research

USF PTSD Pilot Study at Nellis Air Force Base
- Worked a fitness component on a psychological study benefiting Veterans with PTSD.

UNLV Kinesiology Lab **-Lacrosse Velocity Testing**

UNLV Kinesiology Lab- Intermittent Pneumatic compression

Affiliations
National Society of Leaders Spring 2009 – Present
Member
Sigma Phi Epsilon Fraternity Spring 2010- Lifetime
FGCU Division One Cross Country Team (2008-2012) August 2008 - 2012
- Captain of Men's team (2009, 2010,2011)

Certifications

National Strength and Conditioning Association
- Certified Strength and Conditioning Specialist

American Council of Exercise

- Certified Personal Trainer

Functional Movement Screen

- Level 1

Selected Functional Movement Assessment

TRX Level 1 Suspension Course

American Heart Association

- CPR/AED