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entitled

The Effect of Compression Recovery Pants on Cycling Performance

by

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Submitted to the Graduate Faculty as partial fulfillment of the requirements for the

Master of Science Degree in

Exercise Science

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An Abstract of

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The purpose of this study was to investigate the effects of pneumatic compression
devices on cycling performance. Twelve (n=12) well-trained multisport athletes
completed a randomized crossover study. Subjects were required to undertake a
prescribed training session followed by a randomized selection of either twenty minutes
recovery with the use of a pneumatic compression (COMP) device as a recovery aid or
passive recovery using a sham (SHAM) condition. The following day, a 30 minute
maximal exercise test was undertaken and heart rate (HR) and average power output (PO)
was recorded. The same protocol was repeated one week later using a crossover design.
Results showed no significant difference between average PO either with or without the
use of pneumatic compression during recovery (COMP, 262 ± 52 W; SHAM, 263 ±52
W; p>0.05). No difference in peak HR was observed when comparing the use of
compression pants (177 ± 10 bpm) to the SHAM condition (178 ± 9bpm). The results of
the present investigation indicate that the use of a pneumatic compression device does not
have a significant effect on power output or heart rate when used as a recovery aid from
prior bouts of heavy intensity exercise.
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Chapter 1

Introduction

Compressive devices have been used as a tool to help patients with vascular problems for many years. Over this time, these devices have developed from a basic compression sleeve to mechanical pneumatic devices. Although the application of compressive devices in endurance sports has been more recent, the development from a basic sleeve to the use of mechanical devices has also occurred.

As exercise is undertaken, equilibrium is disrupted. Therefore, any action which can aid the body in returning to equilibrium is likely to improve subsequent performance. A 2012 study by de Glanville and Hamlin found a positive effect of lower body garment compression on a subsequent 40km time trial (9). Findings consistent with these have been reflected throughout the literature and endurance athletes continue the use of compression as a way to recover more quickly, and ultimately improve performance.

The effectiveness of compressive devices on exercise performance requires further investigation however, there have been some positive findings. A 2013 study by Driller and Halson investigated the use of lower body compression devices between two 30 minute cycling tests. When investigated, an increase in power output in the group using compression garments was found when compared to wearing baggy shorts. Girth
and blood lactate levels were significantly increased in the baggy shorts group (10). As well as these findings, a 2015 study by Martin et al. showed a significant decrease in blood lactate levels after 25 and 35 minutes of compression recovery following two 30 second wingate anaerobic cycling tests when compared to a control group (23). These findings suggest the use of compression pants as a recovery aid should improve power output in subsequent cycling tests and provide further possibility to investigate the impact of compression wear on athletic performance.
Chapter 2

Review of Literature

There are many factors to consider when looking at a cyclist’s ability to perform well in a race. As the level of competition improves, the difference between first and last can be very small. When looking at the physiological difference between athletes of this level, the results are determined by being able to hold a higher power over the course, and being able to recover from a previous effort quickly in order to sustain another high effort.

An athlete’s ability to hold a higher power over the course is dependent on a variety of factors. Genetics and adaptations to prior training are two key points that determine why one athlete might be able to hold a higher power over a course when compared to another. Adaptations to prior training ensure an athlete’s body is well equipped at handling the stress that is placed on it during a cycling race. In order to do this, a few things occur. Body mass and composition change (34), muscle size and muscle fiber type change (22), the athlete’s heart function changes by increasing left ventricular function and stroke volume (2), and the athlete’s ability to transport and utilize oxygen (34). The goal of training for cycling is to improve these areas.
The role of recovery is important for a few different reasons, firstly it is important for cyclists to recover from sustained efforts during a race in order to put out another strong effort. Secondly, it is important to recover from one stage or training day in order to compete or train again. When a hard effort is undertaken, the body’s homeostasis is disrupted, the goal of recovery is to ensure an athlete can return to homeostasis quickly in order to perform again.

In order to return to homeostasis a few areas must be addressed. Delayed onset muscle soreness and muscle damage must be minimized (21), muscle fatigue must be decreased by replenishing glycogen levels (12, 13, 26) and pH levels must be optimized (36). The goal of recovery aids is to aid with the athlete’s return to homeostasis in order to perform at the highest level.

2.1 Returning to Homeostasis

2.1.1 Delayed Onset Muscle Soreness

Delayed onset muscle soreness refers to the combination of six different mechanisms. The pathway of delayed onset muscle soreness begins with structural muscle damage. Membrane damage of the sarcoplasmic reticulum then occurs which causes calcium to leak out and collect in the mitochondria inhibiting ATP production. The buildup of calcium also activates enzymes which degrade contractile proteins. This is followed by an inflammatory process and shifts of fluid and electrolytes which in turn leads to free nerve endings being stimulated and a sensation of pain being felt (20). Delayed onset muscle soreness leads to a decrease in athletic performance by reducing joint range of motion, shock attenuation and peak torque. Alternations in muscle
sequencing and recruitment patterns may also occur (6). For this reason, decreasing delayed onset muscle soreness is highly important when looking to increase athletic performance.

2.1.2 Muscle Fatigue and Glycogen Levels

Muscle glycogen and blood glucose are the main energy substrates for muscle contraction in the body (26). For this reason, it is important for glycogen levels to be replenished after exercise. Studies have suggested a depletion in muscle glycogen levels significantly contribute to fatigue and delayed recovery in endurance athletes (13). It has been shown that with decreased muscle glycogen, fat oxidation and blood lactate levels increase along with an increase rating of perceived exertion (13). It has also been shown that lower glycogen levels lead to an increase in fatigue due to the impacts on the sarcoplasmic reticulum and the decrease in Ca^{2+} release rate. Given calcium plays a major role in muscle function during exercise by initiating contractile events and binding to calmodulin to activate muscle glycogen breakdown, a decrease in release rate of Ca^{2+} leads to an increase in fatigue (13).

2.1.3 Acid Base Status

There is much debate in the literature regarding the primary site of Hygrogen ion production during exercise. Although this is the case, it is clear that there is a decrease in pH levels during certain exercise. This can be explained partially by an increase in carbon dioxide, an increase in lactate and lactic acid and the release of H^{+} ions during the breakdown of ATP (3). An increase in acidity decreases athletic performance by altering
enzymatic function. Given enzymes require a certain pH level to function at optimum, an increase in H\(^+\) ions ensures enzymatic function decreases leading to a decrease in the ability to produce ATP. As well as this, with a decrease in pH levels, oxygen’s ability to bind to hemoglobin is decreased causing an unloading of O\(_2\) to the tissues.

A change in pH levels is altered by buffers within the body. If the pH level decreases, hydrogen ions are removed, if the pH level increases, they are added to the environment. Intracellular buffers include proteins, phosphate groups and bicarbonate. These buffers act quickly to turn strong acids into weak acids. Extracellular buffers include bicarbonate, hemoglobin and blood proteins.

The most understood mechanism behind acid base balance is the respiratory system. When the amount of CO\(_2\) in the blood increases, the amount of H\(_2\)CO\(_3\) increases, in turn lowering the pH by increasing the acid concentration in the blood. As CO\(_2\) is exhaled through the lungs, the acidity decreases, shifting towards homeostasis (35).

### 2.2 Recovery Aids

The use of recovery aids to improve performance has become much more prevalent in recent years. Along with overwhelming anecdotal evidence supporting the use of recovery aids from athletes and coaches, there has been evidence supporting the effectiveness of compression garments (9, 10, 38), and massage (19, 6, 37) in improving athletic performance. These methods are often coupled with active recovery which has been shown in the literature be a more effective method than passive recovery (19).
2.2.1 Active Recovery

Active recovery is one of the most well understood and widely practiced recovery methods. Multiple studies have found decreased lactate levels following active recovery post exercise as compared to passive recovery (14, 16, 28, 30). The mechanisms behind active recovery can be explained by increased function of the lymphatic system by natural compression, an increase in myokine and anti-inflammatory input and an increase in fluid and metabolite movement out of damaged areas by increased blood flow (5, 15).

2.2.2 Massage

Massage post exercise has been used for many years as a recovery aid in order to improve athletic performance (27, 35, 39). Massage has been shown to be effective in reducing soreness (29, 32, 25) and promoting the healing process (31). In recent years, particularly in endurance sports, massage has taken on a more individual form by including tools such as foam rollers. Foam rolling has shown to be effective in reducing delayed onset muscle soreness (25), decrease inflammation and increase mitochondria function (37).

2.2.3 Compression Garments

The use of compression garments has continued to increase in recent times. Although this is the case, there are many areas that need to be investigated to determine the effectiveness of compression on exercise performance and recovery (4). The
mechanisms behind the use of compression garments has been debated within the literature. Possible reasons for an increase in performance can be explained when considering gradient compression which allows an increase in the body’s natural muscle pump function and hence improves lymphatic return (1, 17, 24). The effectiveness of compression garments may also be explained by the compression itself, reducing the amount of space available for muscle damage to occur (24).

A more recent development in compression use within athletics has been the use of pneumatic compressive devices as a recovery tool. The popularity of pneumatic compression devices has increased due to the ability to couple compression with massage. Although there is overwhelming anecdotal evidence supporting the use of these devices as a recovery aid as well as marketing claims to aid with the recovery pump mechanism, there is little evidence to support their effectiveness.

Although there have been numerous studies examining the impact of compression on exercise performance and recovery, the impact of pneumatic compression devices, particularly with peristaltic pulsing requires further investigation. Despite there being little evidence to determine the physiological factors behind compression pants as a recovery aid, there has been some evidence suggesting a decrease in blood lactate levels with the use of compression pants as a recovery aid (18, 23). Given the overwhelming anecdotal evidence suggesting the effectiveness of compression recovery pants for endurance athletes, the purpose of this study is to determine whether there is an increase in power output when using compression pants as a tool to improve cycling performance over a 30 minute test.
2.3 **Purpose**

The purpose of this study is to determine whether an increase in power is found in a 30 minute all out cycling test when compression pants are used as a recovery method following a controlled training session.

2.4 **Hypothesis**

The use of compression pants as a recovery aid will lead to an increase in average cycling power the following day.

The use of compression pants will show no change to the control when comparing heart rate data between sessions.

2.5 **Significance of the Study**

Previous studies have looked at the impact of compressive devices on cycling performance. This is the first study to look at the impact of power levels over back to back days when using a pneumatic compressive device with peristaltic pulsing. The protocol of this study closely follows the common use of pneumatic compressive devices in cycling training and racing.
3.1 Experimental Approach to the Problem

In the present study, the effects of wearing a non-invasive pneumatic compression device, following a training session was evaluated vs. a passive recovery in the same position. In order to determine the effectiveness of the pneumatic compression device, a randomized crossover study was used where a controlled training session was followed 24 hours later by a 30 minute test for power. Heart rate was measured during all cycling training and testing as well as during the recovery period.

3.2 Subjects

The study was approved by the University of Toledo Institutional Review Board for the use of human subjects in research and carried out in accordance with the guidelines set forth in the Declaration of Helsinki. Each subject had all of the procedures and known risks associated with participating in the investigation explained to them before answering a brief health questionnaire and providing written informed consent. Twelve
participants completed the study (n=12). All participants were healthy, injury free and very familiar with high intensity exercise (triathlon training hours = 12±5 hours per week).

3.3 Procedures

The randomized crossover method was setup whereby each subject was required to attend five sessions. The initial session was used to establish informed consent and take body metrics. Height and body weight were recorded. Participants then underwent a 10 minute warmup period and a 15 minute all out test for power on a stationary bicycle trainer that measures power output (computrainer pro) in order to determine a baseline power in which power output for the remaining sessions was established.

On the second visit, no less than three days following visit one, each subject was randomly assigned to be in the compression group or the sham group for the first week. The diet intake for the day was recorded as well as any nutrition taken on during the sessions. Subjects then underwent a controlled exercise protocol. Following calibration and warming of the rear tire, subjects underwent a 15 minute warmup at 50% of base power followed by a 30 minute interval at 90% of base power and a 5 minute cooldown at 50% of base power. All power numbers were entered into software program (racermate one) prior to the session in order to establish consistency between the sessions.

Following the five minute cool down period all subjects dismounted the bike. Those subjects that were randomly assigned to the compression group then underwent 20 minutes of compression at level four setting in a seated position on the floor. Those
subjects that were randomly assigned the sham group sat in the same position with the compression pants on the lower legs but remained switched off.

After 24 hours of recovery, subjects attended the third session. During the third session the same calibration was done followed by the same warmup as the previous day for 15 minutes at 50% base power. Following the warmup, the racermate program was switched to a flat course and subjects underwent a 30 minute all out trial to test average power. Following the test, subjects underwent a cooldown period. Nutrition and any external stimulation was recorded in order to ensure consistency. Subjects were allowed to drink water during the testing session ad libitum.

The following week, seven days later, subjects attended the fourth session. During this session, subjects followed the same protocol as session two. Those subjects that were previously in the sham group wore the compression pants following the session, while those that previously wore the compression pants did not have the compression pants switched on following the session. The following day, session five was undertaken. Session five followed the same protocol as session 3 from the previous week. Subjects were required to follow the same nutrition, training and rest guidelines during sessions four and five as the previous week in order to ensure consistency.

During each cycling session, subjects rode their own bikes for familiarity with cycling position and cycling mechanics. Prior to each session, the subject’s rear tire was inflated to 110psi. Each subject’s bike was then mounted to the computrainer (Racermate Sport, Seattle, Washington, USA). Prior to the warmup period the weighted pressure of the rear tire was calculated. The tire was then warmed up for 10 minutes before the weighted pressure was calculated and calibrated. All rolling resistance was measured at
2.75±0.25lbs. During the cycling and recovery session, heart rate was measured by placing an external heart rate monitor placed around the chest. Data was collected using a Garmin Edge 500 unit (Garmin, Wichita, Kansas, USA).

When assigned to the compression group, following the training session, subjects were required to use a noninvasive pneumatic compression device (NormaTec pneumatic compression device, Newton Center, MA) for twenty minutes in a seated position. During this time, subjects were allowed to watch television or listen to music but were required to remain in a seated position. Normatec recovery pants comprise of five air pockets. During the 20 minute sessions, pockets inflate and hold up the leg moving from the ankle to the quadriceps. During the sham recovery, subjects remained in the same seated position with the compression pants fitted but not turned on, therefore there was no pressure change during this time.

Following each session, the power levels and average heart rate were recorded. During sessions two and four the average heart rate and power during the warmup, interval, cooldown and recovery were recorded. During sessions three and five the average heart rate and average power during the warmup and all out test were recorded.

### 3.4 Statistical Analysis

Differences between pre- and post-experimental values for power and heart rate were analyzed using a paired t-test. All data was presented as the group mean ± SD. Statistical significance was set *a priori* $p \leq 0.05$. Data was analyzed with Sigma Stat 3.0 (Systat Software, San Jose, CA).
Chapter 4

Results

4.1 Power Output

There was no significant difference observed for average power output for a 30 minute maximum trial when comparing the use of compression recovery pants and passive recovery, respectively (262.46±52W vs. 263±52W) (p>0.05). (Figure 4-1).

Figure 4-1: Group mean power output in Watts in response to thirty minutes of all out cycling following recovery with the recovery pants or a sham.
4.2 Heart Rate

There was no significant difference found in maximum heart rate for a 30 minute maximum trial when comparing the use of compression recovery pants and passive recovery (177 ± 10 bpm vs. 178 ± 9 bpm, p>0.05). (Figure 4-2)

![Max Heart Rate](image)

Figure 4-2: Mean maximum heart rate recorded during 30 minute sessions of pre sham recovery training, test session following passive recovery by a sham, pre compression recovery training and post compression recovery test.
There was also no significant difference found in average heart rate when comparing the use of compression pants and passive recovery (166 ± 11 bpm vs. 167 ± 11bpm, p>0.05). (Figure 4-3).

Figure 4-3. Group mean heart rate during 30 minute test sessions following compressive recovery and passive recovery with a sham condition.
Chapter 5

Discussion

5.1 The Effects of Compression Pants on Power Output

The aim of this study was to determine the effects of pneumatic compressive devices when used as a recovery aid on cycling performance. The findings of this study disproved the first hypothesis by showing there was no significant change in average power output when using compression pants as a recovery aid from a constant training session as compared to passive recovery. No significant differences between compression and sham values were found (Figure 4-1).

A 2015 study by Martin et al., tested the effectiveness of compression pants when used following three anaerobic wingate intervals. Parallel with this study, there were no significant findings on power output when comparing the use of compression pants to the use of a sham however, there were findings of significantly decreased blood lactate levels after 25 and 35 minutes of recovery with compression pants (23).

The use of compression pants for a 20 minute session in a seated position on the floor follows the established norms of the recovery device from athletes and the company itself. Given blood lactate levels have been found to be decreased following 25 and 35
minutes, there may be a need to increase the duration of recovery with compression pants when looking at the effects on athletic performance. Currently there is no data on the most effective position or duration of compression pants, this is an area of study that may need to be looked at in the future.

Given the study design, it was necessary for subjects to keep lifestyle, training and dietary habits constant during the two week study in order to ensure accurate results. Although this was the case and subjects were instructed to do so, certain changes between tests are likely to have impacted the accuracy of the study. Given the influence of diet, sleep and general wellness on exercise performance, these outside influences played a large role in determining the results. For this reason, in order for this protocol to be successful, subject’s nutrition, sleep and activity levels needs to be monitored closely. These details were beyond the means of this study and had a significant impact on the results. A protocol of two sessions per day or one session at night followed by one in the morning where subjects are required to be closely monitored would decrease the chances of these outside influences impacting the study and increase the chances of finding significant results.

5.2 The Effects of Compression Pants on Heart Rate

The second hypothesis stated that there would be no change in heart rate data when comparing the use of compression pants as a recovery aid vs passive recovery (Figures 4-2 and 4-3). This hypothesis was confirmed by the results. Heart rate data was collected throughout each session and during the 20 minute recovery window. There was no significant difference in maximum or average heart throughout any of the sessions as
well as no significant difference in the amount of time taken for each subject to return to a constant during recovery. These findings suggest that using a pneumatic compressive device does little to impact the cardiovascular system when used as a recovery device.

It is unlikely to see a change in heart rate values during an all-out test, particularly with well-trained athletes who are familiar with training and racing at, or near their maximum heart rate. In order to increase the likelihood of finding a change in heart rate values, using less well trained athletes or testing at a pre-determined wattage below maximum has a greater likelihood of yielding significant results.

Given there have been no studies showing an increase in performance when using compression pants and the claim to aid with the muscle pump mechanism in the legs, further research on their effectiveness may need to be directed at the clearance of metabolites following exercise. This was beyond the scope of this study but is an area that may be investigated in the future.
References


