Effects of Intermittent Pneumatic Compression Following Eccentric Exercise on Soreness and Heart Rate Variability

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EFFECTS OF INTERMITTENT PNEUMATIC COMPRESSION FOLLOWING ECCENTRIC EXERCISE ON SORENESS AND HEART RATE VARIABILITY

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Abstract

BACKGROUND: The use of intermittent pneumatic compression (IPC) may provide relief from delayed onset muscle soreness due to strenuous lower body exercise. The purpose of this study is to examine the effects of 20 minutes of IPC following strenuous eccentric exercise on heart rate variability (HRV) and perceived soreness (PS). METHODS: 10 subjects (aged 21.2 +/- .4) who did not regularly participate in resistance training completed 2 trials, no less than 1 week apart. Each exercise session consisted of a 5-minute warmup followed by 3 sets of a superset of 5 Nordic hamstring curls (5 seconds eccentric) and isometric split squats (up to 1 minute each leg). All participants completed both the control and treatment sessions. For the IPC treatment session, participants wore IPC pants and sat on a treatment table with their backs against the wall at 90 degrees for 20 minutes while the pants administered 80 mmHg of pressure. HRV and PS were measured at baseline (morning of each session), 24hr and 48hr following each session. RESULTS: No significant differences were found between treatments for HRV over time ($p = .33$). However, significant differences were found between treatments for PS over time ($p < .05$). CONCLUSION: IPC use following strenuous eccentric exercise did not improve HRV, but did have significant positive effects on PS. A longer treatment may be needed to see results in HRV.
Introduction

Exercise Induced Muscle Damage (EIMD) is an inevitable consequence from eccentric and/or unaccustomed exercise followed by an inflammatory response to allow for muscle repair and subsequent symptoms.\textsuperscript{1-2} Specifically, metabolic stress occurs from the damage caused by exercise, initiating an inflammatory response. The response is associated with soreness and a loss of functional capacity, but is important in repair of the damaged skeletal muscle.\textsuperscript{2}

Strenuous eccentric exercises performed at high intensity by an unaccustomed individual provide an optimal environment for EIMD to occur. The mechanism behind the damage begins with overstretched and disrupted sarcomeres, an abundance of released calcium in the intercellular space, and a loss of excitation contraction coupling.\textsuperscript{3-4} Consequences of the mechanism include muscle damage, decreased muscle function, and increased blood markers such as Creatine Kinase, all of which pause recovery and decrease performance ability.\textsuperscript{5}

The EIMD caused from strenuous eccentric exercise is followed with an inflammatory response of the immune system to regenerate and repair muscles.\textsuperscript{6} Although the inflammatory response is crucial for muscle repair, untreated and chronic inflammation can pose health threats to an extent that chronic inflammatory diseases are the number one threat to human health. Additionally, inflammation associated with extreme exertion can cause renal failure due to the excess release of muscle proteins into the kidneys.\textsuperscript{7-8}

Edema (swelling), delayed onset muscle soreness (DOMS), impaired muscle function, heat/redness and stiffness are commonly reported symptoms of the inflammatory response to EIMD\textsuperscript{4,9-10}. Most symptoms were evident the day after exercise, but different symptoms peaked at different times post-exercise. Swelling, soreness and impaired muscle function peaked at four, one-three, and two days post-exercise respectively.\textsuperscript{5,9,11} Overall performance, strength, and endurance are often hindered due to these symptoms, so proper recovery is essential for athletes, as well as non-athletes, to repair muscles and reach goals.\textsuperscript{2}

The repeated bout effect, stretching, icing, cold water immersion (CWI), heat, massage, foam rolling (FR), non-steroidal anti-inflammatory drugs (NSAIDs) and compression are the most commonly used and widely studied recovery methods from EIMD.\textsuperscript{1,4,12-17} Each method has benefits and downfalls, but NSAIDs are
commonly relied on. However, the correlation NSAIDs have to ADEs should lead users to be cautious of the duration and frequency of use.\textsuperscript{14}

The popularity intermittent pneumatic compression (IPC) has gained recently as a recovery method is likely due to the advanced technologies allowing for an increased blood flow and in turn reduction of swelling from EIMD.\textsuperscript{18-19} Before appearing in recovery from exercise, IPCs have been used in hospitals and clinics for treatment of various blood complications.\textsuperscript{18} In addition to treating blood diseases, IPC has been used in maintenance of blood flow, reduction of fluid retention, reduction of compartmental pressure following injury, elimination of tissue damage and alleviation of pain.\textsuperscript{18,20}

Recovery from EIMD can be measured in many subjective and objective fashions. HRV measures autonomic recovery which is associated with recovery from strenuous exercises on the extremities, as the body demands increased sympathetic activity during and after exertion.\textsuperscript{21-22} Muscle soreness (termed DOMS) can subjectively determine how efficient recovery modalities are, while muscle circumference can objectively determine efficiency of the same stimuli.\textsuperscript{23-24}

IPC as a recovery method of EIMD is increasingly researched, but most current studies did not show significant positive effects on common recovery measurements.\textsuperscript{5,18-19} However, the positive effects of IPC on ANS recovery measurements show promise for future studies aiming to maintain proper health and determine the most effective recovery method succeeding EIMD.\textsuperscript{21}

This research will aim to address an up-and-coming recovery method on common recovery parameters. The hypothesis is that IPC following strenuous eccentric exercise will increase heart rate variability, and decrease reported muscle soreness. These two variables are prime measures of recovery from exercise induced muscle damage.

**Methods**

This study was approved by the Institutional Review Board preceding any data collection.

**Materials**
IPC was administered by RecoveryPump [RP Sports, Dallas, TX] automatic technologies through medium or long pant sizes. A Polar Heart Rate monitor (Polar, Kempele, Finland) was sent home with each participant to obtain HRV data throughout the experiment using the app Elite HRV [EHRV, Asheville, NC].

VAS was used for perceived muscle soreness. Impellizzeri and Maffiuletti\textsuperscript{25} compared the 7-Point Likert Scale and the Visual Analogue Scale (VAS) as ways to measure muscle soreness and found similar sensitivities with a .81 correlation. Additionally, Vickers\textsuperscript{26} stated the Likert Scale should not be anchored to the value of 0 for the lowest and most sensitive soreness. In conclusion, either the Likert Scale or the VAS were valid measures of perceived muscle soreness.\textsuperscript{26} Therefore, reported muscle soreness was derived from the VAS. The VAS uses numbers and pictures that correspond to levels of soreness.\textsuperscript{23}

Participants

Participants recruited for this study were women and men between the ages of 18 and 25 that were enrolled at the College of Saint Benedict and Saint John’s University (CSBSJU) at the time of collection. The study consisted of 10 physically inactive non-athletes. Five of the participants were female, and the other five were male, and they all were current students at CSBSJU.

Procedures

Testing took place in the Exercise Physiology Lab in the Henrietta Academic Building at CSB. The participants (n=10) reported on 5 separate occasions. They reported for one 10-minute session for obtaining study materials and four 40-minute exercise sessions, scheduled 1 week apart. The 40-minute sessions consisted of control treatment, intervention with IPC, intervention with an NSAID or intervention with turmeric supplementation, and the day in which each occurred was randomized. The NSAID and turmeric supplementation interventions were part of a separate research study using the same participants.

The participants first met for an information session where they were required to read and sign the informed consent before any experimentation commenced. Also, during this session, participants were given their Polar HR monitor and their height, weight and age were recorded. When picking up the HR monitor from the Exercise Physiology lab, they were instructed to download the app Elite HRV which is the tool used to measure their recovery in terms of HRV. Participants were instructed to wear their HR monitor the day of,
24 hours after and 48 hours each exercise session before getting out of bed (same time each day). They were instructed to open the app and obtain HRV data for approximately 30 seconds.

Following the information session, the first exercise session was the control for all participants to be sure that the learned and training effects were excluded. Participants were given a briefing of the exercise and experimentation for each day and then completed the baseline measurements of perceived soreness with the VAS, and a warmup lead by researchers. For the VAS, participants chose a number and picture correlated with measurements of how sore they felt at that time, and the results were recorded in an excel file only seen by the researchers. The warm-up consisted of 20 meters of high knees, butt kicks, carioca, spider lunges, and lateral lunges.

Next, the muscle damaging eccentric exercises were completed by participant, and were followed by no treatment (control session). The exercises consisted of 3 sets of 5 Nordic hamstring curls with a 5 second eccentric movement on each rep, followed by a single leg squat on each leg until fatigue, or one-minute each leg, whatever was attainable. The Nordic Hamstring Curl Strap (COFOF, n.d.) was used for the hamstring curls to allow for full range of motion. Researchers demonstrated the exercises and assisted to maintain proper form if needed. Both the dynamic warm-up and the exercise were identical on all days of testing, only the intervention changed. Control exercise session consisted of no intervention preceding or following exercise.

Post-exercise data collection occurred immediately following exercise, by recording the same baseline measurements (perceived soreness with the VAS and HRV). Similarly, 24- and 48-hours following the session, participants reported their HRV and soreness to the researchers via a google form. The second exercise session was conducted one week after exercise session 1 to ensure a washout period long enough that the exercise from the week prior did not interfere with future results. The exercise sessions were scheduled 1 week apart, and which intervention occurred on which session was randomly decided for each participant. The intervention sessions ran identical to the control session, up until immediately following exercise. For the IPC intervention, participants put on the RecoveryPump pants in either medium or long sizes, depending on the participant’s height. They sat against the wall at 90 degrees for 20 minutes while the pants administered 80 mmHg of pressure.
After the exercise sessions, and after the reported soreness and HRV were recorded the two days after the last session, data collection commenced, and the requirements of the participants were eliminated. Participants received a $40 Amazon gift card incentive for completion of data collection. There were a few occasions where participants did not submit soreness or heart rate variability data. These incidents were noted in the file with an asterisk. However, the data was still used because the data created an average. The lack of an extra data point did not nullify the participant's data, but it did decrease the validity of it. Two two-way repeated measures ANOVAs using SPSS were conducted to analyze data. All data is presented as mean +/- standard deviation.

Results

A two-way repeated measures ANOVA was run to determine the effect of Intermittent Pneumatic Compression (IPC) on heart rate variability and perceived soreness (PS) on 10 participants that are presented in Table 1.

Table 1. Descriptive Statistics (n=10)

<table>
<thead>
<tr>
<th></th>
<th>Mean</th>
<th>Standard Deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (years)</td>
<td>21.2</td>
<td>0.4</td>
</tr>
<tr>
<td>Height (cm)</td>
<td>172.1</td>
<td>13.7</td>
</tr>
<tr>
<td>Weight (kg)</td>
<td>77.9</td>
<td>12.2</td>
</tr>
</tbody>
</table>

Analysis of the studentized residuals for HRV showed that there was normality for all conditions as assessed by the Shapiro-Wilk test of normality ($p > .05$). As assessed by studentized residuals greater than ± 3 standard deviations, there were a few outliers present for the HRV results. There was sphericity for treatment*time for HRV, as assessed by Mauchly’s test of sphericity ($p > .05$). Therefore, in the within-subjects effects, we can assume sphericity, which correlates with no significant effects. There was no statistically significant interaction between treatment and time on HRV ($p = .330$). No significant effects were found in any of the within-subjects effects, therefore, simple main effects were not run for HRV. Means and standard deviations are presented in Table 2 and Figure 1.
Table 2. Heart Rate Variability (HRV) vs. Time

<table>
<thead>
<tr>
<th>Time</th>
<th>Control Mean</th>
<th>Control Standard Deviation</th>
<th>Treatment Mean</th>
<th>Treatment Standard Deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Baseline</td>
<td>60.1</td>
<td>9.36</td>
<td>58.8</td>
<td>16.2</td>
</tr>
<tr>
<td>24hr Post-Session</td>
<td>60.8</td>
<td>10.1</td>
<td>52.2</td>
<td>17.4</td>
</tr>
<tr>
<td>48hr Post-Session</td>
<td>52.8</td>
<td>12.6</td>
<td>56.8</td>
<td>8.4</td>
</tr>
</tbody>
</table>

Analysis of the studentized residuals for PS showed that there was normality for all conditions (excluding time points at the beginning of both interventions and at the end of the treatment intervention \( p < .05 \)) as assessed by the Shapiro-Wilk test of normality \( p > .05 \). As assessed by no studentized residuals greater than \( \pm 3 \) standard deviations, there were no outliers present. There was no sphericity for treatment*time for PS, as assessed by Mauchly’s test of sphericity \( p < .05 \). Therefore, in the within-subjects effects, we cannot assume sphericity, and the Greenhouse-Geisser correction is used to correct for this prevalent violation. A repeated measures ANOVA determined that mean PS values differed significantly between the two treatments over time \( p = .007 \), therefore simple main effects were run. There was no difference between time point 1 PS values between treatments \( p = .241 \), but there were statistically significant differences between PS values at time points 2 and 3 \( p = .008 \) and \( p = .005 \). For the main effect of time for the control treatment, there was a
significant difference between time points 1 and 2 \( (p < .001) \), and between time points 1 and 3 \( (p < .001) \), but not between time points 2 and 3 \( (p = 1.00) \). For the main effect of time for the treatment condition, there was a significant difference between time points 2 and 3 \( (p = .002) \), but not between time points 1 and 2 \( (p = .936) \) or between time points 1 and 3 \( (p = 1.00) \). Means and standard deviations are presented in Table 3 and Figure 2.

### Table 3. Perceived Soreness (PS) vs. Time

<table>
<thead>
<tr>
<th>Time</th>
<th>Control</th>
<th>Treatment</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean</td>
<td>Standard Deviation</td>
</tr>
<tr>
<td>Baseline</td>
<td>0.3</td>
<td>0.48</td>
</tr>
<tr>
<td>24hr Post-Session</td>
<td>3.3(^a)</td>
<td>1.2</td>
</tr>
<tr>
<td>48hr Post-Session</td>
<td>3.5(^a)</td>
<td>1.4</td>
</tr>
</tbody>
</table>

\(^a\)p-value < .05 compared to pre  
\(^b\)p-value < .05 compared to 24hr

### Discussion

The results of this study suggest that there is no relationship between HRV and IPC treatment following strenuous eccentric exercise, but there is a significant relationship between PS and IPC treatment. The
hypothesis that IPC increases HRV and decreases SP was partially supported, indicating that IPC can assist recovery.

There was no significant relationship between the control and treatment interventions on HRV measured in the morning, 24 hours after treatment, and 48 hours after treatment. PS values differed significantly between the control and treatment interventions measured at the 3 different time points, meaning that participants seemed to be less sore on the days following IPC treatment. This may be due to the increase in blood flow and reduction of swelling from the eccentric exercise.\textsuperscript{18-19} To further evaluate this relationship, more tests were run within groups and significant differences were found within groups.

In the control group, participants noted significantly higher PS 24 hours as well as 48 hours after the exercise session, than they were at baseline. This indicates that the eccentric exercise performed by the participants induced muscle soreness. In the treatment group, there was no significant difference in soreness values between the baseline and 24 hours as well as 48 hours after the exercise session. This suggests that after IPC treatment, participants were significantly less sore than not having treatment following eccentric exercise. More specifically, there was a significant difference between 24 hour and 48 hour soreness measurements following IPC treatment. It can be assumed that soreness exists for a shorter duration when IPC is used. Even if participants became slightly sore from the eccentric exercise, although not significantly sore, the soreness levels decreased to near baseline by the 48 hour time period.

The results of this study supports findings by others that IPC may be a useful method of recovery from EIMD that doesn’t come with the negative side effects that other recovery modalities often do. This study challenges results by others which have found IPC to not be an effective method in providing relief from EIMD. Stedge and Armstrong\textsuperscript{19} looked at IPC following EIMD in endurance athletes and concluded IPC had potential for immediate pain relief. However, no conclusions of IPC being effective for recovery parameters of extended subjective pain relief or functional recovery in endurance runners and triathletes were found by researchers.\textsuperscript{19} Similarly, Cochrane and colleagues\textsuperscript{18} determined IPC did not improve recovery (with given parameters) from strenuous eccentric exercises more than the control group. The use of IPC for pathological
conditions and the potential benefit was also mentioned, but in conclusion, subjects did not benefit from IPC under these exercise conditions.

However, these studies used different variables to determine recovery which may explain the discrepancies. As the gap in research this study aimed to close was regarding IPC following eccentric exercise on HRV, these HRV results do not support or challenge any research but lay the ground for further research.

It is suspected that the lack of significant differences in HRV measurements between the control and treatment group, is due to the short duration of treatment and time studied, and potential confounds. HRV is a very sensitive measurement that can be affected by a large variety of things. It is nearly impossible to remove all potential confounds of this variable, so although correlation cannot be assumed, recovery may still be impacted by IPC.

With a sample size of only 10 participants, the generalizability of the results is limited making it difficult to make serious implications about the results to a larger population. There were also a few data points that were missing due to failure of the participants to submit their necessary which also creates limitations and reduces the n value to 9 in some instances. Due to the lack of resources available as researchers, the most efficient soreness measurement was using a VAS to measure PS. There are numerous other options to measure EIMD and DOMS such as creatine kinase and other blood inflammation markers that should be of interest to future researchers.5

Additionally, future research on HRV as a measurement of recovery from EIMD and DOMS with a longer duration may be beneficial to understanding treatment for these common consequences of strenuous exercise. Regarding autonomic recovery, measuring time for participants’ heart rate to return to pre-exercise levels with and without the use of IPC could be of interest. Another noteworthy view researchers could take could be to measure performance on lower body athletic tests to see how IPC directly and objectively impacts performance. In conclusion, IPC treatment following strenuous eccentric exercise did not improve HRV but did have significant effects on PS in physically inactive non-athletes from the College of Saint Benedict and Saint John’s University.
References


doi:10.1097/JSM.0b013e31815aed57


doi:10.1017/S0266462399154102