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Effects of Combination Ice and Compression Socks on Resting Calf Blood Flow in Trained Male Athletes

Michael John Hudock Jr.

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Honors Thesis

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Abstract

Compression socks are common tools that are utilized in the realm of athletics. The purpose of the compression is to increase blood flow to the lower extremities, thereby increasing oxygen and energy sources needed for increased skeletal muscle function and/or recovery. Recently, a product has been marketed that combines the compression element with cryotherapy, the goal being increased blood flow to the lower extremities while reducing inflammation post-workout to quicken recovery. However, to our knowledge, direct measures of blood flow using this type of product have not been performed. Thus, this study looks at the effects of compression with and without cryotherapy on the blood flow of trained male athletes. The hypothesis was that compression would increase blood flow, ice would reduce it, and a combination of both would produce an intermediate result. Participants (n=9) were trained, having a body fat percentage that was not considered overweight (≤ 25%) and a minimum VO_2max of 50 mL/kg/min. Those who met the criteria partook in four randomized trials during a single visit: control, compression, ice, and compression with ice. Calf blood flow (CBF; venous occlusion plethysmograph), skin temperature (temperature probe), heart rate (ECG), and blood pressure (sphygmomanometry) were monitored throughout each trial. As compared to control, compression alone decreased CBF (0.88±0.14 vs 1.51±0.12 ml/dl/min). Combined compression and ice resulted in similar CBF values (0.78±0.17 ml/dl/min) as the compression condition, whereas the ice condition had minimal effect on CBF (1.46±0.17 ml/dl/min). Systemically, as per design, heart rate and blood pressure were relatively stable across all four trials. The present results indicate that compression, alone or in combination with ice, does not increase CBF as measured by venous occlusion plethysmograph, at rest in trained males. Further, CBF was not attenuated during the ice alone condition. Taken together, the marketed effects of this product are questioned in the present experimental setup

Acknowledgements

I would like to dedicate my Honors Thesis to my parents because they were the ultimate reason I was able to attend the University of Dayton to pursue my passion. I would also like to thank my advisor, Dr. Anne Crecelius, for providing me with the necessary guidance to complete my thesis.

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Table of Contents

Introduction

The realm of athletics has a myriad of companies that produce products to give athletes fair and competitive advantages over one another, and two tools that are currently implemented are compression garments and cryotherapy techniques. Compression is thought to have several advantages: reduce oscillations of muscles during repetitive exercise, cushion/support muscles for injury prevention during contact sports, and increase venous return to promote blood flow.[8] As for cryotherapy, this technique is thought to help recovery by reducing muscle fibre oedema that is brought about by exercise, and this would help manage pain, promote function of muscles, and reduce damage caused by inflammation.[16]

Compression garments are implemented both for athletic performance as well as recovery. The reduction of muscle oscillations during repetitive exercise as well as support for muscle and tendons during contact sports[8] are primarily the benefits of utilizing them for athletic performance, however the idea of support has become more accepted in repetitive exercise as well. Probably the most commonly held notion about compression garments is in regard to the facilitation of blood flow, since it could potentially have benefits for both exercise and recovery.

A couple ideas have been proposed for how compression garments could facilitate blood flow. One idea involves the compression gradient that many products implement, and this pressure gradient gradually decreases as one goes from the foot to the patella. Popular belief is that by having the pressure gradient, the venous return is thought to increase as a result. Another potential is that the increased extravascular pressure from the garment promotes myogenic relaxation of the vessels.[3] The external pressure leads to decreased transmural pressure of the arterial vessel.[12] Studies have verified the resulting Bayliss Effect, which states that a decrease in the transmural pressure gradient will lead to a myogenic relaxation.[3,7,9] This relaxation of the musculature of the vessels results in vessel dilation, facilitating blood flow. Therefore, the pressure gradient and increase external pressure on the vessels are thought to help facilitate blood flow.

Another tool athletes typically implement in their recovery regimen is the use of cryotherapy (i.e. icing). The popular theoretical basis behind cryotherapy is that the by reducing intramuscular and blood temperature, the net effect would be a reduction in inflammation. Inflammation from exercise is primarily brought about by the generation of Reactive Oxygen Species (ROS) and muscle fibre swelling.[16] Inflammation can help repair muscle damage, however if excessive, secondary damage can be caused by neutrophils and macrophages.[4] This reduction in inflammation prevents excess stress on the body, specifically at the muscles where the stress occurs. A commonly noted mechanism for this action is thought to include limiting metabolic and enzymatic activity through the reduction of the temperature—lower temperatures slow down chemical and biological processes. Furthermore, the idea that a reduction in temperature stimulates the sympathetic nervous system is well established. The stimulation results in the vasoconstriction of blood vessels due to the higher affinity of norepinephrine to alpha-adrenergic receptors of the vascular walls.[15] The resulting vasoconstriction leads to the attenuation of blood flow, reducing negative inflammatory effects.

The use of compression and cryotherapy are common used practices for recovery in the athletic realm, and one company (110%) decided to combine the two tools for an enhanced recovery method. One of the products includes the 110% Overdrive Compression Socks, which consist of graduated compression socks with 20-25 mmHg of external compression[18] and a cover layer for holding the 110% ice packs on top of the compression sock. Currently, few studies exist showing the effects of compression garments on facilitating blood, and none has looked at the combined impact of compression with ice on blood flow. Therefore, the goal of this experiment was to look at the effects of the compression with and without cryotherapy. The group hypothesized that, in comparison to the control, the compression would increase blood flow, ice would attenuate it, and combined compression and ice would produce an intermediate result.

Methods

Subjects

The participants (n=9) that were recruited for the study were males who were considered to be trained athletes. The criteria for being considered a “trained athlete” was recording a body fat percentage that was less than or equal to 25% and a VO_2max of 50 mL/kg/min or greater. The body fat percentage was determined using a Bod Pod (COSMED, Rome, Italy), which measures the displaced air and then utilizes a density equation to estimate the body fat percentage of the participant. For determining the VO_2max of the participants, a self-selected treadmill protocol was used, where the participant selected the initial speed they would start at. They were informed to select a speed that they would be able to maintain even with an increase in grade and that would allow them to reach their maximal level of exertion after about ten minutes of increasing the grade. Upon selecting their speed, the grade on the treadmill was increased was 1.0% every minute until two of three criteria were met for a participant reaching maximal effort: RER greater than 1.0, stabilization of VO_2max, and/or participant asking to stop the test. If they met the inclusion criteria, they were allowed to partake in the second part of the study. By having subjects of the same sex with similar athletic abilities, the hope was to diminish the differences in the effects of the compression and ice between them.

Measurements

The primary measurement for this experiment was the calf blood flow (CBF), and it was recorded via a venous occlusion plethysmograph (D.E. Hokanson Incorporated, Bellevue, Washington). The data collected from the plethysmograph was used to compare the effects of compression, ice, and compression/ice to the control group. Moreover, the values collected were used to calculate the calf vascular conductance (CVC) to take into account changes in mean arterial pressure (MAP) that can affect the blood flow to the calf. In conjunction with measuring the calf blood flow, the other systemic measurements were made as well, including skin temperature (MLT422 AD Instruments Temperature Probe, Colorado Springs, CO), heart rate (DataScope Passport 2 ECG, Shenzhen, China), and blood pressure (DataScope Passport 2 Sphygmomanometer, Shenzhen, China). These measurements were made to see the potential systemic effects of the compression and/or cryotherapy.

Experimental Protocol

For studying the effects of compression with and without cryotherapy on blood in male athletes, participants selected a time to partake in the study, which typically took place around 6:30 am. They could not eat or drink anything for 12 hours prior to the study, so that there would not be any significant changes in blood flow from external factors. For this study, the group used the Overdrive Compression Socks from the company 110%, which consisted of two layers: a compression sock as the base layer and then a cover that possessed with compression-like properties.

As previously stated, the blood flow was measured using a Hokanson venous occlusion plethysmograph. The mercury-in-silastic strain gauge was wrapped around the widest part of the calf muscle. To do this, the two-layered compression stocking was cut at the calf's widest part, so that the strain gauge could rest on the leg while not being interfered with. The compression stocking and strain gauge were chosen based on calf measurements made. The leg was placed in a dependent position to help facilitate venous return for the subsequent measurement—the leg was approximately at a 45º angle in relation to the ground. See Figure 1 for a general depiction of the experimental setup.

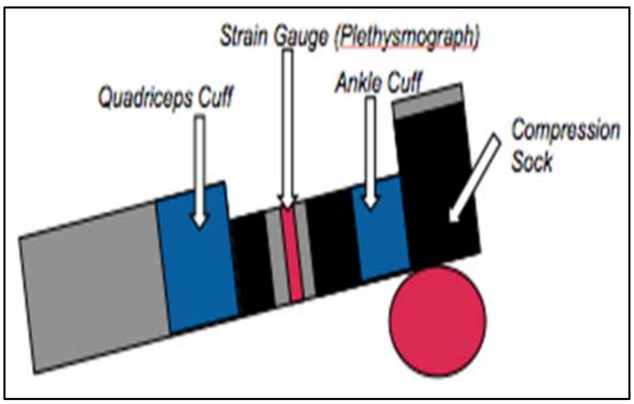


Figure 1: Experimental Setup

For the plethysmograph, there were two cuffs that were placed on the participant's right leg: a smaller, tighter cuff right above the ankle and a larger, cycling cuff above the patella on the lower part of the quadriceps. The smaller cuff above the ankle had a constant pressure of 200 mmHg, and the purpose of this higher pressure was to occlude arterial inflow and venous out flow into the foot. Cutting blood flow to and from the foot eliminated it from affecting the blood flow in the calf, thus only blood could flow into and out of the calf from the core. For the larger cuff that was wrapped above the patella, the pressure was cycling between 0 mmHg (7 seconds) and 50 mmHg (8 seconds). The purpose of the cycling was to temporarily occlude venous outflow so there would be only an inflow of blood into the calf, and this inflow would cause the calf to swell, expanding the strain gauge and providing a reading for the amount of blood flowing into the calf.[10] Then, after the 8 seconds have passed, the upper cuff would deflate, allowing venous outflow. This outflow would allow the calf to return to normal size. Thus, for every 15 seconds, a measurement for the inflow of blood could be recorded.

The study consisted of four trials: control, compression, ice, and compression with ice. The control trial consisted of only the second layer that possessed little compression properties, and the purpose to provide easy comparison with the other trials, since the other three trials had the second layer. The compression trial consisted of the compression sock and the cover. For the ice trial, the cover was used to hold ice packs in place, and the ice packs that were utilized were the ones provided by 110% with the socks. The white sides of the ice packs were placed on the skin—the black part of the ice had the potential to cause an ice burn if placed directly on the skin—and they were cut to fit in only the lower half of the cut compression sock and cover. For the compression with ice trial, the ice packs were cut to fit the size of the calf and then reversed, having the colder black side face toward the skin since the compression sock blocked direct contact with the skin. The cover layer held the ice packs in place. These four trials were randomized to account for any potential local or systemic effects from the previous trial.

The experiment lasted approximately two hours with the four trials taking about five minutes each for a total of twenty minutes of experimentation. The first thirty minutes of the experiment were used to let the participant rest, allowing the blood flow to equilibrate in a resting state. After the initial thirty minutes of rest, the first trial was performed, which lasted approximately five minutes. During the five minutes, the blood flow, heart rate, and temperature were collected continuously. After recording for approximately five minutes, the subject's leg was allowed to equilibrate for ten minutes. Then, the next five minutes were spent preparing for the next trial. See Figure 2 for a visual of the timeline.

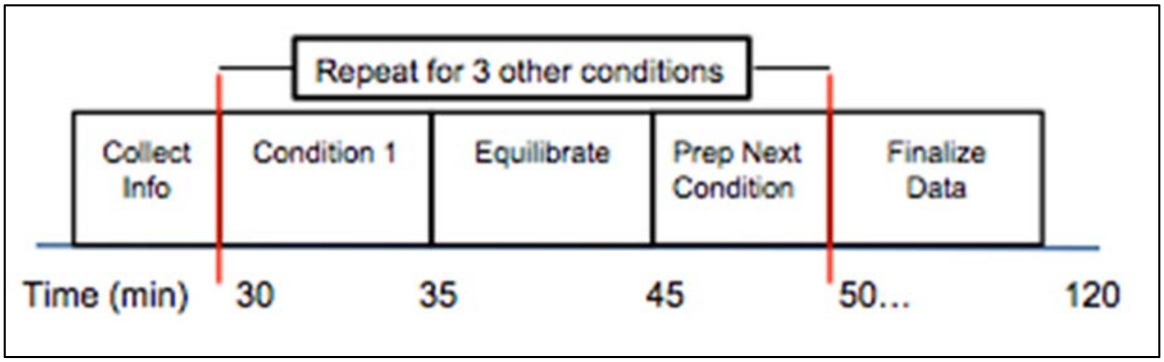


Figure 2: Experiment Timeline

For the results, the calf blood flow (CBF) was measured, and with these measurements, other calculations could be made, including the absolute change in blood flow (AbsΔBF), percent change in blood flow (%ΔBF), and calf vascular conductance (CVC). Both the absolute and percent change in blood flow were calculated in comparison to the control group. The absolute change in blood was calculated using the trial's average blood flow measurements subtracted from the control's, and the percent change in blood flow took the absolute change, divided it by the control's average blood flow, and then multiplied by 100 to yield a percent change from the control. Moreover, the CVC was calculated by taking the blood flow, dividing by the mean arterial pressure (MAP), and then multiplying by 100; the purpose of this is to take into account how blood pressure could affect the blood flow to the calf. These measurements and calculations were used to analyze the variations between trials

Results

The subjects recruited for this experiment were primarily recruited from the student body at the University of Dayton, and they all met the inclusion criteria of a body fat percentage (BF%) less than or equal to 25% and a VO_2max of 50 ml/kg/min or greater. The mean and standard error for the subjects' characteristics are presented in Table 1.

Variable	Mean ± SEM
Age (years)	21.4 ± 0.6
Height (cm)	174.7 ± 2.5
Weight (kg)	74.2 ± 2.9
Body Fat (%)	12.2 ± 2.0
VO_2max (ml/kg/min)	68.3 ± 3.0

Table 1: Subject Characteristics

Condition	Min 1 (°C)	Min 5 (°C)
Control	27.9 ± 0.2	27.8 ± 0.2
Compression	27.7 ± 0.5	27.6 ± 0.4
Ice	27.8 ± 0.3	27.5 ± 0.4
Compression/Ice	27.4 ± 0.7	27.4 ± 0.7

Table 2: Mean and Standard Error for skin temperature at Minute 1 and 5. There was no significant difference between times or conditions.

For the experimental results, the means and standard errors for the blood flow and vascular conductance of the nine subjects are presented in Table 2. As compared to control, compression alone decreased CBF (0.88 ± .14 vs 1.51 ± 0.12) and CVC (1.04 ± 0.18 vs 1.81 ± 0.11). Furthermore, the combined compression and ice resulted in similar attenuations in CBF (0.78 ± 0.17) and CVC values (0.94 ± 0.23) as the compression condition. However, unlike the compression alone and the compression and ice condition, the ice condition had minimal effect on CBF (1.46 ± 0.17) and CVC (1.85 ± 0.23). The percent changes in blood flow, in comparison to the control, for all conditions and time points collected can be seen in Graph 1. Systemically, as per design, heart rate and blood pressure were relatively stable across all four trials (Table 3). Also, the skin temperatures for all four trials were fairly stable, thus cryotherapy (i.e. icing) showed no net effect on CBF or CVC (Table 4).

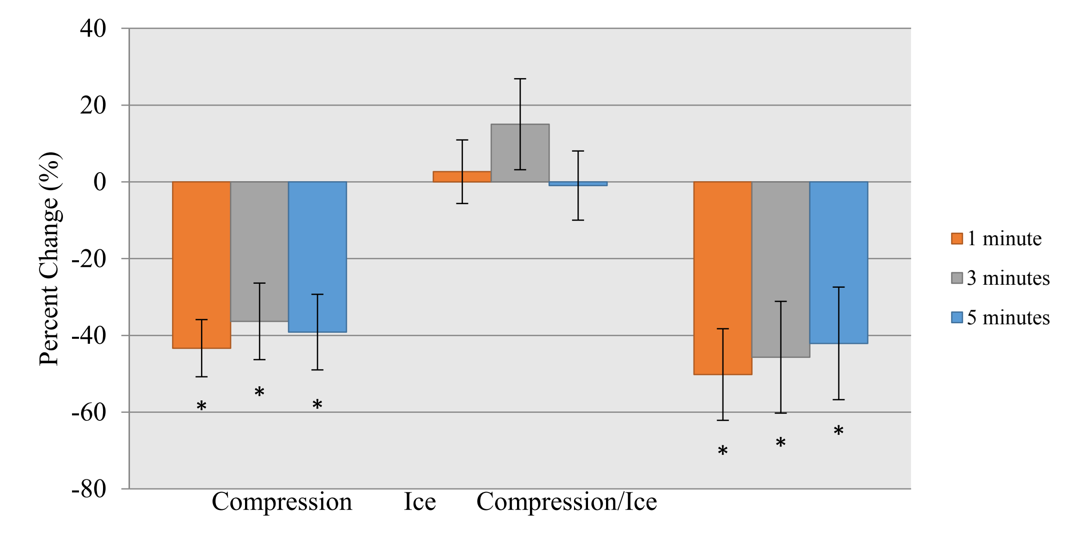
Condition	HR (beats/min)	MAP (mmHg)
Control	50 ± 3	83 ± 2
Compression	52 ± 3	86 ± 3
Ice	51 ± 3	83 ± 2
Compression/Ice	52 ± 3	84 ± 3

Table 3: Mean and Standard Error for Systemic Hemodynamics for all conditions

Condition	Blood Flow (ml/dl/min)	Vascular Conductance (ml/dl/min/mmHg)
Control	1.51 ± 0.12	1.81 ± 0.11
Compression	0.88 ± .14*	1.04 ± 0.18*
Ice	1.46 ± 0.17	1.85 ± 0.23
Compression/Ice	0.78 ± 0.17*	0.94 ± 0.23*

Table 4: Mean and Standard Error for Calf Blood Flow and Vascular Conductance at Minute 5 for all conditions
*$p < 0.05$ in comparison to the control condition

The present results indicate that compression, alone or in combination with ice do not increase CBF, as measured by venous occlusion plethysmograph, or CVC, as calculated by the CBF and MAP, at rest in trained males. Moreover, CBF was not attenuated during the ice alone condition. Taken together, the marketed effects of this product are questioned in the present experimental setup.



Graph 1: Percent Change in Blood Flow in Comparison to Control at Minutes 1, 3, and 5 for Compression, Ice, and Compression/Ice Conditions
*$p < 0.05$ in comparison to the control condition

Discussion

Based on these results, the effects of the compression and ice provided by 110% are put into question. For compression, the primary theoretical basis is that the compression helps increase venous return,[8] which results in the facilitation in blood flow. Although there is not much data concerning the facilitation of blood flow via compression garments, one study did find that the garments helped increase blood perfusion.[3] Therefore, the results from this study question the theory and previous data for compression garments. As for the implementation of the cryotherapy, the results indicate that there is no change in blood flow that results from implementing the 110% ice packs. Typically, when the human body is exposed to cryotherapy techniques, one sees a reduction in blood flow. The cryotherapy typically produces vasoconstriction of the blood vessels due to an increase attraction of norepinephrine to the alpha-adrenergic receptors of the vascular walls.[15] This vasoconstriction ultimately results in decreased blood flow. However, when implementing the cryotherapy techniques as detailed by 110%, there seems to be no such effect, which is likely due to the lower specific heat of ice, in comparison to ice water, and, at times, the compression layer interfering with the ability of the cryotherapy to cool the lower extremities. Thus, these two ideas could potentially attenuate the normal sympathetic response that is normal. Overall, the present results question the efficacy of compression garments and cryotherapy techniques of 110%.

Experimental Setup

Although the results seem to indicate attenuation in blood flow and vascular conductance in the calf when utilizing compression with or without cryotherapy, some considerations need to be made in regard to the current setup of the study. One consideration is the position of the leg: the leg was in a dependent position to facilitate blood flow out of the calf for ease of measurements when utilizing a mercury strain gauge. Thus, implementing a different tool for measuring calf blood flow where the leg does not have to be in this position would be beneficial, since athletes utilizing this product will most likely not have their leg elevated at a 45º angle in the supine position. Another consideration in regard to the setup is the shortened compression sock. The sock was cut approximately 3-4 inches from the top of the compression sock and cover layer because the sock was interfering with the strain gauge. Moreover, the skin temperature was measured to note the effects of ice, however no changes were noted. Skin temperature does not reflect the changes in intramuscular or blood temperature, which are the primary changes in temperature that can affect blood flow—skin temperature is an indirect measurement. The measurements for skin temperature were also 2-3 inches away from the ice pack so that it would not interfere with the strain gauge. Thus, for future studies, one should ideally attempt to measure intramuscular or blood temperature to see the impact of the cryotherapy and/or ask for a perceived temperature rating from the subject for each condition. These are the experimental considerations that should be taken into account for future studies.

Subjects

Considerations also need to be evaluated for the participants recruited for the experiment: male athletes. No females partook in the study, and thus, the results of this study only look at the effects of males, who generally possess a different body structure and composition. Moreover, only males who met the criteria for being an "athlete" (Body fat percentage $\leq$ 25% and a VO_2max > 50 ml/kg/min) partook in the study. These compression socks are geared toward athletes, thus this is why "athletes" were used. However, the general public has access to the product, and thus considering the effects of compression on the CBF and CVC on the general population should be noted for future studies. Thus, these points should be taken into consideration in regard to the results obtained.

Conclusion

Based on the results of this study, the effects of compression in facilitating blood flow in male athletes are put into question. The results indicate a significant reduction in calf blood flow and vascular conductance through the five minutes for the compression with and without cryotherapy, when compared to the control condition. However, no significant changes were noted for the ice condition. Thus, these results do not support the original hypothesis, which predicted compression would facilitate blood flow, ice would reduce it, and a combination would produce an intermediate result.

Therefore, the results seem to indicate that there are limited benefits of the 110% compression garments for facilitating blood flow and their ice packs for stimulating the proper sympathetic response, in male athletes at rest. The recommendation, when looking at the conclusions drawn, would be for male athletes not to utilize the 110% Overdrive Compression Socks to facilitate blood flow and ice packs to reduce blood flow when at rest. However, despite the compression not facilitating blood flow, other potential benefits can still be considered. These benefits include, but are not limited to, reduction of muscle oscillations as well as supporting muscles and tendons to reduce the likelihood of injury. Future studies on compression should look into these other potential benefits.

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