



## An Intermittent Pneumatic Compression Device Reduces Blood Lactate Concentrations More Effectively Than Passive Recovery after Wingate Testing

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### Abstract

**Study background:** With the advancement of technology, therapeutic modalities mimicking “cool down” have become an option for active individuals to try and decrease the recovery time between training sessions and competition. A wide variety of companies that manufacture these modalities have claimed their machines can decrease recovery time by decreasing lactic acid, a known cause of muscle fatigue following exercise. The aim of this study was to investigate an intermittent pneumatic 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 (WAnT).

**Methods:** Twenty-one (n=21) female student-athletes between the ages of 18-25 years old participated in this randomized controlled clinical trial. All subjects participate in a lower extremity dominant collegiate club sport. Following a one minute WAnT, participants were randomly assigned one of three recovery interventions: IPC, active, or passive, each lasting 20 minutes. Objective data included subject's height (cm), weight (kg), and resting levels of blood pressure (BP), heart rate (HR) and blood lactate (BLa). Post exercise BP, HR and BLa were taken immediately following the WAnT and 20 minutes post recovery session.

**Results:** Post recovery, the IPC group had a mean BLa significantly lower than the passive recovery group; there was no significant difference in BLa between the IPC group and the active recovery group.

**Conclusion:** Results indicate that during the recovery phase, an IPC unit is more effective than passive recovery at removing BLa following anaerobic exercise. The IPC unit reduced BLa as efficiently as active recovery as carried out in the current study.

### Keywords

Intermittent pneumatic compression; Blood lactate, Recovery; Performance

### Introduction

With the advancement of technology, therapeutic modalities have aimed to mimic a “cool down” to decrease the recovery time between training sessions and competition. Competitive athletes

obsessively strive to achieve the perfect balance of performance and recovery. It is the goal of any sports medicine or athletic training department to provide athletes with a means to reach this end. Intermittent pneumatic compression (IPC) units and compression garments have claimed to promote recovery after or during athletic activity, respectively. Previous studies suggest that muscle recovery is significantly more effective and produces greater muscle performance than passive rest recovery when IPC is applied to the lower legs. Electromyography (EMG) studies show that muscles fire more effectively when treated with IPC [1]. IPC is also more effective in decreasing exercise-induced swelling, pain, stiffness (i.e. decreased range of motion) and delayed on-set muscle soreness (DOMS) [2]. These machines are marketed to athletes of all levels to optimize performance and are said to work by decreasing lactic acid. To date, there has been no research that explores if the machines actually do what they claim to do.

Physical activity has been shown to increase muscle damage over time with repetitive stress, especially in eccentric motions [2-5]. In addition to this, the acute accumulation of blood lactate (BLa) during high intensity exercise is shown to be a factor in muscle fatigue and can have a negative effect on subsequent performance [6-8]. This acute accumulation of BLa can induce metabolic acidosis which sequentially can decrease the work capacity of a person's muscles leading to a decrease in performance [9]. Due to these post exercise effects of musculoskeletal micro trauma and a build-up of lactic acid, it is important for the active individual to optimize a recovery method such as an active recovery or “cool-down,” defined as sustained exercise at a submaximal level in order to return to baseline. This type of active recovery post exercise is more effective than passive recovery (rest) in decreasing BLa following exercise [7,10]. The lack of appropriate recovery may result in an inability to train at the required intensity or compete at optimal performance. Proper recovery following exercise is important to repair the transitory and long-term impairments created by the stress of training and competition. Following rehydration, correcting the metabolic disturbances and restoring glycogen stores are paramount for recovery exhaustive exercise [10].

In theory, intermittent 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 [11]. 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 reabsorption of interstitial tissue swelling but also promotes healing to injured tissue [2]. The goal of this study was to evaluate the marketed claim, made by IPC companies, that these machines decrease blood lactate, thus aiding in recovery. Therefore, this study investigates the effectiveness of an IPC unit in clearing BLa following maximal anaerobic exercise for a 20 minute recovery session.

### Methods

#### Design

We conducted a randomized controlled trial investigating

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the effect of an IPC unit as a recovery modality. Participants were provided with written and verbal information on the objectives of the study. Informed consent was obtained. The study was approved by the Institutional Review Board at Northeastern University and funded by an undergraduate provost grant. NormaTec Incorporated donated the machines for all data collection.

## Subjects

Twenty-one (n=21) female student-athletes who participate in a lower extremity dominant division 1 club sport volunteered for this study. Subjects between the ages of 18-25 years old were recruited (mean=19 ± 1 yrs, 166 ± 1.5 cm, 66 ± 2 kg) and all participated in either lacrosse (n=19) or field hockey (n=2). All lacrosse athletes were participating in the last couple weeks of “fall ball” which required weekly games and multiple weekly practices. The field hockey females had completed a full fall season, this included 3 days per week of practice and at least 1 game per weekend. Following a standardized Wingate cycling test, each subject was randomly assigned to one of three recovery groups: active (n=7), passive (n=7) or IPC (n=7). Exclusion criteria included male gender, participating in an upper extremity dominant sport, or being unable to complete a biking test due to respiratory or cardiovascular pathology.

## Instrumentation

The NormaTec MVP™ is an FDA-cleared pneumatic compression device. The device is made up of multi-chambered inflatable boots or sleeves, for the legs and arms respectively, which inflate to prescribed pressures. The chambers inflate using a peristaltic pulse pneumatic waveform that simulates the normal physiological changes mimicking the “muscle pump.” Settings on the machine are as follows: pulse pressure, pulsing time, and rest time seen in [table 1](#). The machines used in this study were calibrated to the “recovery flush” setting for the lower extremity. Athletes were fit with the compression boots so that the boot covered the toes up to the groin comfortably. This particular model was chosen, given a recent increase in its use among collegiate and professional athletes [12].

The WAnT (described below) was performed on a Monark Peak Bike Ergomedic 894E [13]. Heart rate (HR) and blood pressure (BP) were measured using the Omron HEM 705 CP automatic device due to its high marks for fulfilling the accuracy criteria of the Association for the Advancement of Medical Instrumentation (AAMI) [14]. Blood lactate measurements were taken using the Lactate Plus portable handheld analyzer, manufactured by Nova Biomedical, USA due to its high inter and intra-analyzer reliability of r=0.988 and r=0.991, respectively [8].

The Lactate Plus has an accuracy correlation of r=0.936 when compared to the laboratory-based Radiometer ABL 700, and was shown to be more accurate and more reliable than two other commonly used hand-held analyzers [8]. For patient compliance, this meter was easy to administer and only required a quick finger prick.

## Procedures

All procedures took place in the exercise physiology lab in the

**Table 1:** NormaTec MVP Post Workout Pressures (mmHg).

	Cell 1	Cell 2	Cell 3	Cell 4	Cell 5	Rest
Pulse Pressure (PP)	70	80	80	80	60	
Pulse Time (PT)	:30	:30	:30	:30	:30	:30

Behrakis Health Science Center building in Boston, MA. Subjects were randomly assigned to one of three recovery groups prior to the start of testing. All testing took place in the evening. Prior to randomization, each participant’s resting BP and HR were obtained using an automatic blood pressure machine. In addition, participants’ height (cm), weight (kg), and resting BLA levels were recorded. Following the standardized WAnT protocol, subjects immediately began their randomly assigned recovery process. All recovery sessions were 20 minutes in length. Group 1 was asked to perform a passive long sit recovery, where the participant sat with their hips at 90° of flexion and knees in full extension. Group 2 was asked to perform an active recovery on an ergometer stationary bike at ~40% of heart rate reserve, HRR, (Karvonen’s Formula; Target Heart Rate = ((max-resting×HR HR)%Intensity) + resting HR) maintained by pulse readings using the Omron HEM 705 CP automatic device every 4 minutes throughout the 20 minute session. Heart rates were taken throughout the recovery session of the active group in order to maintain the required heart rate to be classified as “active”. Group 3 was placed in the IPC compression leg units and placed on the “recovery flush” setting with their hips at 90° of flexion and knees in full extension.

**WAnT:** Monarch Ergometer 894E (stationary bikes) were used. A two minute warm-up was required for each subject using no resistance on the ergometer at a comfortable pace. The test involves the subject completing a one minute “all-out” pedaling sprint on the ergometer while a resistance equal 0.075 kg per body weight is applied to the wheel. The resistance was applied via a brake force. Verbal encouragement was given throughout the one minute test for optimal performance.

**Blood lactate:** A new sterile lancet was used to prick the fingertip of participants before the WAnT, immediately after and then 20 minutes after recovery. Blood samples were collected using the protocols established by the exercise physiology laboratory. The subject was advised to wash hands thoroughly prior to testing, and the site was further sanitized using a sterile alcohol wipe. Each auto-lancet was used one-time only. Blood equal to roughly 25 microliters (one drop) was collected using a lactate test strip and analyzed. Sterile gauze was used to wipe the blood drops off and each site was covered with a sterile bandage following completion of testing.

**Statistical analysis.** SPSS Statistics version 17 was used for all analyses. Descriptive statistics were run for all variables. Two outliers were accounted for within the BLA dataset, one being extremely high and the other extremely low. These two data points were recorded as the next highest and next lowest numbers, respectively. One-way ANOVA was used to detect significant differences across the three different recovery interventions for HR and BLA at the 20 minute mark of recovery. Between group comparisons were made by Turkey’s HSD test. Statistical significance was defined as p<0.05. A Pearson-Product Correlation was used to measure the correlation between HR and BLA following 20 minutes of recovery.

## Results

Participants across all three interventions had a mean BLA at 0 minutes (immediately post WAnT) of 9.94 mM/L ± 0.41 and a level of 9.49 mM/L ± 0.81 at 20 minutes. No statistically significant differences were recorded in pre-WAnT BLA or immediate post-WAnT BLA, with the means across all three interventions being 1.70 mM/L ± 0.87 and 9.94 mM/L ± 0.4.11 respectively.

At the 20 minute recovery mark, there was a statistically significant difference in BLA concentrations between the three groups (Passive=12.61 mM/L  $\pm$  2.82; Active=7.49 mM/L  $\pm$  3.34; IPC=8.36 mM/L  $\pm$  3.04;  $p < 0.05$ ). This difference can be seen in [figure 1](#) in appendix A. Post-hoc Tukey HSD analysis showed that there was a significant difference between the passive group and both the active (5.13,  $p = 0.02$ ) and IPC (4.26,  $p = 0.04$ ). No statistically significant differences were noted between the BLA concentrations for the active recovery and IPC interventions at 20 minutes ( $p = 0.85$ ). The mean change in BLA concentration over the 20 minute recovery period for each recovery group, shown in [table 2](#), identifies that that active recovery and IPC were relatively equally effective in decreasing lactic acid. The mean heart rate for all participants at 0 minutes (immediately post-WAnT) was 144 beats per minute (bpm). The mean heart rate for all participants at the 20 minute mark of recovery was 99 bpm. No statistically significant differences were found between the heart rate at 0 minutes between the recovery groups (Passive=144 bpm  $\pm$  16; Active=150 bpm  $\pm$  17; IPC=139 bpm  $\pm$  26). There was also no statistical significant difference between the means of the passive, active and IPC groups at the 20 minute mark of recovery, with means being 98 bpm  $\pm$  13, 108 bpm  $\pm$  16, and 92 bpm  $\pm$  24, respectively. A Pearson-Product Correlation of 0.190 was found between HR and BLA at the 20 minute mark of recovery ( $p = 0.41$ ).

## Discussion

Our results indicate that an IPC unit is more effective in decreasing BLA concentrations than passive recovery following a WAnT. One reason for the IPC's success in decreasing BLA more than passive might be due to its ability to mimic the muscle-venous pump [10,15]. These outcomes conclude that the IPC machine is a viable recovery tool, and that active individuals may benefit from the use of this modality. Clinically, this machine is another tool in the clinician's tool box to use for the recovery of an athlete. In addition, the results of our study support research demonstrating that active recovery is a better tool for decreasing BLA than passive recovery. This result

reiterates that health care profession that is working with athletes should advise a "cool down" post practice and games. There have been multiple studies exploring how IPC works, however no research, to our knowledge, has been conducted to explore the BLA levels post IPC treatment such as the methods described in this study [3,4,10].

Compression garments have been studied to investigate the effectiveness of decreasing blood lactate levels during and following exercise, but minimal results were found [16]. Due to the shortage in current research about BLA levels and its correlation with IPC treatment we believe this was a relevant study to conduct.

Our results must be interpreted in light of several limitations. Given our small sample size, we were underpowered to detect an effect size less than 1.5; it is possible that with a greater number of subjects we would have been powered to detect an effect between the active recovery group and the IPC group. Future studies with a greater number of participants are necessary to evaluate the effects of the IPC system compared to active recovery. Furthermore, our study was limited to a one minute intense anaerobic workout followed by a 20 minute recovery period which limits our audience to athletes who perform in the anaerobic pathway. Since speeding up recovery time is priority within the athletic population, we suggest that future studies explore the optimal overall effective treatment time. Moreover, future studies should include combining both an active recovery and the IPC modality to appreciate if there is an ideal combination to enhance performance. In addition, the methods of our WAnT may have limitations since we did not allow for a practice trial since our testing was done over a one day time period. In future studies, we would ultimately test the athletes one week apart to adjust for a learning curve. Additional studies are required to evaluate the effect of an IPC machine over extended periods of time with varying degrees of exercise duration and intensity as well as recovery duration. Recently, Cochrane et al. claimed the parameters used to treat muscle damage following strenuous exercise in healthy participants are likely to be very different than those used to treat pathologic conditions [17]. There must be follow-up research to explore the factors that were limited within our study. In conclusion, active individuals may use an intermittent pneumatic compression unit for recovery rather than passive recovery following exercise.

## References

- Weiner A, Mizrahi J, Verbitsky O (2001) Enhancement of tibialis anterior recovery by intermittent sequential pneumatic compression of the legs. *Basic Appl Myol* 11: 87-90.
- Chleboun GS, Howell JN, Baker HL, Ballard TN, Graham JL et al. (1995) Intermittent pneumatic compression effect on eccentric exercise-induced swelling, stiffness, and strength loss. *Arch phys Med Rehabil* 76: 744-749.
- Kraemer WJ, French DN, Spiering BA (2004) Compression in the treatment of acute muscle injuries in sport. *Int J Sports Med* 5: 200-208.
- 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.
- Jakeman JB, Bryne C, Eston RG (2010) Lower limb compression garment improves recovery from exercise-induced muscle damage in young, active females. *Eur J Appl Physiol* 109: 1137-1144.
- Ahmaidi S, Granier P, Taoutaou Z, Mercier J, Dubouchaud H, et al. (1996) Effects of active recovery on plasma lactate and anaerobic power following repeated intensive exercise. *Med Sci Sports Exerc* 28: 450-456.
- Monedero J, Donne B (2000) Effect of recovery interventions on lactate removal and subsequent performance. *Int J Sports Med* 21: 593-597.
- Tanner RK, Fuller KL, Ross ML (2010) Evaluation of three portable blood

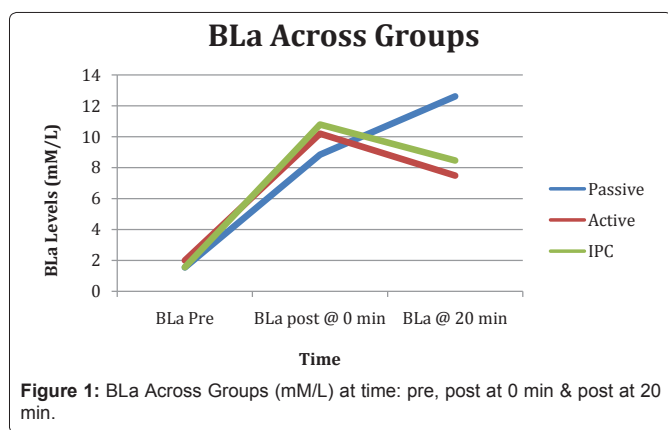


Figure 1: BLA Across Groups (mM/L) at time: pre, post at 0 min & post at 20 min.

Table 2: Mean Difference in BLA Removal (mM/L) per Recovery Group Post-Test through Recovery Phase.

Group	Mean BLA post-test(J)	Mean BLA @ 20 min(I)	Mean difference (I-J)
Passive recovery	8.84 $\pm$ 3.34	12.61 $\pm$ 2.82	3.77
Active recovery	10.20 $\pm$ 5.89	7.49 $\pm$ 3.34	-2.71
NormaTec recovery	10.79 $\pm$ 2.87	8.36 $\pm$ 3.04	-2.43

$p = 0.01$  between groups at 20 min

- lactate analyser; Lactate Pro, Lactate Scout and Lactate Plus. Eur J Appl Physiol 109: 551-559.
9. Myers J, Ashley E (1997) Dangerous curves. A perspective on exercise, lactate and the anaerobic threshold. Chest 111: 787-795.
  10. Barnett A (2006) Using recovery modalities between training sessions in elite athletes. Sports Med 36: 781-796.
  11. Chen AH, Frangos SG, Kilaru S, Sumpio BE, et al. (2001) Intermittent pneumatic compression devices -- physiological mechanisms of action. Eur J Vasc Endovasc Surg 21: 383-392.
  12. <http://www.normatecrecovery.com/news.shtml>
  13. Weinstein Y, Bediz C, Dotan R, Falk B (1998) Reliability of peak-lactate, heart rate, and plasma volume following the Wingate test. Med Sci Sports Exerc 30: 1456-1460.
  14. O'Brien E, Mee F, Atkins N, Thomas M (1996) Evaluation of three devices for self-measurement of blood pressure according to the revised British Hypertension Society Protocol: the Omron HEM-705CP, Philips HP5332, and Nissei DS-175. Blood Press Monit 1: 55-61.
  15. Comerota AJ (2011) Intermittent pneumatic compression: physiologic and clinical basis to improve management of venous leg ulcers. J Vasc Surg 53: 1121-1129.
  16. Duffield R, Cannon J, King M (2010) The effects of compression garments on recovery of muscle performance following high-intensity sprint and plyometric exercise. J Sci Med Sport 13: 136-140.
  17. 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.

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