

## International Journal of Research in Exercise Physiology

Original Research Article

# Ischemic Preconditioning: Implications Associated with Endurance, Power and Rate of Fatigue

Keera M. Clark<sup>1</sup>, Tomiko A. Hiraoka<sup>1</sup>, Torrey A. Waterson<sup>1</sup>, Leslie E. Smith<sup>1</sup>, Devan E. Haney<sup>1</sup>, Adam D. Skinner<sup>1</sup>,  
Akemi G. King<sup>1</sup>, Christina A. Buchanan<sup>1</sup>, Lance C. Dalleck<sup>1</sup>

<sup>1</sup>High Altitude Exercise Physiology Program, Western State Colorado University, Gunnison, CO, USA

### Abstract

**Introduction:** In recent studies, ischemic preconditioning (IPC) has been shown to have a positive effect on endurance, power and reduce fatigue rate. The purpose of this study was to examine whether IPC improves endurance and power output, while decreasing the rate of fatigue in collegiate athletically fit participants. **Methods:** In a double blind crossover study, seven healthy college students (57% male) received IPC (200 mmHg) or a placebo (40 mmHg) during week 1. After the treatment the participants performed a VO<sub>2</sub>max and Wingate test. During week 2, each participant received the opposite treatment from week 1 and the same tests were performed. Age, height, weight, blood pressure, heart rate and oxygen saturation were also assessed at baseline. Statistical analysis: A t-test ( $p < 0.05$ ) using SPSS version 23 was used. **Results:** No significant results were found between variables. VO<sub>2</sub>max and IPC ( $M \pm SD = 39.2 \pm 8.4 \text{ mL} \cdot \text{kg}^{-1} \cdot \text{min}^{-1}$ ) and placebo ( $M \pm SD = 38.2 \pm 13.3 \text{ mL} \cdot \text{kg}^{-1} \cdot \text{min}^{-1}$ ) groups ( $t(6) = .381, p > 0.05$ ). Peak power and IPC ( $M \pm SD = 92.3 \pm 12.1\%$ ) and placebo ( $M \pm SD = 89.9 \pm 13.3\%$ ) groups ( $t(6) = .416, p > 0.05$ ). Power drop and IPC ( $M \pm SD = 92.3 \pm 12.1\%$ ) and placebo ( $M \pm SD = 89.9 \pm 13.3\%$ ) groups ( $t(6) = .416, p > 0.05$ ). Rate of fatigue and IPC ( $M \pm SD = .426 \pm .13\% \cdot \text{W} \cdot \text{sec}^{-1} \cdot \text{kg}^{-1}$ ) and placebo ( $M \pm SD = .412 \pm .12\% \cdot \text{W} \cdot \text{sec}^{-1} \cdot \text{kg}^{-1}$ ) groups ( $t(6) = .64, p > 0.05$ ). **Conclusions:** Although the findings from the present study do not equate to significance, further research is needed to correct the limitations of this study and to assess further implications of IPC.

**Key Words:** Ergogenic aids, VO<sub>2</sub>max, Wingate test

## Introduction

Ischemic preconditioning (IPC) is a technique that may help participants increase their performance and decrease stresses placed on the body<sup>1-2</sup>. In recent studies, clinical patients who have had IPC have expressed more benefits in recovery than those who have not received IPC<sup>3-5</sup>. As a result, the benefits associated with IPC are believed to transfer over to athletic performances as well. This is because under both instances, surgical and exercise-induced, the body still goes under ischemic conditions. IPC is achieved by systemically occluding the blood vessels of one extremity. Since effects of IPC are systemic, therefore any limb can be occluded to produce protective effects throughout the body<sup>6-7</sup>. IPC could be considered a valuable option for increasing athletic performance. Under exercising conditions, the tissues become ischemic therefore, if this treatment were applied before an athletic performance, the body could adapt to these conditions and in turn improve performance.

Current research suggests that using IPC before an exercise test is performed can improve a participant's maximal oxygen consumption, which in turn can potentially improve a participant's athletic performance<sup>7</sup>. IPC may aid in performance outcomes by increasing oxygen delivery to the tissues. In addition, IPC may result in greater ATP utilization, therefore releasing more energy to be used by the tissues<sup>7</sup>. IPC

can potentially improve metabolic functionality by increasing ATP - sensitive potassium channels and skeletal muscle blood flow, while decreasing glycogen and lactate production during an ischemic event<sup>8</sup>. This increase in ATP sensitivity is associated with increased levels of oxygen delivery and lactate removal<sup>9-10</sup>. IPC has been found to improve maximal performance by 1.6% and maximal oxygen consumption by 3% in healthy participants<sup>1</sup>. Therefore, IPC has the potential to aid in both anaerobic and aerobic activities. Current research also indicated that the positive effects of IPC may be due to increased metabolites such as adenosine, bradykinin and other opioids that may play a role in the cardio-protective benefit that is associated with IPC<sup>3-5</sup>.

More research is needed to assess the most effective number of cycles and duration of an IPC treatment to elicit optimal effects of performance. In addition, there also needs to be more research to assess the benefits, risks, the effects IPC has on power output and fatigue. Therefore, the purpose of this study was to assess the effects of IPC on power output, endurance and rate in fatigue in athletic participants. IPC is proposed to help increase blood flow and endothelial functioning by preparing the body and allowing it to adapt to ischemic events (i.e. exercise). In this study, we hypothesized that IPC would produce beneficial effects in athletes, increasing participant's endurance and power output while decreasing rate of fatigue.

## Methods

### Participants

Seven healthy and athletically fit participants (4 men and 3 women) between the ages of 18-24 gave consent to participate in this study. Recruitment was conducted through reaching out to Western State Colorado University coaches using email. After receiving permission to work with their athletes, a specific time was set up to meet with all of the athletes. After a specific time was set, two different meeting times were then scheduled, one with the women's club and another with men's club athletes. The meeting with the women's team was held in the gym, while the meeting with the men's team was conducted in the Mountaineer Field House at Western State Colorado University. Additional athletically fit participants were recruited from the High Altitude Physiology graduate program at Western State Colorado University. This meeting was held in the High Altitude Performance Lab (HAP Lab). After participants showed interest in the study, participant appointments were set up. At the initial appointment participants were asked to sign a consent form, photo release, health history form and a Physical Activity Readiness Questionnaire (PAR-Q). After this initial meeting, the participant's availability was discussed and participant testing appointments were scheduled.

Inclusion criteria for this study consisted of athletically fit participants who were

classified as low-to-moderate risk according to the risk stratification model established by the American College of Sports Medicine (ACSM)<sup>11</sup>. This study was approved by the Human Research Committee at Western State Colorado University.

### Experimental Design

This study was a double blind crossover study. Maximal oxygen uptake ( $\text{VO}_2\text{max}$ ) was used to measure aerobic capacity, while power output and rate of fatigue were measured using a Wingate test.

A baseline protocol was implemented using the following: resting heart rate, resting blood pressure, height, and weight of each participant at the beginning of the 2 week study. We conducted a  $\text{VO}_2\text{max}$  test on a treadmill and a Wingate test on the stationary bike on each athlete, after the IPC treatment was applied to the participant (1 cycle= 5 minutes of inclusion followed by 5 minutes of reperfusion times 3 cycles). The different treatment groups were labeled X and Y so the primary researchers and the participants did not know which treatments each participant received. The IPC treatment was set at 200 mg/Hg and the placebo treatment was set at 40 mg/Hg.

IPC treatment occurred once a week for two weeks. The original group of 7 were split into two sub groups. Some of the participants in the group received the treatment, while the other participants

received a placebo. This was considered week 1. During week 2, the groups switched, so if an participant were in the placebo group for week 1, they were now in the treatment group for week 2.

Both a  $VO_2\text{max}$  and Wingate test were performed 5 minutes after the participant received the placebo or treatment. A separate researcher was asked to assign participants to the treatment or placebo group (X or Y) and then performed the given protocol. The primary researchers then asked the participants to perform a  $VO_2\text{max}$  test and then a Wingate test after a 15-minute rest period. We attempted to keep testing days consistent throughout the course of the study; however this depended on participant schedules. This study was performed at moderate altitude (2348 m).

### **Experimental procedures**

#### *Ischemic Preconditioning Protocols*

In order to test the effects of IPC on power output and fatigue the following protocol was used: the pressure cuff was placed on the right leg of the participant (under resting conditions) and pumped up to 200 mm/Hg. The pressure was held constant for 5 minutes and then released. The participant rested for another 5 minutes to allow blood reperfusion to occur. These steps were repeated for a total of 3 times. After IPC had been applied, the participant was asked to perform a  $VO_2\text{max}$  test. Once the test was complete, the participants had a 15- minute rest and then they were asked

to complete a Wingate test. Normal Wingate testing protocols were setup (as listed below).

#### *Protocol for $VO_2\text{max}$ Testing:*

The  $VO_2\text{max}$  test was established to measure aerobic capacity. Prior to the  $VO_2\text{max}$  test, participants were instructed to put on a mask/mouth piece with a breathing valve to collect expired gases. Participants were instructed to use hand signals to notify researchers that they are ready to stop the test. Participants were asked to walk/run on a treadmill at different levels of speed and grade (incline). Participants were asked to rate their perceived exertion (RPE) during the test using an RPE scale (Borg). Participants performed a warm-up period of 3-minutes, and then the official test began. The test continued until the participant became fatigued and decided to stop, or other symptoms prohibited from further exercise. After testing, participants cooled down for 15-minutes.

#### *Protocol for Wingate Testing*

Wingate testing was designed to establish parameters related to anaerobic power, fatigue and total anaerobic capacity. The equipment that was used for the Wingate test was the Peak Monark Ergonomic 894 E bike (Vansbro Dalarna, Sweden). Protocol consisted of a 5-minute warm up at a pace that was comfortable for the participant with a 10 second sprint at the end of each minute. Once the test started the

participant pedaled to 120 RPMs, then a weight that was set to 7.5% of the participant's body weight in kg dropped. The participant then pedaled against the weight for 30 seconds. Once the Wingate test was completed a 5-minute cool down at a comfortable pace was performed.

### Instrumentation

A Tanita precision digital scale that was made in Japan, was used to determine the participant's body weight in kilograms (kg) and height in centimeters (cm). (Tanita, 2014). A standard sphygmomanometer was used to assess the participant's blood pressure. A standard pulse oximeter was used to determine resting heart rate and resting/exercise O<sub>2</sub> saturation. For the IPC the Hokanson AG101 Cuff (Bellvue, WA) inflator Air source machine was used to induce ischemia for both the treatment and placebo group. The VO<sub>2</sub>max test was performed on a treadmill and expired gases were collected and analyzed with the TrueOne 2400 Metabolic Measurement System (TrueOne 2400, Parvo Medics, Sandy, UT). The Wingate test used the Peak Monark Ergonomic 894 E bike and Monark Anaerobic test software (Vansbro, Dalarna Sweden).

### Statistical analyses

Descriptive statistics were used to determine the mean, standard deviation (SD) and mean percent change with 95% confidence intervals (CI) for all measures. Normality was tested using the

Kolmogorov-Smirnov test. Measurements were recorded as normally distributed if tests were not found significant ( $p > 0.05$ ). Paired  $t$  tests were used to determine differences in percent change in anaerobic performance measures. Alpha level was set at  $p < 0.05$  to determine statistical significance. IBM SPSS version 23.0 (IBM Corporation, Armonk, NY, USA) and GraphPad Prism 6.0 (San Diego, CA, USA) were used to analyze all data.

### Results

The intervention was well tolerated for all seven participants. All seven participants completed an IPC treatment and placebo treatment, a VO<sub>2</sub> max test, and a Wingate test. All of the participants exercise tests and physiological responses to the tests were between normal ranges and are presented in Table 1.

#### VO<sub>2</sub>max

A paired  $t$ -test revealed no significant difference in VO<sub>2</sub>max between IPC ( $M \pm SD = 39.2 \pm 8.4 \text{ mL} \cdot \text{kg} \cdot \text{min}$ ) and placebo ( $M \pm SD = 38.2 \pm 13.3 \text{ mL} \cdot \text{kg} \cdot \text{min}$ ) groups ( $t(6) = .381, p > 0.05$ ).

#### Peak Power

A paired  $t$ -test revealed no significant difference in peak power between IPC ( $M \pm SD = 1199.55 \pm 240.3 \text{ W}$ ) and placebo ( $M \pm SD = 1204.4 \pm 306.6 \text{ W}$ ) groups ( $t(6) = -.087, p > 0.05$ ).

### % Power Drop

A paired *t*-test revealed no significant difference in peak power between IPC ( $M \pm SD = 92.3 \pm 12.1\%$ ) and placebo ( $M \pm SD = 89.9 \pm 13.3\%$ ) groups ( $t(6) = .416, p > 0.05$ ).

### Rate to Fatigue

A paired *t*-test revealed no significant difference in peak power between IPC ( $M \pm SD = .426 \pm .13\% \cdot \text{W} \cdot \text{sec} \cdot \text{kg}$ ) and placebo ( $M \pm SD = .412 \pm .12\% \cdot \text{W} \cdot \text{sec} \cdot \text{kg}$ ) groups ( $t(6) = .64, p > 0.05$ ).

**Table 1.** Responses to  $\text{VO}_2\text{max}$  and Wingate testing in IPC and control conditions.

Treatment	$\text{VO}_2\text{max}$ (mL/kg/min)	Peak Power (W)	Power Drop (%)	Power Drop (W/Sec/kg)
IPC (n = 7)	$39.2 \pm 8.4^a$	$1199.5 \pm 240.3$	$92.3 \pm 12.1$	$0.4 \pm 0.1$
Control (n = 7)	$38.2 \pm 13.3$	$1204.4 \pm 306.6$	$90.0 \pm 13.3$	$0.4 \pm 0.1$

<sup>a</sup>(Values are mean  $\pm$  SD).

## Discussion

The main finding of the current study was that no significant differences were found between IPC and placebo for  $\text{VO}_2\text{max}$ , power output, or rate of fatigue scores. While previous studies<sup>1-2,7-10</sup> have indicated that IPC can have significant benefits to the aforementioned variables, significance in this study was not attained, this could be a result of the limitations of this study (as listed below). Overall, additional research is needed to further assess the implications of IPC and whether or not this treatment could benefit performance and rate of fatigue.

One possible limitation of this study was that the majority of participants had never performed a  $\text{VO}_2\text{max}$  or Wingate test prior to their initial testing appointment. This could have had an effect on the results of this study, as the participant knew what to expect from the test more so during the second testing appointment than they did during their first appointment. One way

that this limitation would have been reduced, was if the primary researchers had scheduled a familiarization test prior to data collection. Another limitation was the modest sample size which limited statistical power.

## Conclusion

More research is needed to fully understand the implications of IPC. More research is needed to suggest benefits and risks of IPC in relation to  $\text{VO}_2\text{max}$ , power output, and fatigue. Additional investigation is also needed to summarize how IPC may aid in performance on the cellular level and what types of populations may benefit most from the associated benefits. Also, the duration of the IPC cycles and resting periods could have affected the results. Further research is needed to determine optimal cycle durations and rest periods during the cycles as well as resting periods before beginning a testing session or performance event.

### Address for Correspondence

Buchanan CA, PhD, High Altitude Exercise Physiology Program, Western State Colorado University, Gunnison, CO, USA, 81231.  
PHONE: (970) 943-2027; FAX: (970) 943-7125;  
EMAIL: [chbuchanan@western.edu](mailto:chbuchanan@western.edu).

### References

1. Jean-St-Michel E, Manlhiot C, Li J, Tropak M, Michelsen MM, Schmidt MR, McCrindle BW, Wells GD, Redington AN. (2010). Remote ischemic preconditioning improves maximal performance in highly trained athletes. *Med Sci Sports Exerc*, 43, 1280-1286.
2. Zhao ZQ, Corvera JS, Halkos ME, Kerendi F, Wang NP, Guyton RA, Vinten-Johansen J. (2003). Inhibition of myocardial injury by ischemic postconditioning during reperfusion: comparison with ischemic preconditioning. *Am J Physiol Heart Circ Physiol*, 285, H579-88.
3. Kubler W, Haass M. (1996). Cardio protection: definition, classification and fundamental principles. *Heart*, 75, 330-333.
4. Balakumar P, Rohilla A, Singh M. (2008). Pre-conditioning and postconditioning to limit ischemia-reperfusion-induced myocardial injury: what could be the next footstep? *Pharmacol Res*, 57, 403-412.
5. Iliodromitis EK, Lazou A, Kremastinos DT. (2007). Ischemic preconditioning: protection against myocardial necrosis and apoptosis. *Vasc Health Risk Manag*, 3, 629-37.
6. Hittinger EA, Maher JL, Nash MS, Perry AC, Signorile JF, Kressler J, Jacobs KA. (2015). Ischemic preconditioning does not improve peak exercise capacity at sea level or simulated high altitude in trained male cyclists. *Appl Physiol Nutr Metab*, 40, 65-71.
7. de Groot PC, Thijssen DH, Sanchez M, Ellenkamp R, Hopman MT (2010). Ischemic preconditioning improves maximal performance in humans. *Eur J Appl Physiol*, 108, 141-146.
8. Gibson N, White J, Neish M, Murray A. (2013). Effect of ischemic preconditioning on land-based sprinting in team-sport athletes. *Int J Sports Physiol Perform*, 8, 671-676.
9. Bailey TG, Jones H, Gregson W, Atkinson G, Cable NT, Thijssen DH. (2012). Effect of ischemic preconditioning on lactate accumulation and running performance. *Med Sci Sports Exerc*, 44, 2084-2089.
10. Incognito AV, Burr JF, Millar PJ. (2016). The effects of ischemic preconditioning on human exercise performance. *Sports Med*, 46, 531-544.
11. Pescatello LS. (2014). *ACSM's Guidelines for Exercise Testing and Prescription* (9th ed.). Baltimore, MD: Lippincott Williams & Wilkins.