

## Acute effect of Ischemic Preconditioning in different blood flow restriction compressions on the anaerobic performance of trained individuals

### Efecto agudo del Precondicionamiento Isquémico en diferentes compresiones de restricción del flujo sanguíneo sobre el rendimiento anaeróbico de individuos entrenados

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**Abstract.** Purpose: to analyze the acute effect of ischemic preconditioning in different compressions of blood flow restriction on the anaerobic performance of trained individuals. Material & methods: the research has a quasi-experimental characteristic, crossed and randomized design, in which the subjects were their own controls and submitted to four experimental conditions before the RAST anaerobic power test: C1 = without IPC; C2 = IPC at 20 mmHg (SHAM); C3 = IPC at 220 mmHg and C4 = IPC at 100% of the auscultatory pulse (AP). The study included 21 trained individuals ( $21.0 \pm 2.3$  years), male, who performed the power test after 4 experimental conditions in a randomized manner. Result: Despite the IPC with 100% of the AP demonstrating a positive trend towards the improvement in the averages of Pmax ( $\Delta = 2.6\%$ ), Pmed ( $\Delta = 0.7\%$ ), Pmin ( $\Delta = 1.8\%$ ) and running time in 35 m ( $\Delta = 0.8\%$ ), none of the variables showed a significant effect between the experimental conditions. Conclusions: It is concluded that, even presenting a subtle improvement in the maximum, average and minimum powers in a 35-meter running test when using the compression of 100% of the AP, the IPC did not demonstrate a significant increase in performance. However, an increase of 2.6% in maximum power can represent the difference between first and second place in a high-performance test.

**Keywords:** sports performance, anaerobic power, ischemic preconditioning, blood flow restriction, vascular occlusion.

**Resumen.** Propósito: Analizar el efecto agudo del precondicionamiento isquémico en diferentes compresiones de la restricción del flujo sanguíneo en el rendimiento anaeróbico de las personas capacitadas. Material y métodos: la investigación tiene un diseño característico cuasi-experimental, cruzado y aleatorizado, en el que los sujetos eran sus propios controles y se sometieron a cuatro condiciones experimentales antes de la prueba de potencia anaeróbica RAST: C1 = sin IPC; C2 = IPC a 20 mmHg (simulacro); C3 = IPC a 220 mmHg y C4 = IPC a 100% del pulso auscultatorio (AP). El estudio incluyó a 21 personas capacitadas ( $21.0 \pm 2.3$  años), hombres, que realizaron la prueba de potencia después de 4 condiciones experimentales de manera aleatoria. Resultado: a pesar de que el IPC con el 100% de la AP demuestra una tendencia positiva hacia la mejora en los promedios de Pmax ( $\Delta = 2.6\%$ ), Pmed ( $\Delta = 0.7\%$ ), Pmin ( $\Delta = 1.8\%$ ) y tiempo de ejecución en 35 m ( $\Delta = 0.8\%$ ), ninguna de las variables mostró un efecto significativo entre las condiciones experimentales. Conclusiones: se concluye que, incluso presentando una mejora sutil en las potencias máximas, promedio y mínimas en una prueba de ejecución de 35 metros cuando se usa la compresión del 100% de la AP, el IPC no demostró un aumento significativo en el rendimiento. Sin embargo, un aumento del 2.6% en potencia máxima puede representar la diferencia entre el primer y el segundo lugar en una prueba de alto rendimiento.

**Palabras clave:** rendimiento deportivo, poder anaeróbico, precondicionamiento isquémico, restricción del flujo sanguíneo, oclusión vascular.

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## Introduction

High performance sport is an area of study that increasingly raises interventions with the aim of improving the athlete's performance. For every modality there is an energetic, physical, technical or tactical requirement that is typical of its demand, whether individual or collective sports. Sports performance is determined by the development of specific skills and the continuous and reliable provision of these skills in competitive situations (Kellmann & Beckmann, 2017; Portenga et al., 2017). It can be influenced by some physical abilities, such as endurance, strength, speed, flexibility and power (Gomes & Souza, 2007; Halson, 2014).

In this perspective, there is the anaerobic power, which can be understood as the maximum energy that can be generated per unit of time by the anaerobic system (Franchini, 2002) and basically depends on the initial concentration of phosphocreatine (CP) in the muscles. The training of this physical component promotes an improvement in the ATP-

CP system through the increase in the reserves of adenosine triphosphate (ATP) and CP in the muscles and the greater activity of key enzymes that act in this system (Wilmore & Costill, 2008). These improvements may contribute to greater resistance to muscle fatigue, thus increasing performance in sport. Anaerobic power is an extremely important component for several sports that feature high-intensity efforts in a short period of time (Wilmore & Costill, 2008).

Every day, coaches and researchers seek commonly created and used methods for the purpose of enhancing the best levels of this physical component, and an ergogenic strategy that has been effective is ischemic preconditioning (IPC), which consists of acute episodes of ischemia and reperfusion (IR), performed in the appendicular skeleton, using pneumatic tourniquets, before performing exercise or sports tests (Cirilo-Sousa & Rodrigues Neto, 2018). But the effectiveness of the IPC intervention in the field of sports science is not yet clear. In fact, some studies report significant benefits in performance, race time, maximum oxygen consumption and anaerobic power (Crisafulli et al., 2011; da

Silva Novaes et al., 2021; da Silva Telles et al., 2023; Griffin et al., 2019; Jean-St-Michel et al., 2011). While others do not show any significant effect (Cocking et al., 2021; Fostiak et al., 2022; Gibson et al., 2015; Lalonde & Curnier, 2015; Lindner et al., 2021; Thompson et al., 2018). However, the number of IR cycles, as well as the duration of the cycles, vary from one study to another (Caru et al., 2019). Furthermore, there seems to be no consensus on the ideal pressure to be used in the cuffs during IPC, which could explain the differences in the results of the studies.

Perhaps the ideal protocol for the application of IPC has not yet been found for physical or sports performance. That is, the number and duration of IR cycles, the ideal pressures to perform ischemia or simulate it (SHAM), and even the time between performing the IPC protocol and the start of the tests are still not properly established in the literature (da Mota & Marocolo, 2016). Therefore, the main objective of this investigation was to analyze the acute effect of ischemic preconditioning in different blood flow restriction compressions on the anaerobic performance of trained individuals.

## Material and methods

### Participants

The population was made up of trained, male individuals, aged between 18 and 30 years, from the city of João Pessoa – PB. The sample was recruited through wide dissemination at universities and clubs in the city of João Pessoa, through banners, posters and social media. The present study included individuals who: 1) answered “NO” to all questions in the physical activity readiness questionnaire – PAR-Q; 2) considered “very active” by the classification table of the international physical activity questionnaire – IPAQ; 3) no physical limitations or musculoskeletal problems; 4) who had an ankle brachial index (ABI) between 0.9 and 1.3, that is, without exposure to lower limb arterial obstructive disease (DAOMI); 5) who voluntarily agreed to participate in the research; 6) who took at least the first two doses or a single dose of the vaccine against COVID-19. Individuals who did not perform 100% of the proposed tests, or were affected by an injury or illness that compromised the performance of the tests during the experimental period, were excluded from the study.

After the eligibility criteria, 28 individuals were selected for the research, however, due to withdrawal, 7 individuals were excluded from the study, ending the research with  $N = 21$  participants, with their characteristics presented in table 1. The experimental protocol and Potential risks involved in the study were described to all participants, and they were allowed to withdraw from any stage of the study without providing any reason. Participants signed the consent form to participate in the study, declaring themselves volunteers. The research followed all the rules of Resolution 466/12 of the National Health Council (CNS) and was approved by opinion number 5,381,704, by

the Ethics and Research Committee involving human beings at the University Center of João Pessoa (UNIPÊ).

Table 1.  
Physical Characteristics of Participants, Blood Pressure at Rest and Auscultatory Pulse, Mean  $\pm$  SD.

Characteristics	Measurements
Age (years)	21.0 $\pm$ 2.3
Height (cm)	176.9 $\pm$ 8.8
Body Mass (kg)	71.6 $\pm$ 9.4
Resting systolic blood pressure (mmHg)	125.2 $\pm$ 11.5
Resting diastolic blood pressure (mmHg)	68.5 $\pm$ 6.6
Auscultatory pulse of right leg (mmHg)	207.1 $\pm$ 25.9
Auscultatory pulse of the left leg (mmHg)	207.1 $\pm$ 27.6

Caption: cm: centimeters; kg: kilogram; mmHg: millimeters of mercury.

### Study design

The procedures for collecting and measuring the variables were carried out by the researcher himself on the premises of the LAF/UNIPÊ Physical Assessment Laboratory, as it provided adequate conditions for data collection. The Participants were instructed to abstain from the ingestion of stimulating supplements, caffeine and alcoholic beverages before and after the experimental protocols and to eat a light meal 2 to 4 hours before each session, in addition to not practicing physical exercise 48 hours before. And the tests were always performed at the same time of day for each volunteer, to avoid possible adverse effects related to circadian rhythm.

All collections took place over the course of 5 meetings, with a week of difference from one to the other. In the first meeting, the initial anamnesis was carried out and the ankle brachial index (ABI), the auscultatory pulse (AP) and the anthropometric measurements of the participants were measured. In the four remaining meetings, the individuals were submitted to each of the four experimental conditions, randomly selected: in the first condition (C1): the individuals were not submitted to IPC before performing the RAST (control); in the second condition (C2): the individuals underwent IPC with 20mmHg (SHAM) before performing the RAST; in the third condition (C3): the individuals underwent IPC at 220mmHg before performing the RAST; in the fourth condition (C4): the individuals were submitted to IPC at 100% of the AP before performing the RAST.

After the experimental protocol, the individuals performed stretching (5 minutes) and warming up, which consisted of running at low intensity for 5 minutes around the court. After warming up, the individuals continued walking for another 5 minutes until the beginning of the RAST, totaling a time window of 15 minutes between the end of the experimental protocol and the beginning of the test.

### Body composition measurements

Anthropometric variables were performed in order to characterize the participants. Height was measured using a stadiometer (Wiso<sup>®</sup>, model E210, Santa Catarina, Brazil), with subjects barefoot forming a right angle with their heels, pelvic girdle, shoulder girdle and occipital region in contact with the instrument (Cirilo-Sousa, 2008). Total

body mass (BM), body mass index (BMI), lean body mass (LBM) and fat percentage (%F) were quantified using bioimpedance (InBody 570 Biospace®, San Francisco – California, USA) with multi-frequency segmental direct measurement and tetrapolar electrode system with 8 tactile points (Bedogni et al., 2002).

### Initial anamnesis and clinical diagnosis

To carry out the anamnesis and as a criterion for inclusion in the research, the physical activity readiness questionnaire - PAR-Q and the international physical activity questionnaire – IPAQ were used (Matsudo et al., 2012).

### Ankle Brachial Index (ABI)

This measurement was performed by measuring the Systolic Blood Pressure (SBP) of the lower limbs (posterior tibial artery) and upper limbs (brachial artery). The instrument used for measurement was a high-frequency portable vascular Doppler (DV2001 - Medpej®, Ribeirão Preto, SP, Brazil). To perform this measurement, the volunteers were instructed to follow the recommendations: do not drink caffeinated beverages, do not smoke, do not have a full bladder, do not exercise in the last 30 minutes before the test, do not cross your arms or legs and do not speak during the procedure. Subsequently, the subjects positioned themselves on a stretcher, in dorsal decubitus, and remained at rest for 10 minutes. Then the measurements of each blood vessel were obtained, in a rotational way, with intervals of 2 minutes between them (Resnick et al., 2004).

### Determination of the Auscultatory Pulse (AP)

The auscultatory pulse for IPC prescription was checked at rest, standing up (in a vertical position oriented in the Frankfurt plane) using a vascular Doppler (MedPej DF - 7001, Ribeirão Preto, SP, Brazil), in which the transducer was positioned over the posterior tibial artery (for the lower limbs), before external compression was performed. During the compression phase, a standard Riester Kompri-meter Pneumatic Tourniquet was used, 96 cm x 13 cm for both legs (Compressive Riester; Jungingen, Alemanha). These were fixed around the most proximal portion of the limb and inflated quickly, from 10 mmHg to 10 mmHg, until the audible sound of the artery disappeared or was diminished to the point of not being perceptible to the evaluator's ears (Laurentino et al., 2018).

### Running Anaerobic Sprint Test (RAST)

The RAST was developed by Wolverhampton University (UK) and adapted from the original WAnT to assess power and anaerobic capacity by measuring the variables maximum power (Pmax) or peak power (PP), mean power (Pmed), power minimum (Pmin) and fatigue index (IF). The RAST test consists of performing six maximum sprints of 35 meters, with a 10-second recovery, and to determine the generated power, it is necessary to measure the time of each sprint and the individual's body mass (Ferna, 2009). To measure the time of each "sprint" and the time interval

between them, two pairs of photocells and the "SPEED TEST 6.0" (CEFISE) program were used, figure 1.

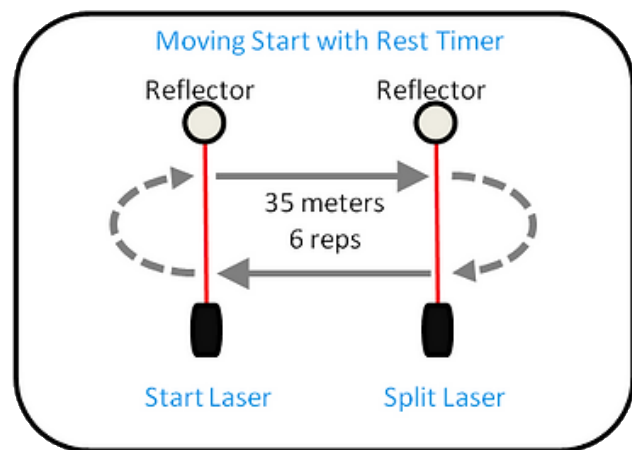


Figure 1. Running Anaerobic Sprint Test.

### Ischemic preconditioning protocol (IPC)

Ischemia was performed bilaterally in the lower limbs using standard Riester Kompri-meter Pneumatic Tourniquet. These were fixed around the most proximal portion of the limb. Three ischemia cycles lasting 5 minutes each were performed, with a 5-minute interval of blood reperfusion between them. Total intervention time of 30 minutes. After the experimental protocol, the individuals performed a 5-minute stretch and a 10-minute warm-up until the start of the RAST, totaling a time window of 15 minutes, between the end of the experimental protocol and the beginning of the test.

### Statistical analyzes

Shapiro - Wilk and Levene tests were performed to check the normality and homoscedasticity of the data. As the data showed normal distribution, the means were compared using the Analysis of Variance (ANOVA) test, followed by the post hoc Bonferroni test. The effect size was calculated by Eta squared ( $\eta^2$ ) and Delta ( $\Delta$ ) was used to express the percentage variation between values. The significance level was set at  $p \leq 0.05$ . All statistical analyzes were performed using the SPSS statistical software package version 20.0 (SPSS Inc., Chicago, IL).

### Results

As can be seen in Table 2, the results show that none of the dependent variables showed a significant effect between the experimental conditions, with maximum power ( $p = 0.686$ ), average power ( $p = 0.821$ ), minimum power ( $p = 0.948$ ), fatigue index ( $p = 0.841$ ) and Time in 35m ( $p = 0.671$ ). However, it is observed that in C4, which used the IPC at 100% of the AP, there was a positive trend towards the improvement in the means of maximum power ( $\Delta = 2.6\%$ ), mean power ( $\Delta = 0.7\%$ ), minimum power ( $\Delta = 1.8\%$ ) and decrease in the mean running time in 35m ( $\Delta = 0.8\%$ ), being more effective in the values of maximum

power, when compared with C1 (control). When compared with C3 (IPC 220 mmHg), C4 (IPC at 100% of AP) showed a slightly more expressive improvement, even if it

was not statistically significant: P.max ( $\Delta = 4.4\%$ ); P.med ( $\Delta = 2.8\%$ ); P.min ( $\Delta = 1.8\%$ ) and Time in 35m ( $\Delta = 1.5\%$ ).

Table 2.

Descriptive characteristics (mean  $\pm$  standard deviation), significance and effect size of dependent variables

Variables	C1	C2	C3	C4	P	$\eta^2$
	NO IPC	IPC 20 mmHg	IPC 220 mmHg	IPC 100% PA		
P.max (w.kg <sup>-1</sup> )	9.08 $\pm$ 1.52	8.72 $\pm$ 1.67	8.93 $\pm$ 1.78	9.32 $\pm$ 1.50	0.686	0.018
P.med (w.kg <sup>-1</sup> )	6.94 $\pm$ 1.17	6.68 $\pm$ 1.15	6.80 $\pm$ 1.11	6.99 $\pm$ 1.16	0.821	0.011
P.min (w.kg <sup>-1</sup> )	5.13 $\pm$ 1.07	5.04 $\pm$ 0.84	5.13 $\pm$ 0.87	5.22 $\pm$ 1.05	0.948	0.004
FI (%)	43.05 $\pm$ 11.02	41.10 $\pm$ 10.61	41.29 $\pm$ 10.52	43.48 $\pm$ 9.95	0.841	0.010
Time 35m (sec.)	5.16 $\pm$ 0.33	5.24 $\pm$ 0.36	5.20 $\pm$ 0.36	5.12 $\pm$ 0.34	0.671	0.019

Caption: RAST: Running Anaerobic Sprint Test; IPC: Ischemic Preconditioning; P.max : maximum power; P.med : average power; P.min : minimum power; FI: fatigue index; p : significance;  $\eta^2$  : effect size.

Regarding the maximum power (P.max), after comparing the means of each experimental condition, C1: who only performed the RAST without the use of IPC (9.08  $\pm$  1.52); C2: who used IPC with 20 mmHg (8.72  $\pm$  1.67); C3: who used IPC with 220 mmHg) and C4: who individualized the pressure by the AP (9.32  $\pm$  1.50), no significant effect was observed ( $p = 0.686$ ) and a very small effect size ( $\eta^2 = 0.018$ ).

With regard to running time in 35 meters (Time 35m), after comparing the means of each experimental condition, C1 (5.16  $\pm$  0.33), C2 (5.24  $\pm$  0.36), C3 (5.20  $\pm$  0.36) and C4 (5.12  $\pm$  0.34), there was no significant effect ( $p = 0.671$  /  $\eta^2 = 0.019$ ). However, although C4 showed a very slight decrease in running time, being a short distance (35m) it may represent a considerable improvement.

## Discussion

The aim of this study was to analyze the acute effect of IPC in different compressions of blood flow restriction on the anaerobic performance of trained individuals. Although IPC, performed at 100% of the auscultatory pulse, has shown a positive trend in increasing anaerobic power, no result was statistically significant, making the null hypothesis of the study accepted.

The IPC demonstrated to have many benefits in a medical environment, mainly in the protection of the myocardium against infarction caused by prolonged periods of ischemia (Murry et al., 1986). However, its effect on skeletal muscle and physical performance remain controversial. The data collected in this study suggest that IPC does not exert a beneficial or deleterious effect on the anaerobic power, on the fatigue index and against the clock of trained individuals, during a power test - RAST, corroborating the findings of recent studies (Cocking et al., 2021; Fostiak et al., 2022; Gibson et al., 2013, 2015; Lalonde & Curnier, 2015; Lindner et al., 2021; Thompson et al., 2018). However, contrary to the results of other studies, where some positive effect appears in the time against the clock, in the potency or in the decrease of the fatigue index, after the treatment with IPC (Crisafulli et al., 2011; Griffin et al., 2019; Jean-St-Michel et al., 2011). Also diverging from a study carried out with swimmers, where IPC caused a negative effect on anaerobic power (Paixão et al., 2014).

IPC managed to demonstrate an increase in performance when applied in submaximal effort tests and when used in recreationally trained individuals (Crisafulli et al., 2011; De Groot et al., 2010). In another similar study, also performing maximal effort tests, using well-trained participants, who performed three 30m sprints with a one-minute recovery between each sprint, found that IPC does not improve sprint performance (Gibson et al., 2013). Likewise, IPC did not improve maximal effort tests on a cycle ergometer where 5 sprints of 6 seconds were performed against 7.5% of body mass (Gibson et al., 2015). But when used in highly trained populations, in maximum sprints of 10m or 20m of distance, it was not successful (Thompson et al., 2018). There was also no positive effect of IPC on power tests such as vertical jump, reactive force index, horizontal jump, 100m sprint and pro-agility (Lindner et al., 2021).

In another test in which 6 sprints were performed at a distance of 30m, where IPC was applied (5 minutes of IPC + 1 minute of reperfusion) before each sprint, the intervention with IPC using pressures of 60% and 80% of the blood flow restriction also failed to significantly improve the time against the clock of trained individuals (Fostiak et al., 2022). These findings suggest that IPC treatment is effective when applied to recreationally trained individuals and in submaximal exercise tests. However, when used in highly trained athletes and in maximal tests of short duration, these responses in potency do not happen. However, despite the fact that the present study was carried out with individuals who were not high-performance athletes, it also did not show significant gains in anaerobic power and in the fatigue index, after a 35-meter running test. Perhaps, due to the characteristic of the test that it was of maximum effort in very short intervals of time.

In a study carried out with swimmers, it was observed that the individuals who performed the IPC before the test took more strokes to cover a certain distance (Jean-St-Michel et al., 2011). This finding may suggest that the treatment with IPC may have caused a loss of efficiency in each stroke performed, however, this deficiency was compensated by the total number of strokes. In this study, changes in stride speed or frequency were not evaluated, since the purpose was to find out whether IPC would have an effect on anaerobic power in a test of relatively short duration,

which basically depends on the ability to generate force in the shortest amount of time, as the case of tasks that require fast acceleration, quality required in several sports. The neural drive and increased stride rate induced by IPC can be expected to have a positive effect on tasks that require high force production, such as sprinting. However, no significant effect was seen in this experiment. A possible reason for the lack of significant findings in the current study could be the fact that a single training session with IPC was not sufficient to cause an accumulation of metabolites necessary to initiate the biochemical cascade associated with IPC (Downey et al., 2007).

In an animal model, IPC has been shown to improve maximal strength, contractility and endurance in skeletal muscle, in addition to preserving phosphocreatine, which are desirable effects of IPC treatment for events or submaximal tests. However, this phenomenon can spare the use of ATP, which would impair the performance result in a maximum effort test, as reported in a study with cyclists (Paixão et al., 2014). This finding may indicate that IPC treatment does not promote beneficial effects in maximal activities, lasting less than 10 seconds, but may improve performance in submaximal tests, lasting more than 10 seconds, as found in other investigations (Chen et al., 2022; Cheng et al., 2021; Slys et al., 2020; Wiggins et al., 2019). Perhaps this was the reason why this and other studies did not show significant results when applying IPC before maximal tests lasting less than 10 seconds (Cocking et al., 2021; Fostiak et al., 2022; Lindner et al., 2021).

Although this study did not find statistically significant differences in its results, improvements were observed in the mean maximum power ( $\Delta = 2.6\%$ ) that are compatible and even a little more expressive than previous studies, which demonstrated an increase of 1.6 % (De Groot et al., 2010; Lalonde & Curnier, 2015). However, the best result achieved in this study was when IPC was used with 100% of the auscultatory pulse, unlike other studies that used 220 mmHg or 50 mmHg > SBP during IPC. In this work, when a pressure of 220 mmHg was used, there was a decrease of 1.7% in the maximum power, when compared to the control group.

Perhaps, these differences in the results when using individualized pressure, having the auscultation pulse of each individual as a parameter, with those when using a standard pressure of 220 mmHg or pressures above SBP, are due to the fact that the sample here analyzed presented mean auscultatory pulse of the right leg ( $207.1 \pm 25.9$ ) and left leg ( $207.1 \pm 27.6$ ), lower than the standard value of 220 mmHg. It should also be noted that, although no subjective perception of pain or exertion table was used during the application of the IPC, many individuals complained of the pain caused by the compression cuffs when subjected to a pressure of 220 mmHg, which can have caused the drop-in income.

Some studies also used individualized pressure to determine the IPC protocol to be used during the intervention (Crisafulli et al., 2011; Fostiak et al., 2022; Jean-St-Michel

et al., 2011; Lalonde & Curnier, 2015; Lindner et al., 2021). However, most used pressures above the auscultatory pulse for vascular occlusion, also generating unnecessary discomfort for individuals (Crisafulli et al., 2011; Jean-St-Michel et al., 2011; Lalonde & Curnier, 2015; Lindner et al., 2021). While another used pressures of 60% and 80% of systolic blood pressure, which can reduce muscle discomfort caused by compression cuffs, however, not completely interrupting local blood flow (Fostiak et al., 2022).

Some of the possible limitations that this study presents are: not evaluating the physiological variables related to muscle contraction and energy production during and after the tests, in order to obtain parameters on the metabolic stress generated by the IPC; not having evaluated individuals with different characteristics and levels of physical conditioning, with the intention of discovering possible responders or non-responders to IPC and not considering different time intervals between the end of the IPC protocol and the beginning of the tests, in an attempt to identify the optimal time window for IPC utilization.

## Conclusions

Although the effect of IPC on anaerobic performance remains controversial, this study was probably the only one so far that used the measurement of the auscultatory pulse as a parameter to individualize the pressure used during treatment, before a maximum test. Even showing a subtle improvement in maximum, average and minimum powers in a 35-meter running test when 100% AP compression was used, IPC did not demonstrate a significant increase in the performance of trained individuals.

Therefore, it is estimated that only one session of treatment with IPC cannot be indicated as an effective method before performing tests or short-term exercises that use anaerobic power as the main component. However, an increase of 2.6% in maximum power can represent the difference between first and second place in a high-performance test. However, long-term studies, with the use of the method for longer periods, are necessary to elucidate the gaps that still exist with regard to its role in sports performance.

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