Acute effect of ischemic preconditioning on the performance of judo athletes

Authors' Contribution:
- **A** Study Design
- **B** Data Collection
- **C** Statistical Analysis
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Abstract

Background & Study Aim: Ischemic preconditioning may improve the physiological responses and performances of athletes in different sport modalities. Similarly, judokas could also benefit from augmented performance the day of a competition. However, until now, there is no evidence of the effect of ischemic preconditioning procedure (IPC) on the performance of these athletes. Thus, the objective of this study was the effect of IPC on the performance of judo athletes.

Material & Methods: The study involved 17 judo athletes (age 21.35 ±3.46 years, practice judo 8.94 ±3.88 years, height 1.73 ±9 m, body mass 69.34 ± 10,94 kg). In the first session, they answered the questionnaires, performed the anthropometric evaluation, the familiarization of the Special Judo Fitness Test (SJFT). The SJFT was used to evaluate the athletes' special physical fitness. In the second and third sessions, two experimental protocols were performed in a randomized and counterbalanced manner: a) IPC (3 cycles x 5 min ischemia at 220 mmHg / 5 min reperfusion at 0 mmHg) + SJFT and b) SHAM (placebo session: 3 cycles x 5 min ischemia at 20 mmHg / 5 min reperfusion at 0 mmHg) + SJFT. A 30-minute interval between the experimental protocols and the SJFT and 72 hours between the 2nd and 3rd sessions was observed.

Results: After performing IPC, judokas performed the highest number of throws in the series (A) and the total number of throws (A+B+C). The SJFT index also showed a significant improvement over the SHAM session.

Conclusions: IPC acutely improves specific performance of judo athletes and may therefore be used during competitions.

Key words: athletic performance • placebo • Special Judo Fitness Test • throws • vascular occlusion

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SHAM – placebo group session.

Uke – training partner who receives the blow.

Tori – the executor of a technique of the judo.

Ippon-seoi-nage – technique of projection applied with arm domain.

Ischemic – characterized by restriction of blood flow to peripheral tissues, organs or sectors of the body and reduced oxygen availability.

Reperfusion – the reestablishment of blood flow and the return of oxygenation to the tissues, organs and sectors of the body.

Placebo *noun* – a tablet that appears to be a drug but has no medicinal substance in it, used in tests and trials [66].

Technique– *noun* a way of performing an action [66].

Tactics – *plural noun* the art of finding and implementing means to achieve immediate or short-term aims [66].

Alatic – *adjective* used for describing metabolism that generates energy without producing lactic acid by using already-present stores of ATP [66].

Lactic testing – *noun* testing the level in lactic acid present in muscles at various stages during an activity [66].

Anaerobic capacity – *noun* the maximum amount of energy that can be produced by anaerobic metabolism [66].

Plyometrics – *noun* a free body movement exercise system that uses no weights or machines and emphasises callisthenics and repeated movements such as jumping high off the ground [66].

Ippon – one point. Achieved through the execution of a valid technique on the opponent [67].

INTRODUCTION

In the judo competition, motor skills are of great importance, such as aerobic endurance, anaerobic power and capacity, strength and flexibility. However, other factors must also be considered for the performance in this modality, such as the duration of the fight, the technical and tactical condition of the fighters and the subjective evaluation of the referee [1]. According to Franchini et al. [2], the technical-tactical aspect is essential to win in this modality. Therefore, besides the high technical-tactical level that an athlete must have to win, there is also the necessity of a good physical condition. The evaluation of the athlete is an essential step to verify their physical condition and, from this, the coach prescribes, periodizes and plans the training. In judo, one test in particular is typically used to assess the athlete's physical fitness, due to its practicality and objectivity; the Special Judo Fitness Test (SJFT). This test has been shown to discriminate the physiological profile and performance abilities of judokas [2, 3].

Coaches of different sports are always in quest of new training methods and techniques that may increase performance. In this aspect, ischemic preconditioning (IPC) has been used with athletes of different sport modalities with the objective of improving physical performance [4]. IPC consists of a short period of ischemia followed by a short period of reperfusion [5]. Ischemia is characterized by restriction of blood flow to peripheral tissues, organs or sectors of the body and reduced oxygen availability [6-8]. On the other hand, reperfusion is defined by the reestablishment of blood flow and the return of oxygenation to the tissues, organs and sectors of the body [9, 10]. Studies have shown that IPC improved the performance of athletes in some sports modalities such as running [11-15], swimming [16-19], rowing [20], diving [20], cycling [21-25], simulated competition indoor cycling [26].

Kjeld et al. [20] observed improved IPC performance in rowers and divers by reducing tissue oxygenation in the forearm and thigh, decreasing rowing time to 1000 meters, and increasing static and dynamic apnea in divers. Paradis-Deschênes et al. [24], when analysing the performance and physiological responses of IPC in cyclists in low and moderate altitude situations, showed that after IPC, the time for the 5 Km was lower, O_2 saturation increased and there was a reduction in the saturation index of the quadriceps tissues and the subjective perception of exertion. Marocolo et al. [16] analysed amateur swimmers after IPC application and found time reduction in the 100-meter swim-crawl test. Ferreira et al. [17] when analysing university swimmers, observed reduction in the total time of 6 sprints of 50 meters and improvement in aerobic and anaerobic performance. Sabino-Carvalho et al. [14] verified a delay in the time of exhaustion during the race, in men and women runners after the application of IPC. Lindsay et al. [26], when analysing the effects of IPC in the performance of a simulated indoor cycling competition, found improvements in aerobic and anaerobic capacity, with modulations in oxidative stress, activation of the immune system and synthesis of nitric oxide and catecholamines.

Hence, due to the positive evidence found in the aforementioned studies in several sports, the ease and low cost in the application of the manoeuvre and the knowledge gap found in the literature regarding the application of IPC in improving the performance of combat sports modalities.

The objective of this study was the effect of IPC on the performance of judo athletes.

MATERIAL AND METHODS

Participants

The study consisted of 17 judo athletes experienced in state competitions (gender 12 males and 5 females, age between 18 and 35 years old, mean 21.35 ±3.46 years old, height 1.73 ±0.9 m, body weight 69.34 ±10.94 kg, body mass index 23.10 ±2.49 kg/m², graduation 3 black belt, 10 brown belt and 4 purple belt, percentage of body fat 18.75 ±7.41%, practicing judo 8.94 ±3.88%

years). The exclusion criteria were smoker, supplementation with creatine and use of anabolic, caffeine, thermogenic and nitric oxide, be practicing judo less than two years, have less than three times a week in training. The data were collected in Petrópolis / RJ, Rio de Janeiro / RJ, Caxambu / MG and Juiz de Fora / MG.

This research complied with the norms of the National Health Council, Resolution 466/12 of 2012 for conducting research on human beings. The research project was approved by the Committee of Ethics in Research in Human Beings of the Federal University of Juiz de Fora (UFJF), opinion n°1.893.384.

Protocol

The experimental protocol was performed in three sessions with an interval of 72 hours between them. In the first session, the volunteers were clarified about the study procedures and after agreeing to sign the Informed Consent Term, they answered the structured questionnaire informing their personal data and the PAR-Q. Anamnesis and body weight evaluation were also performed using the OMRON HBF-514C scale, the stature with the portable stent of the Sanny® brand (Brazil) and with these data the body mass index (kg/m²). To estimate body density, a scientific adipometer (Cescorf®) was used and the percentage of fat calculated by means of the Siri equation [27]. Participants were briefed on the execution of the Special Judo Fitness Test (SJFT) and performed their familiarization with the test and the ischemic preconditioning procedure (IPC). In the second and third sessions, in a randomized and crossover design conducted by "*randomization.com*", the volunteers performed the following protocols: a) IPC + SJFT and b) SHAM (placebo session) + SJFT. In both protocols a time of 30 minutes between the IPC or SHAM and the SJFT was respected.

For IPC, the cuffs were positioned proximally around each thigh (inguinal region) and inflated to 220 mmHg for 5 minutes and deflated at 0 mmHg for 5 minutes of reperfusion. This procedure was repeated three times with the inflated and deflated cuffs totalling a time of thirty minutes of protocol accomplishment. The SHAM session also performed three cycles of 5 min. of ischemia/reperfusion, but the cuffs were inflated to 20 mmHg, causing no arterial or venous occlusion and ischemia. The total vascular occlusion was confirmed by Vascular Doppler (DV-600, Marted, Ribeirão Preto, São Paulo, Brazil) positioned in the tibial artery followed by auscultation of the blood flow. After this cessation the total occlusion was verified. The vascular occlusion technique was performed using a calibrated Premium Nylon sphygmomanometer calibrated with 51 cm by 14.5 cm clamps (WCS® - Brazil) [21].

The Special Judo Fitness Test (SJFT) was adopted as an indicator to evaluate the physical fitness of judo athletes [28]. The SJFT consists of three periods: 15s (series A), 30s (series B) and 30s (series C) separated by 10-sec intervals. During each period, the task of the performer (*tori)* was to perform the largest number of throwing attempts, using the *ippon-seoi-nage* technique, with two partners (*uke* A and *uke* B) of the same weight and six meters from each other while the *tori* was in the middle. Immediately after series C and 1 minute after the end of the test, the heart rate (HR) was measured with the Polar M400 (© 2014 Polar Electro Oy, FI-90440 KEMPELE, Finland). Figure 1 illustrates the SJFT.

Statistical analysis

Data were initially tabulated in Microsoft Office Excel 2007 software. They were then transcribed into SPSS® software version 20.0.0 (IBM® Statistics) in which the data were explored in descriptive and inferential statistics procedures. The general characteristics of the sample were presented as mean standard deviation (±). The data distribution and the homogeneity of variance were verified by the Shapiro Wilk and Levene test, respectively. The magnitude of the difference between the IPC + SJFT and SHAM + SJFT protocols was evaluated by the size of the Cohen's effect (d) defined as the difference between the means, divided by the mean of the standard deviation [29]. The effects were classified as small (0.20), moderate (0.50) or large (0.80). Mean changes in variables (between sessions) were reported with a 95% confidence interval. To test the possible differences between the IPC and SHAM sessions with respect to the (A), (B) and (C) series, the total number of throws (A + B + C), the HR immediately after and 1 minute after the SJFT and the SJFT index the paired *t-test* for single and paired samples was used. To evaluate the significance, $p \leq 0.05$ was adopted.

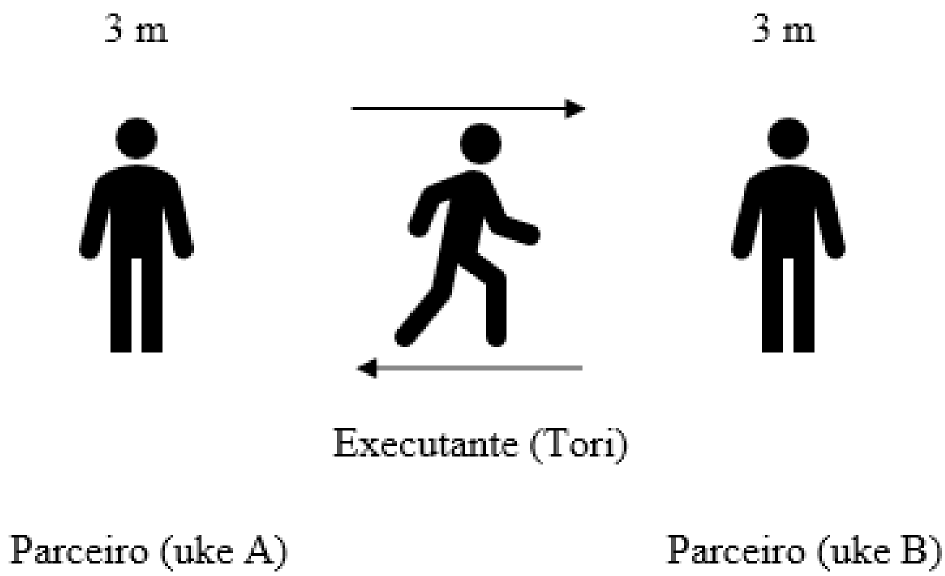

Figure 1. Distance and position of *tori* and *ukes* in SJFT.

Based on the results obtained, the physical fitness index of the SJFT was calculated:

$$\text{SJFT index} = \frac{\text{final FC (bpm)} + \text{FC1 min after the end of the test (bpm)}}{\text{total number of throws}}$$

RESULTS

After IPC athletes performed a larger number of throws in the SJFT series (A) (p = 0.004, d = 0.50, moderate effect) when compared to SHAM sessions. However, there was no differences between IPC and SHAM sessions in the series (B) (p = 0.056, d = 0.27, small effect) and (C) (p = 0.072, d = 0.036, small effect) of the SJFT (Figure 2).

Athletes also performed a greater total number of throws (A + B + C) in IPC vs. SHAM (p = 0.001, d = 0.37, small effect) (Figure 3).

Despite a greater performance in IPC than SHAM, the maximal heart rate recorded immediately (p = 0.79, d = 0.05, insignificant effect) and the recovery HR recorded 1 minute after the SJFT tests (p = 0.97, d = 0.00, insignificant effect) were not significantly difference between conditions (Table 1).

As a consequence, the SJFT index calculated from the performance and the cardiovascular load was affected by the condition (p = 0.001, d = 0.50, moderate effect). Performing IPC before the test reduced the SJFT index value (Figure 4).

DISCUSSION

The main findings of the current study are that the application of 3 cycles of IPC at 200mmHg results in a significant improvement in the performance of trained judo athletes in a maximal specific task. After IPC, judokas were able to complete significantly more throws during the SJFT under the same cardiovascular load (i.e., lower SJFT index). According to Franchini et al. [30], lower SJFT indexes result in a better competitive performance as a consequence of the increase in the number of throws that may be explained by the improvement of the speed and the efficiency of the blow, besides the increase of the alatic and lactic energy system.

The results of this research demonstrated that performing IPC 30 min before the SJFT significantly enhanced the number of throws during the first 15 sec of the test (IPC: 6.35 ±0.86 vs SHAM: 5.94±0.23, p≤0,05). This acute performance enhancement may have been related by a better blood perfusion, leading to a better extraction of oxygen and opening of the ATP-dependent K+ channels, increasing the energy stores after IPC [31, 32], which could increase

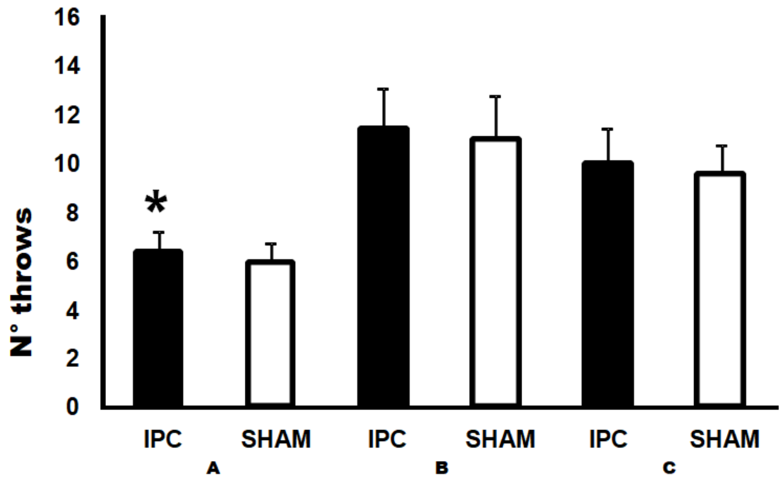

Figure 2. Results in particular SJFT sessions. Note: **A** number of throws in the A series; **B** number of throws in the B series; **C** number of throws in the C series; all expressed in units; *significant difference (p≤0.05) vs. SHAM for the A series.

the performance of fast-twitch muscle fibres during such a maximal task [33]. The study of Miarka et al. [34], carried out with eight brown belt judo athletes of state competitions, corroborates our results in relation to the increase in the number of throws in series A. In that study, four interventions were performed comparing the number of throws in series A, namely: a) SJFT (SJFT Control), b) SJFT performance after plyometric exercise (P + SJFT), c) before the SJFT (FM + SJFT) and exercise contrast (strength + plyometry) and SJFT (CE + SJFT). The authors reported a significant increase in the number of throws for the group P + SJFT (6.4 ±0.5) compared to the SJFT control (5.7 ±0.5). This increase in the SJFT series (A) suggests that plyometric exercise may improve neural stimulation in such a way that it increases the number of throws in the first 15 seconds of the test. This is probably related to the recruitment of the higher-threshold motor units (fast contraction) that are required when high-energy outputs are required [35]. Taken together, one that both may conclude that the plyometric and the IPC interventions improved performance by increasing the number of throws in the first 15 seconds. Thus, it appears that both

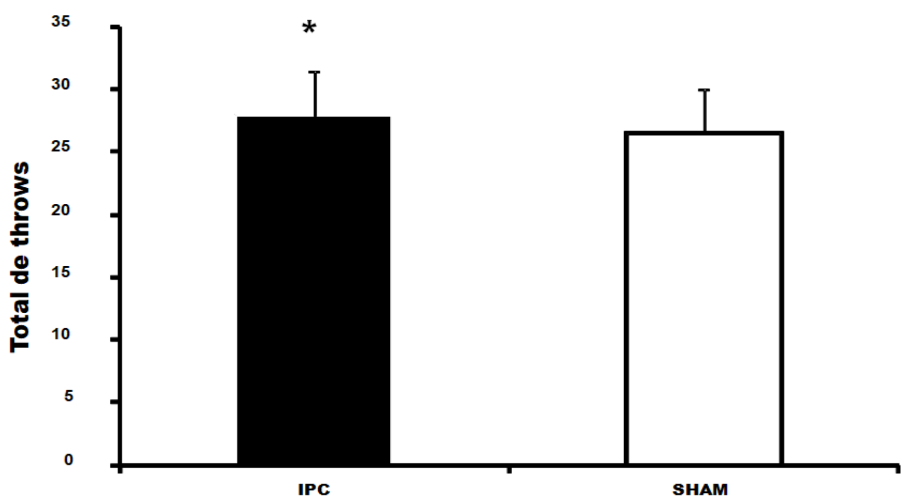

Figure 3. Total throws, e.g. the sum of series A, B and C (all expressed in units; *significant difference (p≤0.05) vs. SHAM).

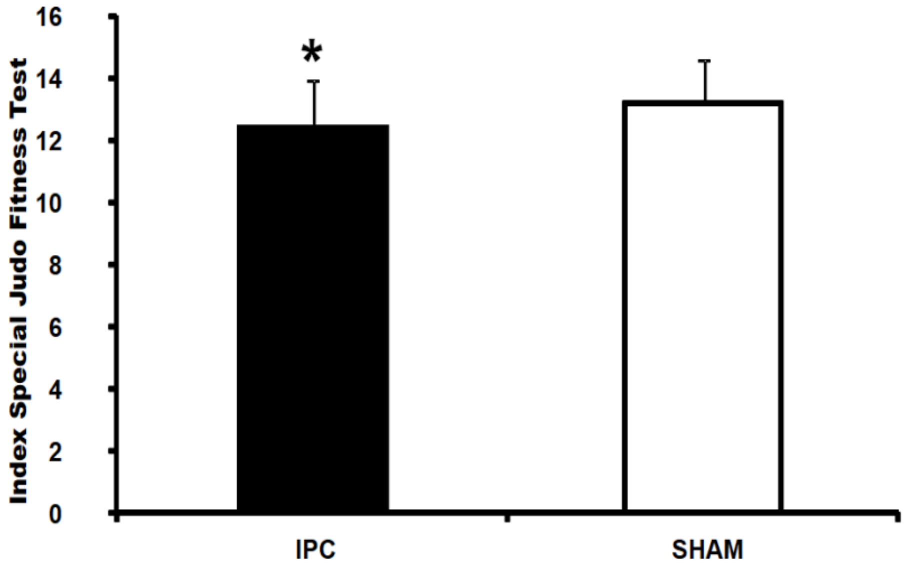

Figure 4. SJFT index expressed in units (*significant difference (p≤0.05) vs. SHAM).

plyometry and IPC may potentiate the anaerobic energy metabolism (ATP-CP, adenosine triphosphate and creatine phosphate, respectively), leading to a greater recruitment of type II fibres.

Other studies present the descriptive results regarding the throw number in the series (A). Wolska et al. [36], in a study conducted with Polish Olympic judokas, found an average of 5.3 ±0.47 throws in the SJFT (A) series. In the study by Hesari et al. [37], with Iranian athletes, the mean was 6.3±0.6 in the series (A). Sterkowicz and Franchini [38] compared Polish and Brazilian athletes of elite and beginners. The authors found significantly higher values in the SJFT (A) series for elite athletes (6.1 ±0.8) when compared to the group of beginners (5.6 ±0.5). Comparing these three studies with our results and those of Miarka et al. [34], it seems that both plyometrics and IPC have placed athletes tested at the same descriptive level as high performance athletes.

The alatic anaerobic system contributes to the technical actions during the combat of judo, considering that these techniques are executed within seconds. Thus, it seems that the effectiveness of the number of throws of the SJFT may concretely increase the possibility of success in combat. The actions of the blows require a very technical movement with maximum power that is mainly derived from the alatic anaerobic system [2, 39].

Master Jigoro Kano, when he created judo, established some principles, among them the *Seiryoku Zen'You*, which is based on the principle of maximum efficiency, that is, to perform the techniques with the maximum of efficiency and the minimum of energy expenditure. It is important to emphasize that in studies on activity time and pause in judo combat, actions lasting 20 to 30 seconds were verified, during which athletes try to carry out the footprint and the perfect *ippon*, interspersed with 10 seconds of interval [40, 41]. This protocol of 20 to 30 seconds of effort for 10 seconds of interval has the same dynamic and physiological request of the protocol of throws of the SJFT [42]. In view of this, it seems that intervention strategies such as IPC or plyometrics [34], before interval training situations or competitions, may favour the improvement of the use of the athletic energy system of athletes in short periods of time. This may be an interesting strategy to increase athletes' performance in the early stages of the competition.

The total number of throws of the SJFT (A + B +C) lasted approximately 1 minute and thirty-five seconds. Franchini et al. [43] suggest that for this test time there is a greater contribution of the anaerobic energy system. However, the study by Julio et al. [44], who evaluated simulated judo struggles for 1, 2, 3, 4 and 5 minutes, found a greater predominance of the oxidative system when compared to the anaerobic system to supply the energy cost of judo matches from the first minute of fight.

When comparing the total number of throws of SJFT (A + B + C), after IPC (27.82 ±3.70), we found a significantly higher value than SHAM (26.47 ±3.56). Research by Miarka et al. [34] did not find a significant increase in the total number of throws after plyometry intervention. In this manner, it seems that IPC contributed to the improvement of the use of the alatic and lactic energy system of judo athletes in our study. In the Miarka et al. [34], plyometrics only contributed to the improvement of the use of the alatic energy system, as a consequence of the higher number of throws in the first 15 seconds (series A) of the SJFT.

Some studies, such as those by Lisbôa et al. [18] in which swimmers were submitted to 4 cycles of 5-min ischemia at 180 mmHg in the arms and 220 mmHg in the thighs by 5-min reperfusion at 0 mmHg and performed a test of 50 meters 2 and 8 hours after application of the IPC, corroborate our findings and present favourable results for the application of IPC.

However, other studies differ from our findings. Barr [45], who carried out a study with Ohio undergraduates who underwent 3 cycles of 5-min of ischemia at 220 mmHg for 5-min of reperfusion at 0 mmHg in the thighs, and after 20 minutes, underwent Wingate anaerobic test. The authors concluded that there was no significant increase in anaerobic potency. Gibson et al. [46] when carrying out a study with rugby, soccer and hockey players applying IPC with 3 cycles of 5-min of ischemia at 220 mmHg for 5 min of reperfusion at 0 mmHg in the thighs 10 minutes before the maximum sprints of 10, 20 and 30 meters. The results also did not indicate significant improvements. One aspect to be highlighted that may elucidate these divergences was that the present study performed the SJFT 30 minutes after the application of the IPC manoeuvre. Salvador et al. [4], in its meta-analysis, warn that the effect of IPC has a time-dependency relationship that must be respected by suggesting an interval of at least 30 to 45 minutes between IPC and the protocol to be performed to obtain possible benefits by using this method. The aforementioned studies by Barr et al. [45] and Gibson et al. [46] did not observe the interval of at least 30 minutes after the application of IPC, before the tests of speed and Wingate. This may have significantly interfered with the results of the anaerobic characteristics tests [32, 47].

This time-dependence relationship may be explained as the reperfusion time after application of the IPC manoeuvre, before applying the test, or performing any exercise. This relationship is directly proportional, in other words, the longer the reperfusion time before starting the test, the greater the ergogenic effect of the IPC. This relationship was documented by Lisbôa et al. [18], when verifying the effects of IPC 1, 2 and 8 hours after the manoeuvre was applied on the performance of the 50-meter swim test. The results showed that 2 and 8 hours later generated significantly greater effects on performance when compared to 1-hour post application. In addition, previous studies [48-50], when evaluating muscle metabolism after IPC on the simultaneous consumption of ATP, PCr and Pi, and consequently pH, provided insight into the energetic state of the tissue and its ability to undergo phosphorylation oxidative. These showed an overcompensation of PCr together with increased ATP/ADP ratio [51]. This increase in PCr formation was observed during reperfusion four hours after IPC, indicating that energy metabolism was improved during the post-ischemic period [50]. Also, this PCr overcompensation is dependent on ATP/ADP ratio and mitochondrial creatine kinase [52], which causes increased oxygen demand in muscle, followed by increased oxidative metabolism in reperfused muscle tissue [50].

In studies with cyclists of different levels of training, IPC promoted an increase in performance in the proposed tests, that is, reduction of the time of accomplishment [21, 23, 26]. Additionally, the IPC in runners also caused a small performance improvement related to the sprint time [15]. In a survey conducted with rowers and divers, a reduction in rowing time and an increase in static and dynamic apnea time, respectively, were observed, indicating improvement in performance [20]. These studies confirm our findings that IPC improves the performance of judo athletes by increasing the number of throws in the SJFT. Although this study did not perform cellular analysis and accumulation of metabolites, we may speculate that the improvement in the number of throws after IPC can be associated with the release of several endogenous substances, such as adenosine, bradykinin, reactive oxygen species and opioids [4, 53,54]. The acute benefits of IPC in exercise performance have been attributed to vasodilation and improvement of oxygen supply associated with increased adenosine, activation of potassium channels in mitochondria, stimulating the release of ATP [21].

The improvement in the performance of judo athletes was represented by the reduction of the SJFT index. This result is a consequence of the increase in the total number of throws (A +B + C), after IPC. Cardiac frequencies collected immediately and 1 minute after SJFT did not show a significant difference between IPC vs. SHAM. The value of this index indicates the performance of the athlete, and the lower the value of the index, the better the result [30, 55]. In the IPC protocol, the judokas of this study presented the SJFT index (12.52 ± 1.41) as a "good" classification, with a significant difference for the SHAM session (13.20 ±1.43), which obtained the «regular», according to reference values of the table created by Franchini et al. [56].

The higher number of throws and, consequently, the improvement of the SJFT index were obtained through high intensity and short duration actions after the application of IPC. These actions are sustained by the anaerobic metabolism that maintains the energy supply through the ATP-CP and glucose pathways [57]. Energy from food degradation is used to produce ATP that is deposited in muscle cells and becomes a unique fuel for the production of mechanical energy during muscle contraction [58]. Part of the ATP replacement comes from the recovery of lactic acid, part is generated by the degradation in the form of CP and, lastly, the latter is stored in the muscle [59]. Thus, the increase in the number of throws may be explained by the fact that IPC can increase muscle efficiency in the use of ATP by preserving ATP [17, 54], by increasing the mitochondrial flow of electrons [14, 60] and by the enhancement of excitation-contraction coupling efficiency [61].

Another possible mechanism, proposed by Pang et al. [32] in an animal model, is related to a more efficient muscular contraction, caused by an ATP-sparing mechanism that, in turn, led to a higher rate of work, caused by an improvement in the excitation-contraction coupling system and higher pumping of Ca^{2+} ions. In addition, Crisafulli et al. [62] suggest a possible mechanism of fatigue reduction. Such a mechanism would be a spontaneous inhibition in type III and IV afferent fibres, increasing the central motor drive [63]. Opioids released after IPC [64] activate the nerve endings receptors of type III and IV afferent fibres during exercise [63, 65]. Therefore, it is possible that the IPC can alter the level of the activation threshold of the receptors, desensitizing the afferent fibres of groups III and IV. This phenomenon, in turn, increases the neural drive and the number of motor units recruited, hence increasing the anaerobic capacity and, consequently, the force production [62].

A limiting factor of this study was the sample being composed of athletes of different training levels, weight categories and technical levels. This happened because of the difficulty of obtaining a high quantity of athletes of the same level, in a single training team. Furthermore, the lack of physiological measures precludes from understanding the physiological mechanisms though which IPC enhanced performance. Future studies should therefore evaluate, at the very least, blood lactate concentration changes and VO_2 responses during testing to elucidate potential mechanisms.

CONCLUSIONS

The findings of this study suggest that IPC improved short-term performance for trained judo athletes during a specific judo physical test, with the same cardiovascular load, compared to the SHAM session. Since the SJFT test can distinguish athletes with different competitive levels and physical conditioning, our results suggest IPC may be used as a non-invasive, easy-to-use tool to enhance judo performance during training or a competition.

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