TITLE: Effect of ischemic preconditioning on acute recovery in elite judo athletes: a randomised, single-blind, crossover trial

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Authors: Bayram Ceylan¹, Hasan Basri Taşkın² and Jožef Šimenko³

¹ Department of Coaching Education, Faculty of Sport Sciences, Kastamonu University, Kastamonu, Türkiye
² Department of Physical Education and Sport Teaching, Faculty of Sport Sciences, Kastamonu University, Kastamonu, Türkiye
³ School of Life and Medical Sciences, University of Hertfordshire, Hatfield AL10 9EU, UK

Correspondence: Dr. Bayram Celaylan; Department of Coaching Education, Faculty of Sport Sciences, Kastamonu University, Kastamonu, Türkiye; Email: bceylan@kastamonu.edu.tr

Preferred running head: IPC recovery in elite judo athletes

ABSTRACT

Purpose: The ischemic preconditioning (IPC) method has been shown to aid the recovery processes; however, no studies have been done to assess its acute recovery usage in judo. This study aimed to examine the IPC of lower limbs effects on recovery after a judo-specific performance in highly trained male judokas and its applicability during a competition day.

Methods: A single-blind, placebo (PLA)-randomised crossover study was carried out on a sample of 13 elite male judo athletes. They undertook measurements of body composition, judo-specific task (special judo fitness test), jump performance, handgrip strength, lactate, blood pressure, perceived exertion and delayed onset of muscle soreness. IPC was applied on the legs and inflated 50 mmHg above the systolic blood pressure for 5 min and repeated three times for each leg, with 5 min of reperfusion. Two-way ANOVA with repeated measurements was used to determine changes between interventions and measurement times. Paired sample t-test and one-way repeated measures ANOVA was used to determine the difference among measurement times. Statistical significance was set at p<0.05. Results: IPC intervention resulted in a) decreased HR at 30 and 60 min during recovery (p=0.002; p=0.001), b) better CMJ performance at 60min (p=0.05), c) lower DOMS scores (p=0.006); d) maintained HGS compared to PLA. Conclusions: The present study revealed that IPC applied to judo athletes following judo-specific exercise resulted in better cardiovascular and neuromuscular recovery and could be a useful tool to enhance recovery during judo competitions break between preliminaries and final block.

Key Words: combat sports, SJFT, lower limbs, occlusion preconditioning, performance

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Number of Figures: 4
Number of Tables: 3
INTRODUCTION

Sports professionals constantly search for new training methods that may increase performance. In this context, ischemic preconditioning (IPC) has been used to improve physical performance. Additionally, IPC was shown to be useful in aiding the recovery processes via increased blood flow, activating the ATP-sensitive potassium channels, elevating adenosine levels, reducing the inflammatory response, lowering the increase in creatine kinase and muscle soreness. Furthermore, it was reported that a single application of IPC can improve strength recovery and reduce muscle swelling following exercise-induced muscle damage. IPC’s positive effects on recovery have been shown in very short (30s – 60s) or long (24h – 48h) periods with high-intensity efforts such as repeated sprints. However, to the best of our knowledge, no study has shown intermittent (30min – 60min) positive effects of recovery after an IPC protocol.

The mechanisms involved in these athletic improvements are likely related to both metabolic and vascular pathways, as it was reported that IPC acts through 3 main pathways (i.e., neuronal, humoral, and systemic response). It has been reported that IPC affects the physiological mechanisms where it slows the consumption of adenosine triphosphate (ATP) and phosphocreatine (PCr) energy by the muscle while increasing its tolerance during myocardial ischemia and the activation of adenosine receptors and nitric oxide secretion that cause vasodilation after reperfusion.

IPC in judo was found to be an effective strategy for improving performance through the increased performance of special judo fitness test (SJFT), decreased rate of perceived exertion, and increased anaerobic power. However, to the best of our knowledge, there hasn’t been any research in judo investigating the IPC use for acute recovery. IPC is a non-invasive, easy-to-use tool that was recommended to be used by athletes during tournaments to facilitate athletes’ readiness. Furthermore, it was also recommended to enhance judo performance during training or competition. The high-performance judo competition typically consists of two sessions, preliminaries and the final block, with an average break on Grands Slams and Grand-Prix between 1-2h. This time gap before the final block represents the optimum time when the IPC could be of greatest use in helping to speed up the recovery. Therefore, the acute loads should be removed quickly and athletes ready for the final block fights.

From the aforementioned, the study hypothesised that IPC could lead to a rapid reversal in recovery kinetics after a judo-specific performance. Therefore, this study aimed to examine the IPC of lower limbs’ effects on recovery after a judo-specific performance in highly trained male judokas and its hypothetical applicability during a competition day.

METHODS

Subjects

Thirteen elite male judo athletes from National Judo Team, regularly involved in high-level competitions, voluntarily participated in this study. Athletes’ characteristics can be found in Table 1. The sample size was justified by a priori analysis in G*power software (Version 3.1.9.7; Universität Kiel, Kiel, Germany) with a type I error of 0.05 and 80% statistical power. Analysis indicated that 12 participants are needed to observe significant, large-sized effects (Cohen’s d = 0.80). The participants trained twice daily for six days per
week and were free of musculoskeletal injuries. All athletes were black belts with 12.1 ± 0.1 years of judo experience. Measurements occurred during the preparatory period, and athletes were not engaged in weight loss. The study was conducted following the Declaration of Helsinki and was approved by the ……… University Clinical Research Ethics Committee (KAEK-143-17.01). Each athlete signed a written informed consent form.

**Design**

This was a single-blind (the athletes were blind to the protocol interventions), placebo (PLA)-randomised crossover study with three sessions separated by 7-day washout. Athletes were randomly assigned to either PLA or ischemic preconditioning (IPC) interventions using a random-numbers generator (www.randomization.com). Three measurements were performed: 1) anthropometrical measurements and familiarisation with tests; 2-3) sessions included the Special Judo Fitness Test (SJFT), post-exercise tests and PLA and IPC interventions, as presented in Figure 1.

Figure 1 about here

Physical, physiological, and perceptual markers were measured before (T1), immediately after (T2), and 30 min (T3) and 60 min (T4) after SJFT. Athletes were instructed not to participate in any training session during the washout period, to refrain from alcohol and caffeinated beverages 24 h prior to testing, and to maintain their daily dietary habits during the study. All measurements were performed in the same judo hall between 10:00 and 12:00 AM in controlled conditions (temperature: 23-25ºC; relative humidity: 45-60%).

**Body composition**

The body height was measured in a standing position barefoot to the nearest 0.1 cm using a stadiometer (Seca 213, Germany). Body composition was determined using a bioelectrical impedance (BIA) device (Tanita, BC-545, Tokyo, Japan). Measurements were performed in the standing position, barefoot, with legs and thighs not touching. The skin and the electrodes were precleaned and dried before the measurement. The general measurement guidelines for BIA were followed: 1) the measurements were taken in the morning (between 10 AM and 12 AM); 2) the respondents were asked to abstain from large meals after 9 PM the evening before the test, and on the day of the measurement they neither ate nor drank before the end of the procedure; 3) participants were asked to refrain from extreme physical exertions 24 hours prior to measuring, and last training should have been performed at least 12 hours prior to testing; 4) the respondents did not consume alcohol 48 hours before the measurement; 5) the respondents were asked to empty their bowels and bladder at least 30 min before the measurement; 6) the respondents were in the standing position for at least 5 minutes before the measurement to redistribute the tissue fluids; 7) hands were not touching the torso and were placed 15 cm laterally from the body.

The high test-retest, reliability and accuracy of BC-545 were reported with ICC=0.99 and correlations with DXA $r > 0.9$. Variables of body mass, body fat percentage, muscle mass, and body fat percentage were recorded for each athlete.

**Judo specific performance**

Judo-specific performance was measured with a judo-specific task named the Special Judo Fitness Test (SJFT). This judo-specific task simulated similar physiological responses to a judo match and reported high reliability (ICC=0.88). Two judokas (uke) were positioned at a distance of 6 m from each other, and test executor (tori) was positioned 3 m from the
judokas. The procedure was divided into three sets – 15 s (A), 30 s (B) and 30 s (C) – with 10-s rest intervals between them. The aim was to throw the uke’s using the ippon-seoi-nage technique in each set as many times as possible. Performance was determined based on the total throws completed during the three sets (A + B + C). The heart rate (HR) was measured with an HR monitor (Seego, Realtrack Systems, Spain) immediately after the test and then 1 min later to calculate the index using the following equation:

\[
\text{Index (bpm throws}^{-1}) = \frac{\text{final HR (bpm)} + \text{HR at 1 min after the test (bpm)}}{\text{Number of throws}}
\]

\[\text{Handgrip strength}\]

The handgrip strength was measured in a standing position, with starting hand randomly chosen by athletes, alternating three times on each side. A handgrip dynamometer (TKK 5401, Takei, Japan) was used with 1-min intervals between attempts and 30 seconds between hands during PLA and IPC interventions. Athletes were instructed to generate the greatest force during 3-5 seconds with fully extended elbow and self-selected wrist and leg positions. The highest value measured for each side was used in further analysis.

\[\text{Jump Performance}\]

The test started with a 5 min warm-up composed of calisthenics and ballistic movements. This was followed by a CMJ demonstration. The participants were instructed to use fast-counter movement to a self-selected depth, followed immediately by explosive upward propulsion to reach maximal jump height movement with the same take-off and landing positions. Two familiarisation trials were performed prior to testing. Each participant performed three maximal CMJs with a 1 min break. The same researcher recorded the jumps with a mobile phone fixed on a tripod (iPhone Xs; Apple, Cupertino, CA, USA) at a sampling rate of 240 Hz, using the My Jump 2 App, set 1.5 meters apart from the athlete. Maximum jump height was taken into further analysis. Application has been shown to be a reliable tool to measure jump performance (ICC = 0.948, TEM = 1.15, CV% = 10.096).

\[\text{Physiological responses}\]

Resting blood lactate (LA) and heart rate (HR) of the athletes were measured following a 30 min rest in the supine position. Immediately, 30 and 60 minutes following SJFT application LA and HR was measured again. LA was measured with a lactate device (Edge Blood Lactate Monitoring System, ApexBio Inc., Taipei City, Taiwan) by the same experienced researcher. Before each measurement, the site was cleaned with alcohol and dried with cotton, obtaining a 0.3 µl blood sample from the fingertip of the middle finger. HR was monitored with an HR monitor (Seego, Realtrack Systems, Spain).

Blood pressure (BP) was monitored with Omron M7 Intelli (Germany) before and 60 min after the experiment.

\[\text{Perceptual scales}\]

After the SJFT, perceived exertion (RPE) was rated on a 15-point scale, ranging from 6 (very light) to 20 (very hard). Also, perceived muscle soreness (PMS) of the lower limbs was measured immediately and 60 minutes following SJFT with a scale from 0 (absence of soreness) to 10 (very intense soreness).

\[\text{Recovery protocol}\]
IPC was conducted in the supine position, according to Daab et al.\textsuperscript{4}, using a pneumatic cuff (77.0 cm length x 21.5 cm width) (Reister, 5255, Germany). The cuff was placed around the upper thigh and inflated to a pressure of 50 mmHg above the systolic blood pressure to inhibit arterial flow for 5 min. Cuff inflation generally took 15–25 s. Occlusion time started to be counted after the target pressure was achieved. This procedure was repeated three times for each leg, with each episode interspersed with 5 min of reperfusion. In PLA, a pressure of 20 mmHg was applied during the occlusion period. The blood flow of the anterior tibial artery was checked throughout the IPC using auscultation to confirm the occlusion. The occlusion was achieved in all participants. The mean pressure was 180±12 mmHG for IPC and 20 mmHG for PLA, respectively.

**Statistical analysis**

Statistical analysis was performed using JASP software (0.15.0.0 Version, The Netherlands). The Shapiro-Wilk test and descriptive methods using skewness and kurtosis coefficients were used to check for the normality of data. Descriptive statistics and 95% confidence intervals (CI) were used to present subjects' characteristics. Two-way ANOVA with repeated measurements (intervention x time) was used to determine changes in HR (2 x 4), LA (2 x 4), PMS (2 x 2), HGS right and left (2 x 3), CMJ (2 x 3) and BP (2 x 2) between interventions and measurement times. Partial eta squared ($\eta^2_p$) was calculated to determine the effect size, using the 0.0099, 0.0588, and 0.1379 considered as small, medium, and large effect sizes.\textsuperscript{25} In case of significant differences between interventions, paired sample t-test was used, while one-way repeated measures ANOVA was used to determine the difference among measurement times. Cohen’s d for paired sample t-test was automatically provided by JASP software and classified as 0.2 (small), 0.5 (medium) and 0.8 (large).\textsuperscript{26} Statistical significance was set at $p<0.05$.

**RESULTS**

The descriptive data for mean baseline participant characteristics can be found in Table 1.

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There was no significant difference in SJFT throw numbers, SJFT index and RPE between interventions ($p>0.05$). The data regarding SJFT variables can be found in Table 2. Athletes rated RPE as 14.9 ± 2.1 during PLA intervention and 15.3 ± 1.8 during IPC intervention ($p=0.05$, d=−0.5 [medium]).

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<th>Table 2 about here</th>
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RPE responses following SJFT performances before IPC and PLA intervention were similar ($p=0.037$, Cohen’s d=−0.651). Athletes classified the exercise intensity as 15.0±2.1 before PLA and 16.2±1.8 before IPC intervention.

The results of the two-way ANOVA presented that there was a significant interaction of intervention and time factors ($F_{3.36}=5.50$, $p<0.02$, $\eta^2_p=0.31$, ES= Large) for HR. There was also a significant main effect of intervention and time separately ($F_{1.12}=5.24$, $p=0.04$, $\eta^2_p=0.30$, ES= Large; $F_{3.36}=5.50$, $p<0.001$, $\eta^2_p=0.96$, ES= Large). When paired sample t-test was applied, there was significant difference in HR$_{T_1}$ (PLA=64.7±7.4, IPC=59.4±6.1, $p=0.02$, $d=0.7$ [medium]), HR$_{T_3}$ (PLA=87.1±10.9, IPC=73.3±11.6, $p=0.01$, $d=1.1$ [large]) and HR$_{T_4}$ (PLA=80.5±9.5, IPC=65.7±10.2, $p<0.001$, d=0.5 [medium]) while there was no difference in
HR values between interventions following SJFT application (HR_{T2}) (PLA=163.9±31.6, IPC=172.6±12.5, p=0.31, d=0.3 [small]). According to one-way repeated measures ANOVA results, there was a significant difference in HR among all measurement times for both PLA and IPC conditions (F_{3,36}=92.87, p<0.001, \eta^2_p=0.89, ES=Large; F_{3,36}=755.29, p<0.001, \eta^2_p=0.98, ES=Large, respectively). Figure 2 presents HR changes in both interventions.

According to two-way ANOVA results, there was no significant interaction of intervention and time factors on LA (F_{1,122}= p<0.16, \eta^2_p=0.15, ES=Large). While there was significant effect of time factor (F_{3,36}=119.4, p<0.001, \eta^2_p=0.90, ES=Large), there was no significant effect of intervention (F_{3,36}=1.94, p<0.14, \eta^2_p=0.14, ES=Large). The results of one-way repeated measures ANOVA revealed a significant main effect of time in LA in both PLA (F_{3,36}=59.0, p<0.001, \eta^2_p=0.83, ES=Large) and IPC groups (F_{3,36}=129.82, p<0.001, \eta^2_p=0.92, ES=Large). LA changes between interventions can be found in Figure 3. As highlighted with percentage changes in Figure 3, LA following IPC intervention decreased by 11.6% more than PLA.

There was a significant interaction of intervention and time on HGS\textsubscript{right} (F_{2,24}=5.14, p=0.014, \eta^2_p=0.30, ES=Large) which indicates differences in HGS\textsubscript{right} between both groups at different measurement times. However, there was no significant effect of intervention and time factors separately (F_{1,12}=0.48, p=0.499, \eta^2_p=0.03, ES=Small; F_{2,24}=1.20, p=0.318, \eta^2_p=0.09, ES=Small, respectively). In contrast to HGS\textsubscript{right}, there was no significant interaction of intervention and time factors on HGS\textsubscript{left} (F_{2,24}=5.83, p=0.061, \eta^2_p=0.20, ES=Small). Moreover, there was no significant effect of intervention and time factors on HGS\textsubscript{left} separately (F_{1,12}=0.45, p=0.513, \eta^2_p=0.03, ES=Small; F_{2,24}=2.00, p=0.156, \eta^2_p=0.14, ES=Large, respectively). Changes in athletes’ HGS\textsubscript{right} and HGS\textsubscript{left} performances can be found in Table 3.

According to two-way ANOVA results, there was a significant interaction of intervention and time on CMJs (F_{2,24}=5.34, p=0.012, \eta^2_p=0.30, ES=Large). Nevertheless, there was no main effect of intervention factor on CMJs (F_{1,12}=0.17, p=0.685, \eta^2_p=0.01, ES=Small) while there was a significant main effect of time factor (F_{2,24}=3.69, p=0.04, \eta^2_p=0.23, ES=Large). When a one-way ANOVA was carried out, there was a significant difference among measurement times during PLA intervention, i.e. T_1, T_2 and T_4, (F_{2,24}=3.55, p=0.04, \eta^2_p=0.23, ES=Large) and also during IPC intervention (F_{2,24}=4.77, p=0.018, \eta^2_p=0.28, ES=Large). Athletes presented better CMJ performance at 60 min following IPC intervention compared to PLA (p=0.013). CMJs performance of the athletes is presented in Figure 4.

There was no significant interaction of intervention and time on PMS (F_{1,12}=0.31, p=0.584, \eta^2_p=0.026, ES=Medium). There was a main effect of intervention factor on PMS (F_{1,12}=5.55, p=0.002, \eta^2_p=0.57, ES=Large), there was also a significant main effect of time factor (F_{1,12}=93.16, p<0.001, \eta^2_p=0.88, ES=Large). When paired sample t-test was carried out to see differences between interventions, there was no significant difference in PMS\textsubscript{T2}
Furthermore, the SJFT index achieved by study participants with dyad 11; however, previous research has shown that HGS decreased in the middle of the competition 12. In addition, IPC was shown to delay the development of fatigue during handgrip exercise and prolonged time to task failure 33. This information is essential for judo, where elite athletes have 5-7 fights 31 if they want to be in the contest for medals and therefore, maintaining HGS is of great importance. IPC use between the preliminary and final
block of the competition could help maintain high initial HGS, delay the development of
fatigue and speed up the recovery.

The IPC impacts HR with faster heart rate recovery (HRR) after exercise \(^{10}\) with
significant HRR at the 30s \(^{29}\) and 60s \(^{10}\). Only one IPC study from sub-elite rugby players
demonstrated no acute impact on HRR after 1h \(^{34}\). Therefore, the current study is the first one
using IPC for acute recovery that reported significantly higher HRR in an intermittent period
at 30 min (PLA=87.1±10.9, IPC=73.3±11.6, \(p=0.01, \ d=1.1 \) [large]) and 60 min
(PLA=80.5±9.5, IPC=65.7±10.2, \(p<0.001, \ d=0.5 \) [medium]) after high-intensity exercise. It
was discussed that IPC-induced acceleration of HRR 30min and 60min could be explained by
faster cardiac vagal reactivation as studies showed that HRR in short- and long-term is largely
determined by cardiac vagal reactivation post-exercise, with a negligible influence of the
sympathetic branch \(^{10}\). It was also suggested that a greater increase in parasympathetic activity
is an important factor in HRR after IPC \(^{10}\).

Lactate levels when IPC was applied before exercise have been reported to attenuate
blood lactate accumulation \(^{35}\), or no significant effect was noted \(^{5,10}\). The present study's LA
levels align with the literature, as LA levels did not significantly differ between conditions.
However, a decreasing trend in LA by 11.6% in IPC intervention compared to PLA was
noted. This could still have practical implications for judo recovery as more than 10% lower
LA levels entering a final block fights could have an essential impact on judokas
performance. PMS scale after 60 min presented a significantly lower score after the IPC
intervention vs PLA (PLA=3.6 ± 1.2, IPC=2.8 ± 0.8, \(p=0.006, \ d=0.9 \) [large]). Similar findings
have been reported in studies conducted on physically active men \(^{30}\) and soccer players \(^{4}\).
Additionally, no significant changes in RPE and BP were noted.

Literature noted that post-exercise Ischemic preconditioning (PEIPC) protocols for
recovery had not been standardised yet. Therefore, it was recommended that a higher dose of
PEIPC should be administered in highly trained subjects to elucidate beneficial effects. We
recommend future studies exploring higher than > 50 mmHg above SBP in elite athletes with
a 60-90 mmHg above SBP. Additionally, the higher IPC pressure could be combined with a
shorter duration. The current study protocol targeted the break between preliminaries and the
final block (30-min per leg; 3 x 5-min occlusion and 5-min reperfusion). However, shorter
protocols (e.g., 2 x 2–3 min occlusion/reperfusion), which could be more time-efficient (e.g.,
8–12 min)\(^{36}\) and performed bilaterally, should be investigated. This would hypothetically
mean that IPC could be applied between fights where breaks could vary from 10min
(minimum break between fights by IJF rules) \(^{16}\) to 30min - 45 min, varying on weight
category, the number of competitors and the format of the competition.

It was reported that the use of IPC in various forms on healthy individuals carries a
small risk as it produces trauma to major vessels and direct stress to the target organ/part of
the body \(^{37}\). It was also reported that it might potentially increase the risk for deleterious
cardiovascular events (e.g., cardiac arrhythmia, myocardial infarction) \(^{38}\) and excessive
venous compression could elevate venous pressure, which could damage the valves in veins
and lead to chronic venous insufficiency \(^{39}\). Nonetheless, the IPC has been shown to attenuate
Platelet-Mediated Thrombosis \(^{40}\) and the data from numerous research suggest that it is a
simple, safe, and feasible method capable of improving aerobic and anaerobic performance
\(^{1,41–43}\).

As the literature on IPC recovery is limited to team sports, this study sheds light on its
acute effects during recovery in combat sports, specifically in judo, where athletes have
limited time for recovery between fights. Another strength of this study is that the participants
were high-level athletes. As for limitations, our participants were in the preparation period; however, a high SJFT index was achieved, demonstrating the participants’ good physical fitness. There was no SJFT after 1h of IPC recovery, which could better imitate the competition environment. Therefore, further studies should investigate IPC in real-world or simulated competition. Also, BP kinetics was not measured, which could give a better insight into the IPC mechanisms. In addition, previous studies have not investigated IPC usage on acute recovery in elite judo athletes, limiting the findings' discussion. Additionally, further studies connected to IPC performance in athletic populations should also include parameters such as heart rate variability (HRV) to analyse vagal reactivation or/and the use of Muscle Oxygen Monitors to monitor oxygen levels in the muscles before, during and after the intervention as this would give a broader understanding of IPC effects.

PRACTICAL APPLICATION

The IPC in judo could be a valuable tool for coaches and athletes to enhance recovery during breaks between preliminaries and final blocks in judo competitions, as IPC is an affordable and widely available method. It could also be used in high-intensity randori training camps in between training sessions to speed up recovery and in other combat sports.

CONCLUSION

The current study demonstrated that IPC could be beneficial for improved recovery between judo competition blocks (preliminary and final). Furthermore, the results of this study were the first to show IPC’s positive intermittent acute recovery in 30 and 60 min after the intensive sport-specific exercise. However, further studies should investigate the influence of shorter but higher-pressure IPC protocols that could be used in between fights where the breaks are shorter and unpredictable.

ACKNOWLEDGEMENTS

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REFERENCES


Table 1. Baseline characteristics of participants (Mean ± SD) with confidence intervals (95% CI)

<table>
<thead>
<tr>
<th>Variables</th>
<th>Mean ± SD</th>
<th>95% CI</th>
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<tbody>
<tr>
<td>Age (years)</td>
<td>18.6 ± 0.9</td>
<td>18.1 – 19.2</td>
</tr>
<tr>
<td>Body mass (kg)</td>
<td>72.4 ± 7.1</td>
<td>68.1 – 76.7</td>
</tr>
<tr>
<td>Height (cm)</td>
<td>1.74 ± 0.05</td>
<td>1.71 – 1.77</td>
</tr>
<tr>
<td>Body fat percentage (%)</td>
<td>7.6 ± 2.4</td>
<td>6.1 – 9.0</td>
</tr>
<tr>
<td>Fat-free mass (kg)</td>
<td>63.4 ± 4.9</td>
<td>60.5 – 66.4</td>
</tr>
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Table 2. Athletes' SJFT throw numbers before PLA and IPC interventions

<table>
<thead>
<tr>
<th>Variables</th>
<th>PLA</th>
<th>95% CI</th>
<th>IPC</th>
<th>95% CI</th>
<th>t</th>
<th>P</th>
<th>ES</th>
</tr>
</thead>
<tbody>
<tr>
<td>SJFT A (throws)</td>
<td>6.0 ± 0.4</td>
<td>5.7-6.2</td>
<td>6.2 ± 0.4</td>
<td>5.9-6.5</td>
<td>1.361</td>
<td>1.199</td>
<td>0.377</td>
</tr>
<tr>
<td>SJFT B (throws)</td>
<td>11.6 ± 0.7</td>
<td>11.2-12.0</td>
<td>11.4 ± 0.9</td>
<td>10.9-11.9</td>
<td>0.693</td>
<td>0.502</td>
<td>0.192</td>
</tr>
<tr>
<td>SJFT C (throws)</td>
<td>10.5 ± 0.8</td>
<td>10.0-11.0</td>
<td>11.0 ± 0.8</td>
<td>10.6-11.5</td>
<td>1.620</td>
<td>0.131</td>
<td>0.449</td>
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<tr>
<td>SJFT A HR</td>
<td>154 ± 17</td>
<td>144-164</td>
<td>152 ± 15</td>
<td>144-161</td>
<td>0.766</td>
<td>0.458</td>
<td>0.213</td>
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<tr>
<td>SJFT B HR</td>
<td>169 ± 15</td>
<td>160-178</td>
<td>169 ± 14</td>
<td>161-178</td>
<td>0.116</td>
<td>0.910</td>
<td>0.032</td>
</tr>
<tr>
<td>SJFT C HR</td>
<td>171 ± 12</td>
<td>164-179</td>
<td>173 ± 13</td>
<td>165-180</td>
<td>0.899</td>
<td>0.386</td>
<td>0.249</td>
</tr>
<tr>
<td>SJFT HR 1min</td>
<td>149 ± 10</td>
<td>143-155</td>
<td>146 ± 12</td>
<td>145-153</td>
<td>0.945</td>
<td>0.363</td>
<td>0.262</td>
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<tr>
<td>SJFT index</td>
<td>11.4 ± 0.8</td>
<td>10.9-11.9</td>
<td>11.1 ± 0.8</td>
<td>10.6-11.6</td>
<td>1.361</td>
<td>0.198</td>
<td>0.378</td>
</tr>
</tbody>
</table>

Legend: SJFT – special judo fitness test; PLA – placebo protocol; IPC – ischemic preconditioning protocol; CI – confidence interval; HR – heart rate; ES – Effect size as Cohen's d.
Table 3. Handgrip strength performance of the athletes during PLA and IPC interventions

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<thead>
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<th>Variable</th>
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<tbody>
<tr>
<td></td>
<td>PLA</td>
<td>95% CI</td>
<td>IPC</td>
<td>95% CI</td>
</tr>
<tr>
<td></td>
<td>(n=13)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>HGSright</td>
<td>T1</td>
<td>46.9 ± 8.0 (42.2-51.8)</td>
<td>44.8 ± 4.9 (41.9-47.8)</td>
<td></td>
</tr>
<tr>
<td>(kgf)</td>
<td>T2</td>
<td>43.2 ± 3.8 (41.6-46.2)</td>
<td>45.7 ± 4.5 (43.1-48.5)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>T4</td>
<td>43.8 ± 3.7 (41.6-46.0)</td>
<td>45.7 ± 4.7 (42.9-48.6)</td>
<td></td>
</tr>
<tr>
<td>HGSleft</td>
<td>T1</td>
<td>46.1 ± 5.5 (42.8-49.5)</td>
<td>45.6 ± 5.2 (42.5-48.8)</td>
<td></td>
</tr>
<tr>
<td>(kgf)</td>
<td>T2</td>
<td>44.8 ± 4.5 (42.0-47.6)</td>
<td>44.8 ± 4.7 (42.0-47.7)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>T4</td>
<td>44.8 ± 5.6 (41.5-48.3)</td>
<td>46.0 ± 4.9 (43.0-49.0)</td>
<td></td>
</tr>
</tbody>
</table>

Legend: T1= Rest; T2= 0 min; T4= 60 min; HGS – hand grip strength

Figure 1. Design of the experimental protocol
**Figure 2.** Heart rate changes in PLA and IPC interventions

**Figure 3.** LA changes in PLA and IPC interventions.
Figure 4. The CMJ performance in PLA and IPC interventions.