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# **Intermittent cooling during judo training in a warm/humid environment reduces autonomic and hormonal impact.**

**Running head:** Effects of Intermittent Cooling in Judo Training

Eduardo Carballeira,<sup>a</sup> José Morales,<sup>b</sup> David H. Fukuda,<sup>c</sup> María L. Granada,<sup>d</sup> Vicente Carratalá-Deval,<sup>e</sup> Alfonso López Díaz de Durana,<sup>f</sup> Jeffrey R. Stout<sup>c</sup>

a. Performance & Health Group, Department of Physical Education and Sport Sciences, University of A Coruña, Oleiros, Galicia, Spain

b. Faculty of Psychology, Education Sciences and Sport Blanquerna, Ramon Llull University, Barcelona, Spain

c. Institute of Exercise Physiology and Wellness, University of Central Florida, Orlando, Florida, United States of America

d. Clinical Biochemistry Department, University Hospital Germans Trias i Pujol, Autonomous University of Barcelona, Barcelona, Spain

e. Faculty of Physical Activity and Sports Science, University of Valencia, Valencia, Spain

f. Faculty of Physical Activity and Sports Science. Polytechnic University of Madrid, Madrid, Spain

## **Corresponding Author:**

Eduardo Carballeira, PhD

Performance & Health Group, Department of Physical Education and Sport, Faculty of Sport Sciences and Physical Education, University of A Coruña, Avenida Ernesto Che Guevara, 121, Oleiros, Galicia, Spain

Tel: +34 667 896 263

Email: [educarballeira@gmail.com](mailto:educarballeira@gmail.com)

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**Corresponding Author:**

Eduardo Carballeira, PhD

Performance & Health Group, Department of Physical Education and Sport,  
Faculty of Sport Sciences and Physical Education, University of A Coruña,  
Avenida Ernesto Che Guevara, 121, Oleiros, Galicia, Spain

Tel: +34 667 896 263

Email: [educarballeira@gmail.com](mailto:educarballeira@gmail.com)

# Intermittent cooling during judo training in a warm/humid environment reduces autonomic and hormonal impact.

## ABSTRACT

The purpose of this study was to identify the effects of superficial cooling on physiological responses while training in a warm, humid environment during an international judo training camp. Sixteen judokas (8 women and 8 men) participated in the experiment. Four high-level women and four men were randomly assigned to wear a cooling vest (vest group, VG) during the recovery periods within a training session (i.e. 8 bouts of 5 min fighting with 5 min rest) and up to 10 min after the session, while the remaining athletes in the control group (CG) trained without the use of any cooling aids. No differences between groups were reported in well-being prior to the session or in perceived fatigue following the session. The temperature was increased after the training session ( $p=0.02$ ) without significant differences between groups; however, CG demonstrated a moderate effect size ( $ES=0.95$ , 90% confidence interval [CI] from 0.09 to 1.82; probability of superiority [PS]=74.9%) in contrast to the small effect for VG ( $ES=0.28$ , 90% CI from -0.55 to 1.11; PS=57.9%). There were time  $\times$  group interactions for heart rate variability (HRV; lnRMSSD) ( $p<0.01$ ; VG vs. CG, PS=79.0%) and the dehydroepiandrosterone-cortisol ratio (DHEA/C ratio) ( $p=0.04$ ; VG vs. CG, PS=99.9%). VG preserved the cardiac autonomic control ( $p>0.05$ ;  $ES=-0.06$ , 90% CI=-0.88 to 0.76; PS=51.7%) compared to the large decrement of CG ( $p<0.05$ ;  $ES=-1.18$ , 90% CI=-2.07 to -0.29; PS=74.9%). Furthermore, VG showed an increase of DHEA/C ( $p<0.01$ ) from pre- to post-session based on a moderate decrease of cortisol ( $p>0.05$ ;  $ES=-0.67$ , 90% CI=-1.52 to 0.17; PS=68.2%) with a concomitant small increase of DHEA ( $p>0.05$ ;  $ES=0.46$ , 90%CI=-0.38 to 1.29; PS=62.7%). Conversely, the control group showed a moderate effect for increased DHEA and a small effect for increased cortisol following training. No significant interactions or main effects were shown for isometric handgrip values. Cooling vests diminished the cardiovascular strain and hormonal

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4 impact of the judo training session in high-level athletes and may be considered for recovery  
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6 purposes during exercise in warm/humid environments.  
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11 **Key Words:** cooling vest; heart rate variability; hormones; isometric handgrip; perceived  
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## INTRODUCTION

Judo is a high-intensity intermittent sport that places great demands on the neuromuscular and cardiovascular systems. Several studies have reported decrements in strength and power (11,13) and significant alterations in heart rate values after simulated judo fights (11,17). The high level of effort achieved during judo matches has been found to disturb biochemical and hormonal homeostasis (12). This homeostasis disturbance likely originates in the high intensity grip fighting required by judo athletes to gain control of their opponent before attacking. Judoka spends from 49% to 58% of the activity period during competition engaged in grip contest (32). The standard judo uniform (i.e. judogi) is made primarily of cotton and is required to have a weight between 650 and 750 g/m<sup>2</sup> (Judogi Regulation, application of 1st April 2015, International Judo Federation). When combined with harsh ambient conditions, these characteristics put judo athletes at risk for heat-related-illness (heat cramps, heat syncope, heat exhaustion, heat stroke, hyponatremia, dehydration), especially during training (24).

Judokas perform between 5 and 7 fights in a tournament with fewer high-intensity efforts than when training. Furthermore, data reported in the literature indicate that physical stress is greater during training sessions than during competitions (48). High-level judokas attend international training camps organized by the International Judo Federation during which they perform a large number of sparring bouts (i.e. randori) with substantial external load requirements (34). In a recent study, Morales et al. (34) employed an individualized and specific method of external load quantification during an international training camp which was shown to be highly related to various methods of internal load quantification (i.e. perceived-based and heart rate –based methods) as well as  $VO_{2max}$  obtained in a maximal incremental test and judo-specific testing performance.

Heat production during intense exercise is up to 20 times greater than at rest and can increase at a rate of 1°C every 5 min in the belly of the quadriceps following the initiation of high-intensity exercise (36). Heat production is directly proportional to exercise intensity, thus strenuous exercise may result in increased body temperatures, which are compounded when exercise is performed in hot-humid conditions (3). The most prestigious judo competitions are disputed during summer (p.e. World Championships and Summer Olympic Games), therefore judokas may train and compete in warm/hot environments with high relative humidity during the international circuit period. Often before and after these competitions, judokas participate in training camps where they perform high external loads in an uncompensable environment leading to the accumulation of fatigue. It has been reported that a judo training session leads to decreased hydration status when performed at moderate to high temperatures which negatively affects the immune system (9). In addition to the warm ambient temperature, neuromuscular activity causes an increase in body heat production from the breakdown of energy substrate. Taken together, judo training might lead to adverse effects on health when performed in hot environments if adequate hydration is not ensured (9). Furthermore, the situation may be aggravated by weight cutting strategies employed by judokas close to competition, particularly in higher level judokas (4).

It is widely demonstrated that cooling strategies can significantly improve sports performance in a hot environment (39). Preventing temperature increases during training might reduce internal load requirements (i.e. heart rate, perceived exertion, etc.), subsequently allowing for better recovery after the session when judokas face the same relative external load. Cooling strategies have been employed in several experiments to prevent metabolic and cardiovascular strain (49) and to enhance recovery or maintain physical and cognitive performance capacities (41,45). Recently it has been suggested that the attenuation of the rising body temperature during exercise may be a better than the pre- or post-exercise cooling strategies (6). In the latter

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4 review, authors reported that exercise performance improvement with precooling was  $5.7 \pm$   
5  $0.9\%$  (ES=0.44) and  $9.9 \pm 1.9\%$  (ES=0.40) with per-cooling interventions (i.e. during exercise).  
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8 Furthermore, Bongers et al. (6) found different effects on performance outcomes among the  
9 cooling techniques employed in the studies reviewed, with wearing ice vests during exercise  
10 (+21.5%, ES=4.64) being significantly more effective than cold water ingestion (+11%, ES=1.75)  
11 or cooling packs (+8.4%, ES=0.39). The structure of judo training camps facilitates the inclusion  
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17 of cooling strategies during the rest periods between sparring bouts; however, even though  
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19 many athletes are employing intra-session cooling strategies, the physiological effects of this  
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21 practice during judo training have yet to be investigated.  
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27 Therefore, the objective of our study was to evaluate the acute effect of cooling vests between  
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29 rounds of sparring during an international training camp. We hypothesized that this intermittent  
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31 cooling vest strategy would attenuate the impact of the judo session on the cardiovascular,  
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33 endocrine, and neuromuscular systems, and reduce the perceived exertion during training.  
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## 37 **MATERIAL & METHODS**

### 38 **Experimental Approach to the Problem**

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41 A randomized controlled trial with two experimental conditions (cooling and control) was used  
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43 for this investigation. The experiment was conducted in summer one month before the 2016  
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45 Olympic Games during the Olympic Training Camp (OTC) in Castelldefels. This OTC served as  
46  
47 a preparation event for the Olympic judokas from 60 countries. The experiments were  
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49 performed at the same time of the day (9:30 am) to control for the potential influence of  
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51 circadian variations. Due to alternating start times, the evaluation was performed on day 1 for  
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53 women and day 2 for men. At the beginning of the training session, temperature (Day 1=  $26.9^{\circ}\text{C}$   
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55 and Day 2=  $27^{\circ}\text{C}$ ) and humidity (Day 1= 70% and Day 2= 67%) were registered with a weather  
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57 station (model WMR928NX, Oregon Scientific, Maidenhead, UK). Psychometric (i.e. wellness  
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4 and perceived effort) and physiological measures (i.e. tympanic temperature, heart rate  
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6 variability, hormonal changes, handgrip strength) were evaluated before and 10 min after the  
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8 realization of a judo training session. The protocols and procedures of the project were in  
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10 compliance with the ethical guidelines for biomedical research on human subjects of the World  
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12 Medical Association's Declaration of Helsinki ([2013](#)) and further amendments. The study was  
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14 approved by the Sport School of Spanish Judo Federation and the Human Research Ethics  
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16 Committee of Ramon Llull University.  
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## 23 **Subjects**

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25 Sixteen high-level judokas participated in the study. Eight men (age:  $21.3 \pm 2.8$  yr; height:  $172 \pm$   
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27  $8$  cm; **body mass**:  $73 \pm 10$  kg) and eight women (age:  $22.6 \pm 1.7$  yr; height:  $160 \pm 7$  cm; **body**  
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29 **mass**:  $57 \pm 6$  kg) were recruited according to the following inclusion criteria: 1) were at least a  
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31 black belt (1<sup>st</sup> DAN) and had earned a national medal in their country within the last two years,  
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33 2) were able to complete all of the sparring bouts during the investigation. Furthermore,  
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35 exclusion criteria were set to ensure design quality and lack of bias, including significant  
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37 physical limitations (all orthopaedic limitations, injuries, illness, disease, etc.) and medication or  
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39 ergogenic aid (creatine, protein powder, etc.) usage that could influence physical performance  
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41 or the interpretation of the results. All participants provided written informed consent.  
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## 46 **Procedures**

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48 One week before the intervention, the randori maximal time to exhaustion (i.e. RMTE) for each  
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50 judoka was determined to quantify the external load during the training session using the work-  
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52 endurance-recovery (i.e. WER) quantification method as described by Morales et al. (34). The  
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54 WER method aims to determine the level of exercise-induced physiological stress using the  
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56 ratio of cumulated work-endurance limit, which is associated with the neperian logarithm of the  
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4 ratio of work-recovery. The inter-subject coefficient of variation for RMTE was 7.9% indicating  
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6 similar specific endurance levels amongst the judoka.  
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10 On day 1 of the OTC, participants completed paperwork and were measured for height and  
11 body mass wearing light clothing and no footwear. Afterward, participants were familiarized with  
12 the procedures of the experiment. On the day of the experiment, judokas warmed up for 20  
13 minutes. During the main part of the training session, judokas performed eight judo bouts lasting  
14 5 min with 5 min rest interspersed between fights resulting in WER values between 3.2 and 3.8.  
15 These values were similar to those reported previously and have shown to be highly related to  
16 session-RPE (34). In order to evaluate the effects of intermittent cooling, an experimental group  
17 (vest group) of eight judokas (4 women and 4 men) were randomly selected to wear a cooling  
18 vest (Artic Heat Body Cooling Vest, Burleigh Heads, Australia), weighing 800g to 1kg when  
19 activated, during each 5-min rest period and for 10 min after the judo session (Figure 1). The  
20 remaining athletes were allocated to the control group and were not permitted to utilize the  
21 cooling vests during the rest or recovery periods. All the judokas were encouraged to fight at  
22 high intensity against similar level adversaries. Before and after the intervention, cardiovascular,  
23 neuromuscular, psychometric and hormonal variables were evaluated. Participants were  
24 instructed to refrain from exhausting exercise and to avoid consuming caffeine, chocolate,  
25 nutritional supplements or alcoholic beverages 24h before the intervention. Furthermore,  
26 participants were advised to sleep at least 8 hours in the night before the judo session. To avoid  
27 dehydration, drinking water ad libitum was permitted during a training session.  
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### 51 **Wellness scale and effort perception**

52 A psychometric questionnaire, based on previous recommendations (26), was used to assess  
53 general indicators of athlete wellness. The survey was comprised of 4 questions relating to the  
54 quality of sleep, perceived fatigue, general muscle soreness and stress levels with each  
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question scored on a seven-point scale (scores of 1–7 with 0.5 point increments; 1 and 7 representing poor and very good wellness ratings, respectively) (23). The questionnaire was completed at the beginning of the evaluation process (Figure 1).

Furthermore, the participants' perception of effort using the modified CR-10 RPE or session-RPE was recorded 15 to 30 min following the conclusion of each training session (16). The recorded values provided a numerical score between 0 (i.e. no effort) and 10 (i.e. maximal effort) indicating the global intensity of each training session including warm-up, cool down, and recovery intervals. Recently, it has been suggested that the product of the session-RPE and session duration (min) accurately represents the training session "load" in judo (2).

### **Tympanic temperature**

Tympanic temperature was obtained with participants in a seated position at the same time as the HRV assessment (Figure 1). The thermometer (Braun ThermoScan PRO 6000 Ear Thermometer, Braun, Kronberg, Germany) measured the infrared radiation generated by the eardrum and the surrounding tissue. To enhance accuracy, each scan consisted of eight measurements per second with the highest temperature being displayed. The technical error of measurements amounted to 0.2° for temperatures in the range 35.5–42.0°C.

### **Heart rate variability assessment**

Judokas sat silently in a comfortable chair with minimal movement for 5-min on arrival to the training facility and 10-min after the judo training session to evaluate heart rate variability (HRV) (Figure 1). Respiratory rate was spontaneous as negligible differences have been shown in parasympathetic-related HRV indices (i.e. RMSSD) during controlled versus spontaneous breathing (37). All R–R intervals were recorded continuously with a validated Polar RS800 heart-rate monitor (Polar Electro OY, Kempele, Finland) (25) at a sampling frequency of 1,000 Hz.

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4 R–R interval data files were transferred to a computer using Polar-specific software (Polar  
5 Protrainer 5, Polar Electro, Kempele, Finland). Further signal processing was performed using a  
6 dedicated HRV analysis program (Kubios HRV Analysis version 2.0, The Biomedical Signals  
7 Analysis Group, University of Kuopio, Finland). Occasional ectopic beats were automatically  
8 replaced with the interpolated adjacent R–R interval values. The natural logarithm of the square  
9 root mean of the sum of the squared differences between adjacent normal R–R intervals  
10 (lnRMSSD) was calculated from the last 3 min of the 5-min (seated) recordings to provide an  
11 index of cardiac parasympathetic activity (43). The analysis was restricted to lnRMSSD due to  
12 greater reported reliability compared with spectral indices during ambulatory trials with variable  
13 respiration rate (22).  
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### 27 **Salivary hormones**

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29 Thirty minutes before and after the judo session [\(Figure 1\)](#), saliva samples were collected for  
30 the analysis of endocrine responses, cortisol (C), dehydroepiandrosterone (DHEA) and the  
31 ratios between them (DHEA/C).  
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38 A collection of saliva samples for DHEA was accomplished by having the athletes spit directly  
39 into polypropylene tubes. The samples were processed in two aliquots and kept frozen at -20°C  
40 until assayed and concentrations were measured using commercially available enzyme-  
41 immunoassay (Salimetrics, State College, PA). The sensitivity of the DHEA was five pg/mL, and  
42 the interassay coefficient of variation was <8.5%.  
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51 Saliva samples for cortisol were collected with a Salivette® (Sarstedt, Nümbrecht,  
52 Germany). The Salivette® devices were centrifuged and the saliva samples stored at -20°C  
53 until assayed. Salivary cortisol was measured by an automated electrochemiluminescence  
54 assay (ECLIA) (Roche Diagnostics GmbH, Mannheim, Germany). The sensitivity of the assay  
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4 was 0.054 ug/dL, and the interassay coefficient of variation at a mean concentration of 0.34  
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6 ug/dL was 7.1%.  
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### 9 **Grip strength measurements**

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11 Maximum voluntary isometric contraction strength of the finger flexors was evaluated in both  
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13 hands. The test was performed once with each hand always starting with the dominant hand  
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15 (HGD) determined as the lifting hand (or tsurite) during a judo throw. After that, judokas  
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17 performed the test with the non-dominant hand (HGND) determined as the pulling hand (or  
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19 hikite) during a judo throw. The hand dynamometer employed (Hoggan microFET, Salt Lake  
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21 City, USA) was capable of measuring in a range between 0.5 and 100 kg, and an accuracy of  
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23 1%. Each judoka adapted the dynamometer to the size of his or her hand and applied force as  
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25 hard as possible for 5 s. The arm being tested was positioned close to the body and extended  
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27 while the judoka kept both feet on the floor.  
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34 **\*\*\*Insert Figure 1 over here\*\*\***  
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### 38 **Statistical analysis**

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40 Data are presented as the mean  $\pm$  standard deviation (SD). The distribution of each variable  
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42 was examined using the Shapiro-Wilk test, and if normality distribution was not satisfied, HRV  
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44 variables were log-transformed and adjusted to avoid the use of negative values [ $y = \ln(1+x)$ ].  
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46 Therefore, a two-way mixed-model ANOVA [group (vest and control) x time (pre- and post-test),  
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48 was applied to assess the effects of the cooling vests on the temperature, HRV, handgrip and  
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50 hormonal parameters. Where appropriate, univariate contrast and Bonferroni-adjusted post-hoc  
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52 analyses were performed. We relied on independent-samples non-parametric Mann-Whitney  
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54 U-tests were used to compare the differences between the vest and control groups for the  
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4 session-RPE and well-being ratings. All analyses performed with SPSS 22.0 for Windows  
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6 software (SPSS Inc) and  $p < 0.05$  was used to established significance.

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8 The effect size (ES) of changes and 90% confidence interval was calculated employing Hedges'  
9 g within each group for a intra-subject analysis (28) and standardized mean differences based  
10 on the pooled pretest standard deviation for the magnitude of effects between groups (35).  
11 Hedges' g is obtained by multiplying Cohen's d by a correction factor to remove a slight bias of  
12 this estimator in small samples. Interpretation of differences within groups and between groups  
13 are provided by the common language effect size, also known as the probability of superiority  
14 (PS) (28), which expresses the probability that a randomly sampled person from one group will  
15 have a higher observed measurement than a randomly sampled person from the other group  
16 (i.e. for between designs) or the probability that an individual has a higher value on one  
17 measurement than the other (i.e. for within-designs).

## 31 32 33 34 35 **RESULTS**

### 36 **Session-RPE and Wellness variables**

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38 Wellness ratings were no significant<sup>ly</sup> different ( $p < 0.05$ ) between the VG ( $12.75 \pm 1.87$ ) and  
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40 the CG ( $12.51 \pm 3.16$ ). Moreover, session-RPE was no significant<sup>ly</sup> different ( $p < 0.05$ ) between  
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42 the VG ( $479.4 \pm 48.4$ ) and the CG ( $495.6 \pm 59.5$ ).

### 43 44 45 46 **Temperature, HRV, and handgrip variables**

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48 Pre- and post-test temperature, HRV, and handgrip values are presented in Figure 2. The main  
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50 effect for time ( $F_{1,14}=6.48$ ,  $p=0.023$ ) was found for temperature with greater values in the post-  
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52 test compared to the pre-test, while a time  $\times$  group interaction ( $F_{1,14}=10.70$ ,  $p=0.006$ ) was  
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54 presented for HRV. There were no significant between-group differences during the pre-test for  
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56 any of the variables, but there were significant differences during the post-test for HRV ( $p < 0.05$ )  
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4 with greater values in the VG. Pairwise comparisons showed that HRV significantly decreased  
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6 (p<0.05) compared to pretest values in CG, while HRV was maintained in the VG. There is a  
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8 79% chance that a judo player picked at random from the vest group will have a lower impact on  
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10 HRV post-training than a judo player from the control group (Table 1). Finally, no significant  
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12 interactions or main effects were shown for dominant or non-dominant isometric handgrip  
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14 values.  
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## 22 **Hormonal variables**

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24 Pre- and post-test hormonal values are presented in Figure 3. No time × group interactions or  
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26 main effects were shown for cortisol or DHEA; however, there was a time × group interaction  
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28 effect ( $F_{1,14}=3.81$ ,  $p=0.041$ ) on the DHEA/C ratio. No significant between-group difference was  
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30 found during the pre- or post-tests. Within-group comparisons showed that the DHEA/C ratio  
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32 increased significantly from pre- to post-test for the VG ( $p=0.002$ ) while being maintained in the  
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34 CG. The cortisol was moderately reduced (PS=68.2%), with a concomitant small increase of  
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36 DHEA (PS=62.7%) after the training session in VG (Table 1). The group that used the cooling  
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38 vest had a markedly different hormonal response to the control group. It should be noted that  
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40 the PS was 99.9% in the values of the DHEA/Cortisol ratio in the group wearing a vest. (Table  
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## DISCUSSION

The purpose of this study was to examine the effect of cooling vests on temperature, HRV, and perceived exertion, as well as neuromuscular and hormonal markers in elite judo athletes during a training session. The results confirm some of our previous hypotheses and suggest that the use of cooling vests during judo training sessions can reduce body temperature, accelerate post-exercise parasympathetic reactivation (i.e. lnRMSSD), and decrease the production of catabolic hormones (i.e. cortisol). Nevertheless, contrary to our hypothesis, we did not find a lower perception of effort in the vest group compared to the control group, or differences in handgrip strength in response to training.

### Well-being before session and session-RPE

Both groups showed comparable well-being ratings before the session demonstrating that all the judokas initiated training under similar conditions. Regardless of the intervention, judokas reported similar perceived exertion during the training session. The effect of cooling strategies on perceived exertion is unclear as inconsistent results have been found (39,47). Cooling vests have demonstrated to reduce perceived exertion following fixed-intensity exercise (39); however, during self-paced, open skill sports, such as judo, intensity and performance are likely mediators of effort. Some beneficial effects of inter/intra-exercise cooling strategies have been proposed, including reductions in cardiovascular strain, lower skin temperature, enhanced central nervous system function and cognitive performance, and improved perception of thermal sensation, comfort, and exertion (41,45). As perceived exertion is a relative measure, after experiencing a “comfortable state” when fighting, both groups may have adjusted their training intensities to achieve an acceptable level of exertion. In this regard, Marcora and Staiano (31) stated that perception of effort and potential motivation are the key-determinants of exercise tolerance, and they suggested that perception of effort may be the cardinal “exercise stopper”.



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4 In our study, the global external load was designed to be similar between judokas. However no  
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6 indices of fight intensity were measured (psychometric test, performance perception, numbers  
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8 of actions per fight, etc.). Therefore, future studies addressing this issue are warranted.  
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## 10 11 **HRV and temperature changes**

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13 The results showed that the factor time (i.e. pre-, post-) affected temperature and HRV. However, there  
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15 was only an interaction effect (i.e. time x treatment) on HRV. While temperature has an influence on  
16  
17 HRV, these distinct physiologic mechanisms do not respond in parallel during recovery and after the  
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19 application of cooling strategies (29). The interaction between plasma volume and autonomic control  
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21 could play a role in the differences found in the behavior of temperature and HRV; however, conflicting  
22  
23 reports exist with respect to these factors (29). Leicht et al. (29) hypothesized that small plasma volume  
24  
25 changes likely stimulate baroreflex-mediated parasympathetic activation, whereas large plasma volume  
26  
27 changes likely result in an opposite effect (i.e. parasympathetic inhibition and/or sympathetic  
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29 activation). Hydration status of the participants was not controlled for in the current study, thus future  
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31 investigations should account this for this potential interaction. Furthermore, while tympanic  
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33 temperature is reliable, it is not an accurate method to reflect core temperature (19). Therefore,  
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35 peripheral cold stimulation by cooling vest could have produced peripheral vasoconstriction with its  
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37 subsequent influence on HRV without any significant effect on core temperature (14).  
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46 LnRMSSD, a parasympathetic-based HRV index, showed a significant decrease ( $p < 0.05$ ) in the  
47  
48 control group, which means that the recovery process may have been attenuated in this group.

49  
50 In contrast, the vest group showed no changes after the session, confirming either reduced  
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52 cardiovascular strain during training or a more rapid parasympathetic reactivation following the  
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54 training session. Numerous studies have shown that different cooling strategies used in sports  
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56 training accelerate parasympathetic reactivation after intense exercise in well-trained athletes  
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58 (10,40,43). Cold exposure may suppress sympathetic activity while arterial baroreflex activation  
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4 likely results in cardiac parasympathetic modulation (38). Peripheral vasoconstriction following  
5 cold stimulation and subsequent changes in blood volume activate low blood pressure  
6 baroreceptors that are responsible for reducing the activity of sympathetic nerves while  
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8 changing the control of autonomic cardiac activity towards a parasympathetic dominance (38).  
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15 The use of cooling vests have been suggested as one of the most effective strategies to  
16 enhance exercise performance during the pre-exercise period in moderate ambient conditions  
17 (<30°) (5); however, to the best of our knowledge, this is the first study that has reported an  
18 impact on parasympathetic reactivation while wearing cooling vests during and shortly after  
19 exercise. In the present study, cooling vests were employed during training, taking advantage of  
20 the pauses between bouts of effort and 10-min after the training session. This approach was  
21 used to mitigate the deleterious effects of exercising in the heat, namely, central fatigue caused  
22 by inhibition of brain areas responsible for motor activation, reduced cerebral blood flow, and a  
23 low serotonin:dopamine ratio in the hypothalamus (45).  
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35 The cardiovascular system plays a key role in facilitating recovery, including thermoregulation  
36 and delivery/removal of nutrients and waste products, which are likely affected by the relative  
37 intensity of the previous exercise (43). In this sense, the hemodynamic response to exercise  
38 represents an interaction between the effects of exercise and the modulating action of the two  
39 branches of the autonomic nervous system (ANS) that contribute to restore the cardiovascular  
40 system to homeostasis in the short-term (i.e. acute action) or set the system in a higher level of  
41 homeostasis in the long-term (i.e. adaptation action) (43). It has been suggested that a faster  
42 cardiac parasympathetic reactivation following a training session is a good marker of  
43 cardiovascular recovery, and when parasympathetic reactivation is measured shortly after the  
44 session (i.e. 0 - 90 min), may reflect the ability to clear metabolic accumulation (43).  
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57 It is well known that cooling techniques applied during recovery produce a temperature drop and  
58 accelerate parasympathetic reactivation (29). Accelerated parasympathetic reactivation during  
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4 training could benefit the cardiovascular response to subsequent stressful situations, such as  
5 successive exercise bouts or the next training session. In this sense, faster cardiac  
6 parasympathetic reactivation has shown to maintain performance during short training blocks  
7 comprised of consecutive days of intense exercise (42). However, it has been reported that  
8 certain level of sympathetic stimulation is necessary before a high-intensity bout, as an  
9 exceeded of parasympathetic activity in a subsequent high-intensity effort can slow oxygen  
10 consumption on-kinetics and reduce oxygen utilization by muscles (44). Therefore, there is still  
11 no consensus with regard to the role of accelerated parasympathetic reactivation after exercise  
12 and improvements in subsequent exercise performance when only a short duration (i.e. hours)  
13 separates exercise bouts. Future investigations should highlight the effect of different cooling  
14 strategies on parasympathetic reactivation and the impact of this phenomenon on subsequent  
15 exercise performed within a short time (i.e. hours) as well as any potential long-term adaptations  
16 (i.e. days, weeks).  
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### 33 34 **Hormonal response**

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36 Hormonal variation following exercise may show the catabolic or anabolic tendencies of a  
37 specific training load (27). In particular, a non-invasive sampling of salivary hormones, which  
38 have been shown to be highly related to serum samples, provides a method highly suitable for  
39 the serial follow-up of athletes and may be used as a marker of training stress (20,21,27).  
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41 However, often findings of these hormonal measures are controversial and may not coincide  
42 due to inter-individual variability produced by exercise (21) as well as sex, age, training status,  
43 nutrition, and time of day (20). In the present study, each of these factors was controlled, with  
44 the exception of sex, as we would have needed a larger sample in each group to have higher  
45 statistical power for comparing the effect of cooling vest regarding sex.  
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4 Cortisol is a biomarker that can be used to observe changes in the hypothalamic-pituitary-  
5 adrenal (HPA) system because it responds to the body's catabolic activity (27) and is  
6 recommended as an indicator of the stress produced by training (20). DHEA is a steroid  
7 hormone and testosterone precursor released by the adrenal cortex, that plays a regenerative  
8 role during the stress response to physical exercise (21,46). Thus, the relationship between  
9 cortisol and DHEA is considered a marker of the HPA axis (46). Because DHEA is the  
10 predominant adrenal steroid in both sexes, it provides an advantage over testosterone in  
11 evaluating the anabolic response to exercise in women (8).  
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24 The results of our study demonstrated that the DHEA to cortisol ratio in the vest group  
25 significantly increased following training but did not appear to be affected in the control group.  
26 Furthermore, there is a 99.9% chance that a judo player picked at random from the vest group  
27 will have a higher increment on DHEA/Cortisol than a judo player from the control group. The  
28 small effect indicating a potential increase in cortisol for the control group follows the expected  
29 hormonal response after high-intensity exercise (27,46); however, the athletes using cooling  
30 vests experienced a moderate decrements in cortisol concentration (PS=68,2%) compared to  
31 baseline. While non-significant, the impact on cortisol in the vest group may have been related  
32 to the purported attenuation of the inflammatory response via cooling-induced vasoconstriction  
33 and the associated maintenance of cellular integrity by limiting circulatory and lymphatic  
34 permeability (33). Lindsay et al. (30) argue that cooling methods are a very effective strategy for  
35 alleviating the catabolic environment and soreness associated with combat sports. These  
36 authors compared two groups of mixed martial arts (MMA) competitors with different recovery  
37 strategies after training showing that cold-water immersion attenuated increases in salivary  
38 cortisol concentrations compared to passive recovery. At the same time, we observed non-  
39 significant changes in DHEA concentrations following the training session. With consideration  
40 for the individual DHEA and cortisol responses to exercise and significant differences in the  
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4 DHEA to cortisol ratio in the current investigation, the vest group may have benefitted from  
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6 decreased physiological demands for muscle repair and a more rapid recovery process. In this  
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8 line, Fonseca et al. (15) reported lower increment of muscle damage markers (i.e. lactate  
9 dehydrogenase) 24h after a jiu-jitsu training (i.e. 120-min) where athletes were subjected to a  
10 recovery protocol utilizing cold-water immersion (6.08°C ± 0.58°C) for 16-min. During our study,  
11 judo athletes wore cooling vests intermittently during and after the training session. While  
12 distinct differences exist between these protocols, it can be suggested that cooling strategies  
13 have a positive impact on the hormonal response to the high intensity effort required by combat  
14 sports. As our results highlight the acute response, additional investigation is needed to  
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16 determine the potential chronic effects of cooling strategies during training.  
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## 27 **Handgrip results**

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29 Isometric handgrip tests have been employed extensively in the literature to evaluate strength in  
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31 judokas (18), and successive judo bouts reportedly cause a reduction in both hands (7).  
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33 However, limited research has been conducted on the effects of judo training sessions on  
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35 handgrip performance. We found no significant changes in handgrip strength after the judo  
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37 training session in either group; however, the strength tests were conducted at the end of the  
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39 measurement protocol, approximately 20 min after the session, which may have allowed for  
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41 sufficient recovery. While handgrip strength between judokas and non-judokas have shown to  
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43 be comparable, judo athletes are more resistant fatigue (1) indicating that forearm muscles are  
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45 highly utilized during judo practice. Therefore, it stands to reason that judokas would have high  
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47 recovery capacity in their forearms and less recovery time should be employed in future  
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49 investigations attempting to analyze the effects of a judo session in handgrip performance.  
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51 Because pulling and pushing actions are also used during gripping activities in judo, the  
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53 inclusion of multi-joint strength tests should be considered in subsequent studies.  
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## **Limitations**

Several limitations of the current investigation should be acknowledged. The experiment was performed in a sample of high level athletes during an international training camp which made it difficult to evaluate the athletes for a longer period of time (i.e. 24h and 48h) or the completion of a cross-over design. A small sample size could be taken as a limitation; however, in order to attenuate the impact of a small sample size, we reported estimates of the effect size for the analysis and interpretation of the intra-subject (Hedges' g) and between subject (standardized mean differences with pooled SD of pre-test) results. Furthermore, while no changes were found for isometric handgrip values, judo efforts are not limited to forearm muscles (11) and the extended recovery time after the judo session combined with the potential for judo athletes to possess high recovery capacities for these muscle groups may have influenced the strength outcomes. Finally, we measured tympanic temperature to evaluate the effects of cooling vests on thermoregulation mechanisms; however, tympanic measurement has shown to consistently underestimate rectal temperature (mean bias =  $-0.67^{\circ}\text{C}$ ) (19). Thus, other methods, such as ingestible telemetric sensors, should be employed to monitor core temperature.

## **PRACTICAL APPLICATIONS**

Often judokas must fight in a hot/humid environment during training and competitions. Cooling strategies have been employed extensively in the literature demonstrating positive effects when exercising in hot/humid environments: reductions in cardiovascular strain, lower skin temperature, enhanced central nervous system function and cognitive performance, and improved perception of thermal sensation, comfort and exertion. However, there is a lack of studies that have analyzed the effects of cooling strategies during judo training or competitions. The results of the present study demonstrated that a superficial garment (i.e. cooling vest)

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4 reduced the impact of a combat-based judo training on indicators of parasympathetic activity  
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6 over the heart (i.e. lnRMSDD) and may have induced decreased physiological demands for  
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8 muscle repair and a more rapid recovery process, as indicated by the significant increase in the  
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10 DHEA to cortisol ratio in the vest group following training. Probably the absence of effects of the  
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12 cooling vest on the perceived exertion has its origin like the effort in judo since the intensity of  
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14 the effort can be self-regulated according to the preference of the judoka. The self-regulated  
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16 intensity and the characteristics of strength evaluation (i.e. handgrip test and time of recovery  
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18 before the evaluation) may have influenced the strength outcomes. Futures studies controlling  
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20 fight intensity and choosing strength test that best represents the effort in judo are warranted.  
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22 Additionally, this approach should be implemented in a situation of accumulative training to  
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24 study the mid-term effect on the different parameters that define training load during combat-  
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26 based judo sessions. However, it seems fair to advise coaches and their judokas to wear the  
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28 cooling vest whenever they want to prevent a major impact on autonomic heart control and a  
29  
30 catabolic state when training in a warm and humid environment. While cooling vests are being  
31  
32 utilized by many national teams during judo training camps, to the best of our knowledge, this is  
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34 the first study to investigate the effects of this strategy on a judo training session. During  
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36 informal interviews, the participants that wore the cooling vests in our study reported that the  
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38 sensation was comfortable, that they could fight more intensely, and that they believed the vests  
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40 were a valuable and affordable tool for training in the heat. Nonetheless, more studies are  
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42 warranted to elucidate the effects of wearing cool vests on strength and endurance during  
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44 subsequent training sessions while long-term studies would allow for determination of the  
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46 effects on the adaptation of physical capacities.  
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56  
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58  
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10 **Figure 1. Schematic representation of the experimental procedure.**  
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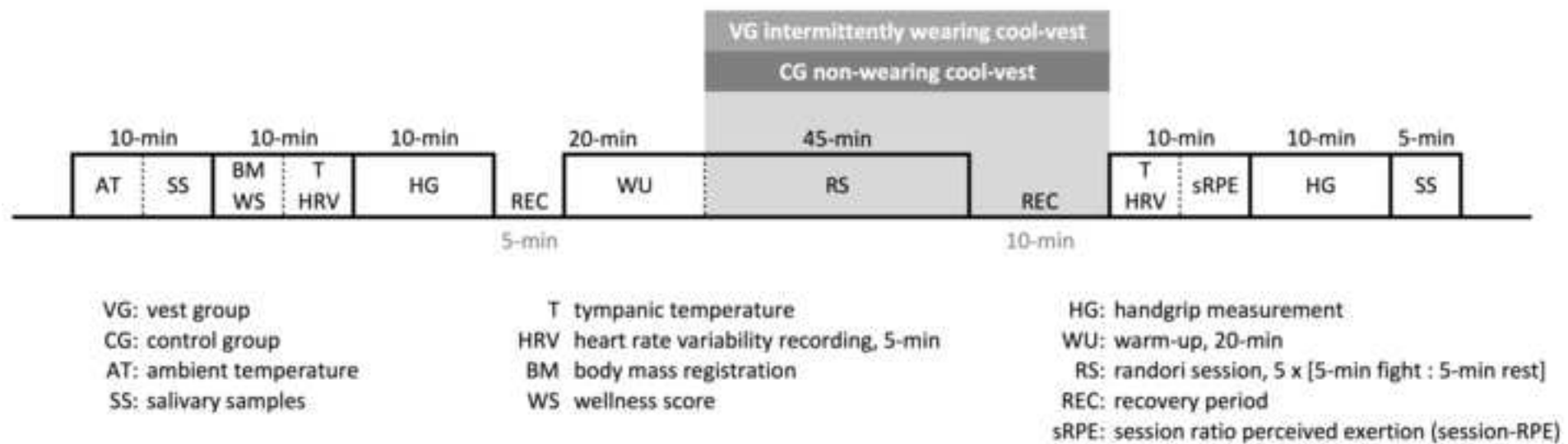
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17 **Figure 2.** Pre- and post-training session group mean values (with standard deviation  
18 represented as error bars) for body temperature, heart rate variability (HRV), and strength.

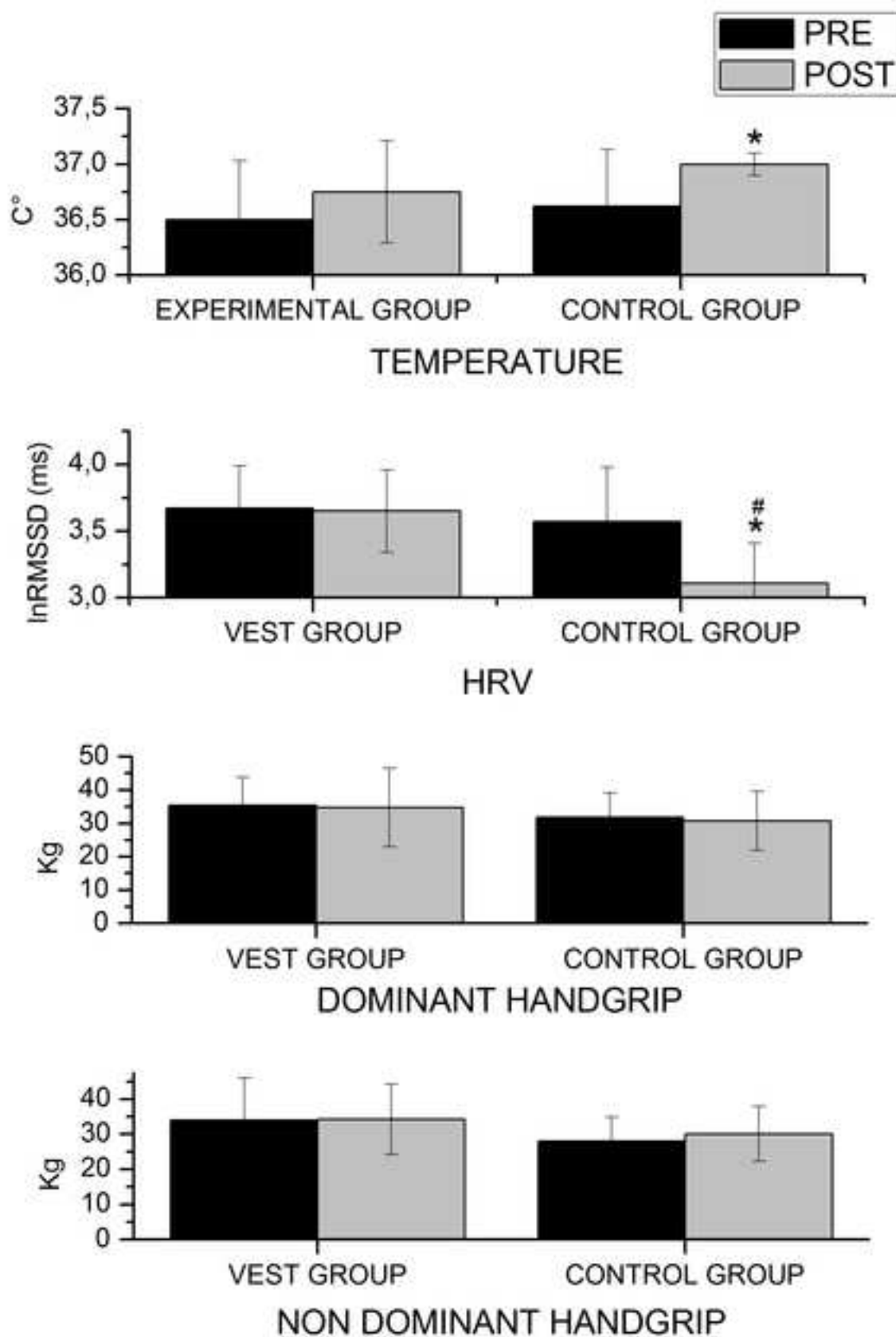
19 \*Significant differences versus pre-values; # Significant differences between groups at that  
20 moment of measurement.  
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29 **Figure 3.** Pre- and post-training session group mean values (with standard deviation  
30 represented as error bars) for cortisol (C), dehydroepiandrosterone (DHEA), and DHEA/C ratio.

31 \*Significant differences versus pre-values.  
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38 **Table 1.** Effect size and magnitude of change for temperature, heart rate variability (HRV),  
39 hormonal, and strength variables  
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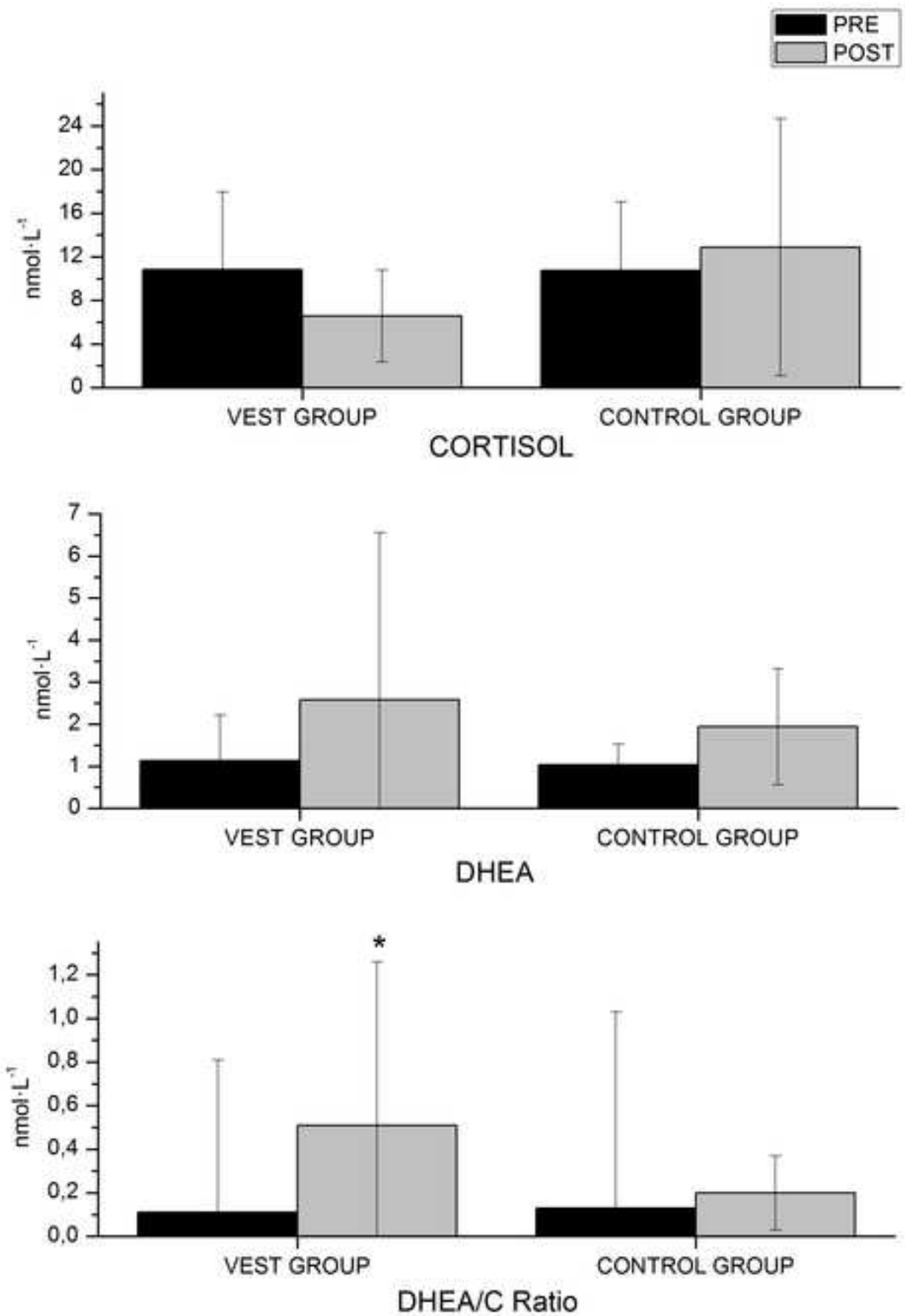


Table 1. Effect sizes pre- post- and between groups

| COMPARISONS     | Vest Group                   | Control Group                 | Between groups                |
|-----------------|------------------------------|-------------------------------|-------------------------------|
|                 | Post vs. Pre                 | Post vs. Pre                  | VG vs. CG                     |
|                 | ES [90% CI]                  | ES [90% CI]                   | ES [90% CI]                   |
|                 | PS                           | PS                            | PS                            |
| Temperature     | 0.28 [-0.55; 1.11]<br>57,9%  | 0.95 [0.09; 1.82]<br>74,9%    | -0.24 [-1.09; 0.60]<br>56,7%  |
| HRV             | -0.06 [-0.88; 0.76]<br>51,7% | -1.18 [-2.07; -0.29]<br>79,8% | 1.14 [0.50; 1.78]<br>79%      |
| Cortisol        | -0.67 [-1.52; 0.17]<br>68,2% | 0.21 [-0.62; 1.03]<br>55,9%   | -0.98 [-1.92; -0.04]<br>75,6% |
| DHEA            | 0.46 [-0.38; 1.29]<br>62,7%  | 0.80 [-0.05; 1.66]<br>71,4%   | 0.67 [-2.05; 3.39]<br>68,2%   |
| DHEA/Cortisol   | 0.51 [-0,33; 1.34]<br>64,1%  | 0.10 [-0.72; 0.92]<br>52,8%   | 4.24 [-1.90; 10.38]<br>99,9%  |
| Dominant HG     | -0.06 [-0.88; 0.77]<br>51,7% | -0.11 [-0.94; 0.71]<br>53,1%  | 0.05 [-0.37; 0.47]<br>51,4%   |
| Non-dominant HG | 0.03 [-0.80; 0.85]<br>50,8%  | 0.26 [-0.57; 1.08]<br>57,3%   | -0.17 [-0.47; 0.12]<br>54,8%  |

ES: effect size; PS: probability of superiority or common language effect size; VG: vest group; CG: control group; HRV: heart rate variability; DHEA: dehydroepiandrosterone; HG: handgrip.