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INTERMITTENT COOLING DURING JUDO TRAINING IN A WARM/HUMID ENVIRONMENT REDUCES AUTONOMIC AND HORMONAL IMPACT

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ABSTRACT

Carballeira, E, Morales, J, Fukuda, DH, Granada, ML, Carratalá-Deval, V, López Díaz de Durana, A, and Stout, JR. Intermittent cooling during judo training in a warm/humid environment reduces autonomic and hormonal impact. *J Strength Cond Res* XX(X): 000–000, 2018—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 4 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-minute fighting with 5-minute rest) and up to 10 minutes after the session, whereas 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 before the session or in perceived fatigue after 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] = 0.09–1.82; probability of superiority [PS] = 74.9%) in contrast to the small effect for VG (ES = 0.28, 90% CI = −0.55 to 1.11; PS = 57.9%). There were time × group interactions for heart rate variability (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%). Vest group preserved the cardiac autonomic control ($p > 0.05$; ES = −0.06, 90% CI = −0.88 to 0.76; PS = 51.7%) compared with the large decrement of CG ($p \leq 0.05$; 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 presession to postsession 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 CG showed a moderate effect for increased DHEA and a small effect for increased cortisol after training. No significant interactions or main effects were shown for isometric handgrip values. Cooling vests diminished the cardiovascular strain and hormonal impact of the judo training session in high-level athletes and may be considered for recovery purposes during exercise in warm/humid environments.

KEY WORDS cooling vest, heart rate variability, hormones, isometric handgrip, perceived exertion

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 $g \cdot m^{-2}$ (Judogi Regulation, application of April 1, 2015, International

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Judo Federation). When combined with harsh ambient conditions, these characteristics put judo athletes at risk of heat-related illness (heat cramps, heat syncope, heat exhaustion, heat stroke, hyponatremia, and 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) used 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 $\dot{V}O_2$max 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 minutes in the belly of the quadriceps after 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 (i.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 used 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 used 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 better than the preexercise or postexercise cooling strategies (6). In the latter review, authors reported that exercise performance improvement with precooling was 5.7 ± 0.9% (effect size [ES] = 0.44) and 9.9 ± 1.9% (ES = 0.40) with per-cooling interventions (i.e., during exercise). Furthermore, Bongers et al. (6) found different effects on performance outcomes among the cooling techniques used in the studies reviewed, with wearing ice vests during exercise (+21.5%, ES = 4.64) being significantly more effective than cold-water ingestion (+11%, ES = 1.75) or cooling packs (+8.4%, ES = 0.39). The structure of judo training camps facilitates the inclusion of cooling strategies during the rest periods between sparring bouts; however, although many athletes are using intrasession cooling strategies, the physiological effects of this practice during judo training have yet to be investigated.

Therefore, the objective of our study was to evaluate the acute effect of cooling vests between rounds of sparring during an international training camp. We hypothesized that this intermittent cooling vest strategy would attenuate the impact of the judo session on the cardiovascular, endocrine, and neuromuscular systems, and reduce the perceived exertion during training.

~~Material and~~ Methods

Experimental Approach to the Problem AU2

A randomized controlled trial with 2 experimental conditions (cooling and control) was used for this investigation. The experiment was conducted in summer 1 month before the 2016 Olympic Games during the Olympic Training Camp (OTC) in Castelldefels. This OTC served as a preparation event for the Olympic judokas from 60 countries. The experiments were performed at the same time of the day (9:30 AM) to control for the potential influence of circadian variations. Because of alternating start times, the evaluation was performed on day 1 for women and day 2 for men. At the beginning of the training session, temperature (day 1 = 26.9° C and day 2 = 27° C) and humidity (day 1 = 70% and day 2 = 67%) were registered with a weather station (model WMR928NX; Oregon Scientific, Maidenhead, United Kingdom). Psychometric (i.e., wellness and perceived effort) and physiological measures (i.e., tympanic temperature, heart rate variability [HRV], hormonal changes, and handgrip strength) were evaluated before and 10 minutes after the realization of a judo training session. The protocols and procedures of the project were in compliance with the ethical guidelines for biomedical research on human subjects of the World Medical Association's Declaration of Helsinki (2013) and further amendments. The study was approved by the Sport School of Spanish Judo Federation and the Human Research Ethics Committee of Ramon Llull University.

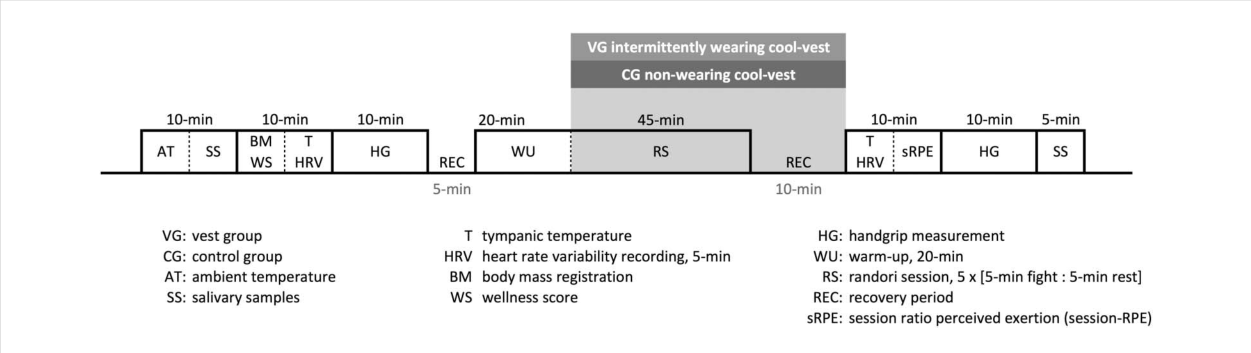

Figure 1. Schematic representation of the experimental procedure.

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Subjects

Sixteen high-level judokas participated in the study. Eight men (age: 21.3 ± 2.8 years; height: 172 ± 8 cm; body mass: 73 ± 10 kg) and 8 women (age: 22.6 ± 1.7 years; height: 160 ± 7 cm; body mass: 57 ± 6 kg) were recruited according to the following inclusion criteria: (a) were at least a black belt (first DAN) and had earned a national medal in their country within the past 2 years and (b) were able to complete all the sparring bouts during the investigation. Furthermore, exclusion criteria were set to ensure design quality and lack of bias, including significant physical limitations (all orthopedic limitations, injuries, illness, disease, etc.) and medication or ergogenic aid (creatine, protein powder, etc.) usage that could influence physical performance or the interpretation of the results. All participants provided written informed consent. AU4

Procedures

One week before the intervention, the randori maximal time to exhaustion (i.e., RMTE) for each judoka was determined to quantify the external load during the training session using the work-endurance-recovery (i.e., WER) quantification method as described by Morales et al. (34). The WER method aims to determine the level of exercise-induced physiological stress using the ratio of cumulated work–endurance limit, which is associated with the Napierian logarithm of the ratio of work-recovery. The intersubject coefficient of variation for RMTE was 7.9%, indicating similar specific endurance levels among the judoka.

On day 1 of the OTC, participants completed paperwork and were measured for height and body mass, wearing light clothing and no footwear. Afterward, participants were familiarized with the procedures of the experiment. On the day of the experiment, judokas warmed up for 20 minutes. During the main part of the training session, judokas performed 8 judo bouts lasting 5 minutes with 5-minute rest interspersed between fights resulting in WER values between 3.2 and 3.8. These values were similar to those reported previously and have shown to be highly related to session–rating of perceived exertion (RPE) (34). To evaluate the effects of intermittent cooling, an experimental group (vest group [VG]) of 8 judokas (4 women and 4 men) were randomly selected to wear a cooling vest (Artic Heat Body Cooling Vest; Artic Heat, Burleigh Heads, Australia), weighing 800 g–1 kg when activated, during each 5-minute rest period and for 10 minutes after the judo session (Figure 1). F1 The remaining athletes were allocated to the control group (CG) and were not permitted to use the cooling vests during the rest or recovery periods. All the judokas were encouraged to fight at high intensity against similar level adversaries. Before and after the intervention, cardiovascular, neuromuscular, psychometric, and hormonal variables were evaluated. Participants were instructed to refrain from exhausting exercise and to avoid consuming caffeine, chocolate, nutritional supplements, or alcoholic beverages 24 hours before the intervention. Furthermore, participants were advised to sleep at least 8 hours in the night before the judo session. To avoid dehydration, drinking water ad libitum was permitted during a training session.

Wellness Scale and Effort Perception

A psychometric questionnaire, based on previous recommendations (26), was used to assess general indicators of athlete wellness. The survey was comprised 4 questions relating to the quality of sleep, perceived fatigue, general muscle soreness, and stress levels with each question scored on a 7-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 15–30 minutes after 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 (minutes) accurately represents the training session "load" in judo (2).

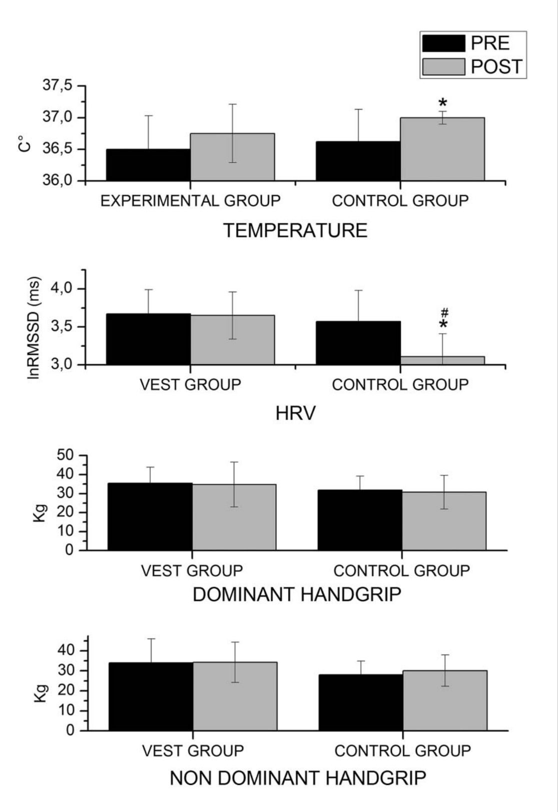

Figure 2. Pretraining and posttraining session group mean values (with *SD* represented as error bars) for body temperature, heart rate variability (HRV), and strength. *Significant differences vs. prevalues; #significant differences between groups at that moment of measurement.

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 8 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-minute on arrival to the training facility and 10 minutes after the judo training session to evaluate HRV (Figure 1). Respiratory rate was spontaneous, as negligible differences have been shown in parasympathetic-related HRV indices (i.e., RMSSD) during controlled vs. 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.

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

Table 1. Effect size and magnitude of change for temperature, heart rate variability (HRV), hormonal, and strength variables.*

	Vest group	Control group	Between-groups
Comparisons	Post vs. Pre, ES (90% CI); PS	Post vs. Pre, ES (90% CI); PS	VG vs. CG, ES (90% CI); PS
Temperature	0.28 (−0.55 to 1.11); 57.9%	0.95 (0.09 to 1.82); 74.9%	−0.24 (−1.09 to 0.60); 56.7%
HRV	−0.06 (−0.88 to 0.76); 51.7%	−1.18 (−2.07 to −0.29); 79.8%	1.14 (0.50 to 1.78); 79%
Cortisol	−0.67 (−1.52 to 0.17); 68.2%	0.21 (−0.62 to 1.03); 55.9%	−0.98 (−1.92 to −0.04); 75.6%
DHEA	0.46 (−0.38 to 1.29); 62.7%	0.80 (−0.05 to 1.66); 71.4%	0.67 (−2.05 to 3.39); 68.2%
DHEA/cortisol	0.51 (−0.33 to 1.34); 64.1%	0.10 (−0.72 to 0.92); 52.8%	4.24 (−1.90 to 10.38); 99.9%
Dominant HG	−0.06 (−0.88 to 0.77); 51.7%	−0.11 (−0.94 to 0.71); 53.1%	0.05 (−0.37 to 0.47); 51.4%
Nondominant HG	0.03 (−0.80 to 0.85); 50.8%	0.26 (−0.57 to 1.08); 57.3%	−0.17 (−0.47 to 0.12); 54.8%

*ES = effect size; CI = confidence interval; PS = probability of superiority or common language effect size; VG = vest group; CG = control group; DHEA = dehydroepiandrosterone; HG = handgrip.

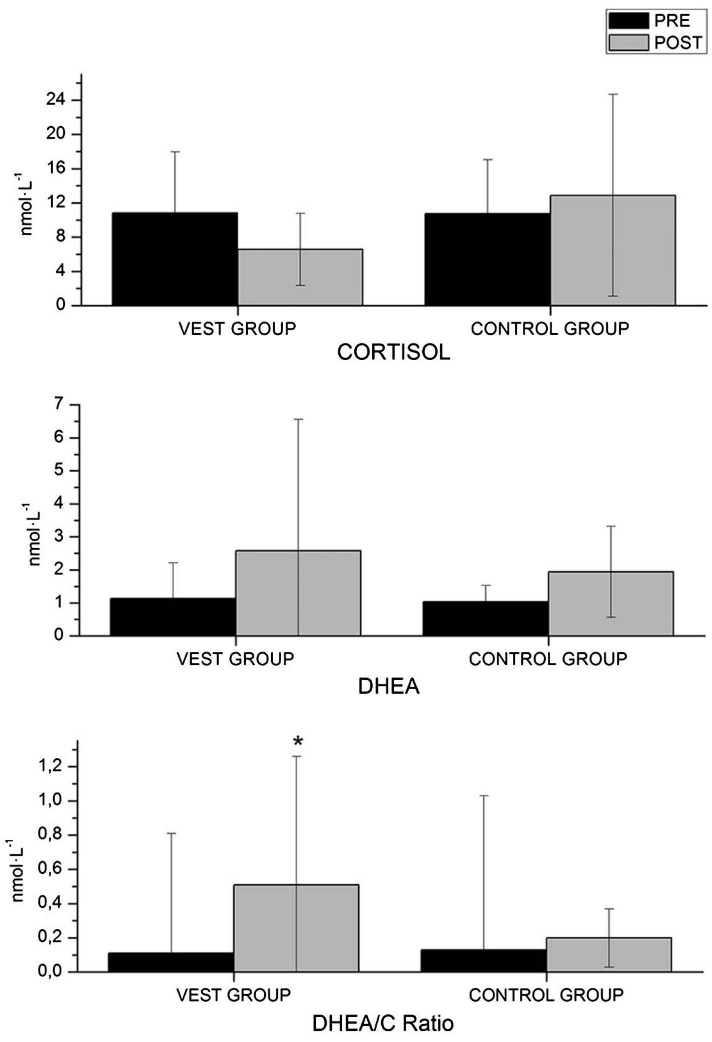

Figure 3. Pretraining and posttraining session group mean values (with *SD* represented as error bars) for cortisol (C), dehydroepiandrosterone (DHEA), and DHEA/C ratio. *Significant differences vs. prevalues.

Salivary Hormones

Thirty minutes before and after the judo session (Figure 1), saliva samples were collected for the analysis of endocrine responses, cortisol (C), dehydroepiandrosterone (DHEA), and the ratios between them (DHEA/C).

A collection of saliva samples for DHEA was accomplished by having the athletes spit directly into polypropylene tubes. The samples were processed in 2 aliquots and kept frozen at −20° C until assayed and concentrations were measured using commercially available enzyme immunoassay (Salimetrics, State College, PA, USA). The sensitivity of the DHEA was 5 pg/mL, and the interassay coefficient of variation was <8.5%.

Saliva samples for cortisol were collected with a Salivette (Sarstedt, Nümbrecht, Germany). The Salivette devices were centrifuged and the saliva samples stored at −20° C until assayed. Salivary cortisol was measured by an automated electrochemiluminescence assay (Roche Diagnostics GmbH, Mannhein, Germany). The sensitivity of the assay was 0.054 $\mu g \cdot dL^{-1}$, and the interassay coefficient of variation at a mean concentration of 0.34 $\mu g \cdot dL^{-1}$ was 7.1%.

Grip Strength Measurements

Maximum voluntary isometric contraction strength of the finger flexors was evaluated in both hands. The test was performed once with each hand always starting with the dominant hand (HGD) determined as the lifting hand (or tsurite) during a judo throw. After that, judokas performed the test with the nondominant hand (HGND) determined as the pulling hand (or hikite) during a judo throw. The hand dynamometer used (Hoggan microFET, Salt Lake City, UT, USA) was capable of measuring in a range between 0.5 and 100 kg, and an accuracy of 1%. Each judoka adapted the dynamometer to the size of his or her hand and applied force as hard as possible for 5 seconds. The arm being tested was positioned close to the body and extended while the judoka kept both feet on the floor.

Statistical Analyses

Data are presented as the mean ± *SD*. The distribution of each variable was examined using the Shapiro-Wilk test, and if normality distribution was not satisfied, HRV variables were log-transformed and adjusted to avoid the use of negative values [$y = \text{Ln}(1 + x)$]. Therefore, a 2-way mixed-model analysis of variance (group [vest and control] × time [pretest and posttest]) was applied to assess the effects of the cooling vests on the temperature, HRV, handgrip, and hormonal parameters, where appropriate, univariate contrast and Bonferroni-adjusted post hoc analyses were performed. We relied on independent samples nonparametric Mann-

Whitney *U* tests that were used to compare the differences between the vest and CGs for the session-RPE and well-being ratings. All analyses performed with SPSS 22.0 for Windows software (SPSS, Inc., Chicago, IL, USA) and $p \leq 0.05$ was used to established significance.

The ES of changes and 90% confidence interval was calculated using Hedges' *g* within each group for a intrasubject analysis (28) and standardized mean differences based on the pooled pretest *SD* for the magnitude of effects between groups (35). Hedges' *g* is obtained by multiplying Cohen's *d* by a correction factor to remove a slight bias of this estimator in small samples. Interpretation of differences within-groups and between-groups is provided by the common language ES, also known as the probability of superiority (PS) (28), which expresses the probability that a randomly sampled person from 1 group will have a higher observed measurement than a randomly sampled person from the other group (i.e., for between designs) or the probability that an individual has a higher value on 1 measurement than the other (i.e., for within designs).

RESULTS

Session–Rating of Perceived Exertion and Wellness Variables

Wellness ratings were no significantly different ($p \leq 0.05$) between the VG (12.75 ± 1.87) and the CG (12.51 ± 3.16). Moreover, session-RPE was no significantly different ($p \leq 0.05$) between the VG (479.4 ± 48.4) and the CG (495.6 ± 59.5).

Temperature, Heart Rate Variability, and Handgrip Variables

F2 Pretest and posttest temperature, HRV, and handgrip values are presented in Figure 2. The main effect for time ($F_{1,14} = 6.48$, $p = 0.023$) was found for temperature with greater values in the posttest compared with the pretest, whereas a time × group interaction ($F_{1,14} = 10.70$, $p = 0.006$) was presented for HRV. There were no significant between-group differences during the pretest for any of the variables, but there were significant differences during the posttest for HRV ($p \leq 0.05$) with greater values in the VG. Pairwise comparisons showed that HRV significantly decreased ($p \leq 0.05$) compared with pretest values in CG, whereas HRV was maintained in the VG. There is a 79% chance that a judo player picked at random from the VG will have a lower impact on HRV posttraining than a judo player from T1 the CG (Table 1). Finally, no significant interactions or main effects were shown for dominant or nondominant isometric handgrip values.

Hormonal Variables

F3 Pretest and posttest hormonal values are presented in Figure 3. No time × group interactions or main effects were shown for cortisol or DHEA; however, there was a time × group interaction effect ($F_{1,14} = 3.81$, $p = 0.041$) on the DHEA/C ratio. No significant between-group difference was found during the pretests or posttests. Within-group comparisons showed that the DHEA/C ratio increased significantly from pretest to posttest for the VG ($p = 0.002$) while being maintained in the CG. The cortisol was moderately reduced (PS = 68.2%), with a concomitant small increase of DHEA (PS = 62.7%) after the training session in VG (Table 1). The group that used the cooling vest had a markedly different hormonal response to the CG. It should be noted that the PS was 99.9% in the values of the DHEA/cortisol ratio in the group wearing a vest (Table 1).

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. AU5 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 postexercise 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 VG compared with the CG, or differences in handgrip strength in response to training.

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 after 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 interexercise/intraexercise 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."

In our study, the global external load was designed to be similar between judokas. However, no indices of fight intensity were measured (psychometric test, performance perception, numbers of actions per fight, etc.). Therefore, future studies addressing this issue are warranted.

The results showed that the factor time (i.e., pre and post) affected temperature and HRV. However, there was only an interaction effect (i.e., time × treatment) on HRV. Although temperature has an influence on HRV, these distinct physiologic mechanisms do not respond in parallel during recovery and after the application of cooling strategies (29). The interaction between plasma volume and autonomic control could play a role in the differences found in the behavior of temperature and HRV; however, conflicting reports exist with respect to these factors (29). Leicht et al. (29) hypothesized that small plasma volume changes likely stimulate baroreflex-mediated parasympathetic activation, whereas large plasma volume changes likely result in an opposite effect (i.e., parasympathetic inhibition and/or sympathetic activation). Hydration status of the participants was not controlled for in the current study, thus future investigations should account this for this potential interaction. Furthermore, although tympanic temperature is reliable, it is not an accurate method to reflect core temperature (19). Therefore, peripheral cold stimulation by cooling vest could have produced peripheral vasoconstriction with its subsequent influence on HRV without any significant effect on core temperature (14).

LnRMSSD, a parasympathetic-based HRV index, showed a significant decrease ($p \leq 0.05$) in the CG, which means that the recovery process may have been attenuated in this group. By contrast, the VG showed no changes after the session, confirming either reduced cardiovascular strain during training or a more rapid parasympathetic reactivation after the training session. Numerous studies have shown that different cooling strategies used in sports training accelerate parasympathetic reactivation after intense exercise in well-trained athletes (10,40,43). Cold exposure may suppress sympathetic activity, whereas arterial baroreflex activation likely results in cardiac parasympathetic modulation (38). Peripheral vasoconstriction after cold stimulation and subsequent changes in blood volume activate low blood pressure baroreceptors that are responsible for reducing the activity of sympathetic nerves while changing the control of autonomic cardiac activity toward a parasympathetic dominance (38).

The use of cooling vests has been suggested as one of the most effective strategies to enhance exercise performance during the preexercise period in moderate ambient conditions (<30°) (5); however, to the best of our knowledge, this is the first study that has reported an impact on parasympathetic reactivation while wearing cooling vests during and shortly after exercise. In this study, cooling vests were used during training, taking advantage of the pauses between bouts of effort and 10 minutes after the training session. This approach was used to mitigate the deleterious effects of exercising in the heat, namely, central fatigue caused by inhibition of brain areas responsible for motor activation, reduced cerebral blood flow, and a low serotonin:dopamine ratio in the hypothalamus (45).

The cardiovascular system plays a key role in facilitating recovery, including thermoregulation and delivery/removal of nutrients and waste products, which are likely affected by the relative intensity of the previous exercise (43). In this sense, the hemodynamic response to exercise represents an interaction between the effects of exercise and the modulating action of the 2 branches of the autonomic nervous system that contributes to restore the cardiovascular system to homeostasis in the short term (i.e., acute action) or set the system in a higher level of homeostasis in the long term (i.e., adaptation action) (43). It has been suggested that a faster cardiac parasympathetic reactivation after a training session is a good marker of cardiovascular recovery, and when parasympathetic reactivation is measured shortly after the session (i.e., 0–90 minutes), may reflect the ability to clear metabolic accumulation (43).

It is well known that cooling techniques applied during recovery produce a temperature drop and accelerate parasympathetic reactivation (29). Accelerated parasympathetic reactivation during training could benefit the cardiovascular response to subsequent stressful situations, such as successive exercise bouts or the next training session. In this sense, faster cardiac parasympathetic reactivation has shown to maintain performance during short training blocks comprised consecutive days of intense exercise (42). However, it has been reported that certain level of sympathetic stimulation is necessary before a high-intensity bout, as an exceeded of parasympathetic activity in a subsequent high-intensity effort can slow oxygen consumption on kinetics and reduce oxygen utilization by muscles (44). Therefore, there is still no consensus with regard to the role of accelerated parasympathetic reactivation after exercise and improvements in subsequent exercise performance when only a short duration (i. e., hours) separates exercise bouts. Future investigations should highlight the effect of different cooling strategies on parasympathetic reactivation and the impact of this phenomenon on subsequent exercise performed within a short time (i.e., hours) as well as any potential long-term adaptations (i.e., days and weeks).

Hormonal variation after exercise may show the catabolic or anabolic tendencies of a specific training load (27). In particular, a noninvasive sampling of salivary hormones, which have been shown to be highly related to serum samples, provides a method highly suitable for the serial follow-up of athletes and may be used as a marker of training stress (20,21,27). However, often findings of these hormonal measures are controversial and may not coincide because of interindividual variability produced by exercise (21) as well as sex, age, training status, nutrition, and time of day (20). In this study, each of these factors was controlled, with the exception of sex, as we would have needed a larger sample in each group to have higher statistical power for comparing the effect of cooling vest regarding sex.

Cortisol is a biomarker that can be used to observe changes in the hypothalamic-pituitary-adrenal (HPA) system because it responds to the body's catabolic activity (27) and is recommended as an indicator of the stress produced by training (20). Dehydroepiandrosterone is a steroid hormone and testosterone precursor released by the adrenal cortex, which plays a regenerative role during the stress response to physical exercise (21,46). Thus, the relationship between cortisol and DHEA is considered a marker of the HPA axis (46). Because DHEA is the predominant adrenal steroid in both sexes, it provides an advantage over testosterone in evaluating the anabolic response to exercise in women (8).

The results of our study demonstrated that the DHEA to cortisol ratio in the VG significantly increased after training but did not seem to be affected in the CG. Furthermore, there is a 99.9% chance that a judo player picked at random from the VG will have a higher increment on DHEA/cortisol than a judo player from the CG. The small effect indicating a potential increase in cortisol for the CG follows the expected hormonal response after high-intensity exercise (27,46); however, the athletes using cooling vests experienced a moderate decrements in cortisol concentration (PS = 68.2%) compared with baseline. Although nonsignificant, the impact on cortisol in the VG may have been related to the purported attenuation of the inflammatory response through cooling-induced vasoconstriction and the associated maintenance of cellular integrity by limiting circulatory and lymphatic permeability (33). Lindsay et al. (30) argue that cooling methods are a very effective strategy for alleviating the catabolic environment and soreness associated with combat sports. These authors compared 2 groups of mixed martial arts competitors with different recovery strategies after training showing that cold-water immersion attenuated increases in salivary cortisol concentrations compared with passive recovery. At the same time, we observed nonsignificant changes in DHEA concentrations after the training session. With consideration for the individual DHEA and cortisol responses to exercise and significant differences in the DHEA to cortisol ratio in the current investigation, the VG may have benefitted from decreased physiological demands for muscle repair and a more rapid recovery process. In this line, Fonseca et al. (15) reported lower increment of muscle damage markers (i.e., lactate dehydrogenase) 24 hours after a jiu-jitsu training (i.e., 120 minutes) where athletes were subjected to a recovery protocol using cold-water immersion (6.08 ± 0.58° C) for 16 minutes. During our study, judo athletes wore cooling vests intermittently during and after the training session. Although distinct differences exist between these protocols, it can be suggested that cooling strategies have a positive impact on the hormonal response to the high-intensity effort required by combat sports. As our results highlight the acute response, additional investigation is needed to determine the potential chronic effects of cooling strategies during training.

Isometric handgrip tests have been used extensively in the literature to evaluate strength in judokas (18), and successive judo bouts reportedly cause a reduction in both hands (7). However, limited research study has been conducted on the effects of judo training sessions on handgrip performance. We found no significant changes in handgrip strength after the judo training session in either group; however, the strength tests were conducted at the end of the measurement protocol, approximately 20 minutes after the session, which may have allowed for sufficient recovery. Although handgrip strength between judokas and nonjudokas have shown to be comparable, judo athletes are more resistant fatigue (1) indicating that forearm muscles are highly used during judo practice. Therefore, it stands to reason that judokas would have high recovery capacity in their forearms and less recovery time should be used in future investigations attempting to analyze the effects of a judo session in handgrip performance. Because pulling and pushing actions are also used during gripping activities in judo, the inclusion of multijoint strength tests should be considered in subsequent studies.

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 (i.e., 24 and 48 hours) or the completion of a crossover design. A small sample size could be taken as a limitation; however, to attenuate the impact of a small sample size, we reported estimates of the ES for the analysis and interpretation of the intrasubject (Hedges' g) and between-subject (standardized mean differences with pooled *SD* of pretest) results. Furthermore, although 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° C) (19). Thus, other methods, such as ingestible telemetric sensors, should be used to monitor core temperature.

PRACTICAL APPLICATIONS

Often judokas must fight in a hot/humid environment during training and competitions. Cooling strategies have been used 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 this study demonstrated that a superficial garment (i.e., cooling vest) reduced the impact of a combat-based judo training on indicators of parasympathetic activity over the heart (i.e., lnRMSDD) and may have induced decreased physiological demands for muscle repair and a more rapid recovery process, as indicated by the significant increase in the DHEA to cortisol ratio in the VG after training. Probably, the absence of effects of the cooling vest on the perceived exertion has its origin such as the effort in judo because the intensity of the effort can be self-regulated according to the preference of the judoka. The self-regulated intensity and the characteristics of strength evaluation (i.e., handgrip test and time of recovery before the evaluation) may have influenced the strength outcomes. Futures studies controlling fight intensity and choosing strength test that best represents the effort in judo are warranted. In addition, this approach should be implemented in a situation of accumulative training to study the mid-term effect on the different parameters that define training load during combat-based judo sessions. However, it seems fair to advise coaches and their judokas to wear the cooling vest whenever they want to prevent a major impact on autonomic heart control and a catabolic state when training in a warm and humid environment. Although cooling vests are being used by many national teams during judo training camps, to the best of our knowledge, this is the first study to investigate the effects of this strategy on a judo training session. During informal interviews, the participants that wore the cooling vests in our study reported that the sensation was comfortable, that they could fight more intensely, and that they believed the vests were a valuable and affordable tool for training in the heat. Nonetheless, more studies are warranted to elucidate the effects of wearing cool vests on strength and endurance during subsequent training sessions, whereas long-term studies would allow for determination of the effects on the adaptation of physical capacities.

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