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CLINICAL FEATURE
ORIGINAL RESEARCH

The use of continuous vs. intermittent cold water immersion as a recovery method in basketball players after training: a randomized controlled trial

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ABSTRACT

Objectives: The main objective of this study was to compare two cold water immersion protocols, continuous or intermittent, on recovery in basketball players.

Methods: Ten male basketball players (age: 14 ± 0.4 years, body mass: 65.4 ± 9.1 kg, height: 175 ± 7.3 cm, body fat %: 10.3 ± 4) were included in the study. After three 90-minute training sessions (avg. heart rate 158 ± 11.92, 156 ± 7.06 and 151 ± 10.44 bpm), participants were grouped into a continuous immersion (12 min at 12 ± 0.4°C) group, intermittent immersion (4 x 2 min immersion at 12 ± 0.4 °C + 1 min out of water) group and a control group (CG). Countermovement jump (CMJ), muscle pain and thigh volume were measured.

Results: Both cold water immersion protocols were effective in reducing the pain 24 and 48 hours after training compared with the CG (F (3.54) = 2.91, p = 0.016, η_p^2 = .24). Concerning CMJ change, % differences occurred at 24 (Z = 11.04, p = 0.004) and 48 hours (Z = 14.01, p < 0.001) in comparison with the CG. Regarding the muscle volume, the statistical analysis did not report a significant interaction (F (3.54) = 2.42, p = 0.058).

Conclusion: Both cold water immersion CWI protocols are effective in improving recovery in basketball players.

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KEYWORDS
Recovery; basketball; hydrotherapy; performance

1. Introduction

Cold water immersion (CWI) has become a recovery method most used by specialists in sports sciences who seek to minimize fatigue and accelerate recovery processes [1,2]. In this way, several reviews of these methods [2–4] as well as meta-analyses [5–8] have demonstrated the beneficial effect of these techniques in recovery, while another meta-analysis reports no significant effect in recovery [9,10]. Specifically, experimental studies indicate that CWI generates a series of physiological changes including reductions in skin and core body temperatures [11,12], acute inflammation [4], muscle spasms and sensations of pain [13,14], localized edema [15], physiological and functional symptoms related to delayed-onset muscle soreness (DOMS) [16–18], fatigue perception [19], and creatine phosphokinase (CPK) levels [15,20,21] as well as improvement in recovery perception [18,22]. However, other studies have reported that this type of recovery technique has no effect or even detrimental effects on recovery [21,23]. Most of these studies have compared CWI under control or passive recovery conditions, using continuous immersions [15,23–26]. Conversely, CWI techniques have been used intermittently, and these studies have concluded that this form of immersion does not have any effect on recovery and performance [19,27,28]. Furthermore, another study [29] reports positive effects on recovery using CWI intermittently. These conflicting findings make it necessary to find more scientific evidence to develop definite conclusions.

Despite the extensive dissemination and use of this recovery technique [2], to the best of our knowledge, there are only two studies that have reported on the use of this technique in basketball players [17,22]. Both of these studies used CWI intermittently, reporting positive effects on player recovery; however, there are no reports of studies in basketball players using continuous CWI (CnCWI) or that have compared continuous and intermittent CWI (InCWI). The physiologic mechanisms proposed for the use of intermittent immersions include a pumping effect caused by the vasoconstriction and vasodilatation, which occur due to the change of temperature. This pumping effect stimulates the transport of waste and nutrients in the body [4]. Continuous immersions are advocated due to the higher exposure to the cold and enhanced effects of vasoconstriction and hydrostatic pressure, which together facilitate processes such as the rapid diminution of body temperature and an acceleration in processes associated with a decrease in pain [30]. Based on the above studies, our hypothesis was that the response of recovery indicators varies significantly depending on the type of CWI protocols. Therefore, the main purpose of this study was to compare the effect of two CWI protocols in the recovery in basketball players.

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2. Methodology

2.1. Experimental design

The distribution of participants into groups was made using a table of random numbers. A counter-balanced crossover design was applied in which players in experimental group 1 received CnCWI, subjects in experimental group 2 received InCWI, and subjects in the control group (CG) underwent passive recovery, as shown in Figure 1. This study was carried out at the beginning of the period of competition.

2.2. Participants

A complete basketball team comprising players who were between 14 and 15 years (14 ± 0.4 years) of age with a body mass of 65.4 ± 9.1 kg, a height of 175 ± 7.3 cm, and a fat percentage of 10.3 ± 4.3% participated in this study. Players had a sporting experience of 3 years on average (3 ± 1). The players had three-weekly training sessions. Each training session lasted 1:30 h, and players also participated in competition once a week, resulting in a total of 22 games during the regular season (Figure 1). Their participation in the study was voluntary, and the experimental procedures, associated risks, and benefits were explained to each player documented in an informed consent form signed by their parents. The study was designed according to recommendations for clinical research by the World Medical Association Helsinki Declaration, Fortaleza, 2013. The protocol was reviewed and approved by the ethics committee of the Faculty of Sports Sciences of the Universidad de Extremadura. The criteria used for excluding players from the study included musculoskeletal or joint injuries during the last 2 months and not having medical permission to carry out high-intensity exercises.

2.3. Materials and methods

2.3.1. Body composition and anthropometric measures

Body mass was determined using a Tanita Ironman (Tanita Corporation, Tokyo, Japan) (model BC-1500, Japan) with ±0.1 kg precision. Height was measured using a wall stadiometer. Fat percentage was calculated using the Jackson and Pollock formula on skinfold data from seven sites (chest, midaxillary region, subscapular region, triceps, suprailiac, abdomen, and thigh) [31] using a Lange skinfold caliper from Beta Technology (Cambridge, UK). These measurements were taken under the International Society for the Advancement of Kinanthropometry protocol [32], and all participants were measured by an experienced researcher.

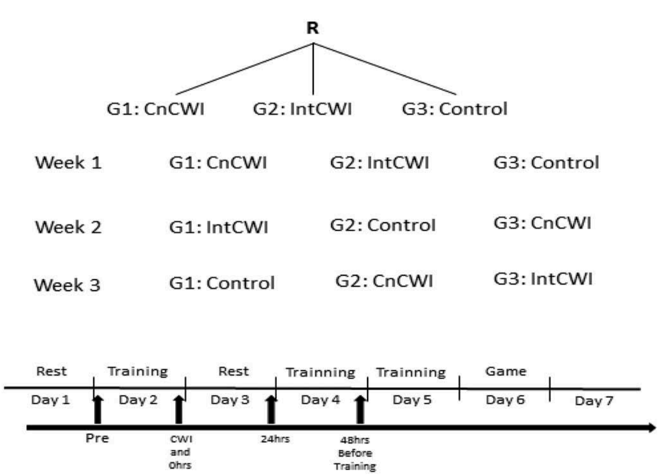

Figure 1. Random treatment assignments and weekly work diagram during the study.
Note: R: random assignment

Water temperature was controlled and recorded using a digital thermometer 'DeltaTrak,' Model 12,207 (Lima, Peru) at 1-min intervals.

WIMUTM (RealTrack Systems, Almería, Spain), an inertial performance device designed for controlling and monitoring of physical activity, can be used both indoor and outdoor. *WIMUTM* consists of several sensors, including accelerometers or gyroscopes, and includes Global Positioning System technology. The device also records physical activity on Garmin Premium cardiac tape (pulsometer).

2.3.2. Recovery and performance indicators

2.3.2.1. Perceived pain. The visual analogic scale (0–10) was used to measure perceived pain by the subjects. In this case, 0 indicates no pain and 10 indicates extreme pain. To determine the pain level, subjects were asked to perform a 90-degree half squat and indicate the muscle pain perceived at the thigh level. This method has been previously used as a noninvasive form of monitoring changes in pain perception after exercising and consequent muscle injury. This type of perceptual score has been used in several studies to evaluate the effectiveness of recovery interventions after high-intensity intermittent exercises [13,27].

2.3.2.2. Thigh volume and circumference. Thigh volume and circumference were measured with an anthropometric measuring tape. Circumference was measured at two locations on the leg, sub-gluteal, and above the knee. A permanent marker was used to ensure retest reliability (before the recovery protocol and at 0, 24, and 48 h after treatment). These data allow the calculation of the thigh volume, which is an indicator of inflammation and muscle injury [33]. The formula developed by [34] was used to calculate muscle volume as follows:

$$\mathrm{Vol} = h/12 \times \pi \times \left[C1^2 + C2^2 + (C1) \times (C2)\right],$$

where h = high thigh; Π = 3.14; C1 = sub-gluteal circumference; C2 = above knee circumference.

2.3.2.3. Jumping ability. The countermovement jump (CMJ) test was performed using the Bosco protocol. Measurements were carried out using an OptoJumpNext 'Ob' by Microgate Bolzano (Italy). Three trials were carried out with a 2-min recovery time, and the best jump was recorded for each measurement episode. A CMJ presents the test–retest reliability for jump height with intraclass correlation (0.98). The CMJ performance is characterized by a very low variability between tests (coefficient of variation of 3.0%) [35]. All variables were measured before (baseline) and immediately after the recovery protocol (0 h) as well as at 24 and 48 h after treatment.

2.4. Procedure

The anthropometric characteristics of subjects in the study sample were measured 2 days before carrying out the trial. Baseline measurements for dependent variables were taken 2 h before the experimental protocol was applied. Performance and recovery variables were measured in the following order: muscle pain perception, muscle volume and circumference, and the CMJ test. Additionally, dietary and exercise control was achieved by instructing participants to abstain from caffeine and alcohol for 24 h to avoid strenuous exercise for 8 h prior to testing and to maintain their normal diet before both testing days

2.4.1. Fatigue protocol

Subjects underwent three 90-min sessions focused on training technical and tactical skills (average hazard ratio: 158 ± 11.92 bpm; 156 ± 7.06 bpm; and 151 ± 10.44 bpm, respectively). The structure of the training sessions was similar consisting of 10 min of activity with technical and tactical elements, 5 min of active stretching, and 75 min of training divided into approximately seven to eight 10-min tasks.

2.4.2. Recovery protocol

Participants rotated through the following three conditions of the study: CnCWI protocol (12-min immersion with temperature at 12 ± 0.4°C), CWI protocol (4 times × 2-min immersion with temperature at 12 ± 0.4°C + 1 min out of water at room temperature), and CG (passive recovery, 12-min sitting down). These protocols were selected because the temperature range between 5ºC and −20ºC and the time of immersion, 5–15 min, were recommended by [2], as well as [8] who reported that protocols with temperature ranges between 11ºC and 15ºC for 10–15 min had a positive effect size compared to protocols with temperature between 5ºC and 10ºC with an immersion time under 10 min.

The immersions were carried out in a 5 × 2.4-m inflatable swimming pool, and ice was used to lower the water temperature. Subjects were sitting during immersion, with their legs completely extended, and the water reaching navel height. Immersions were carried out immediately after the training session. Dependent variables were measured again at 0 h or immediately after the recovery protocol and again 24 and 48 h after treatment, in the same order as the baseline measurements.

2.5. Statistical analysis

Descriptive statistics (mean and standard deviation) were calculated for all variables. The normality of the data was evaluated using the Shapiro–Wilks test. The results indicated normality for all variables except muscle volume and CMJ performance, which were analyzed in terms of percentage change with respect to the previous value (baseline). Since the values of these two variables were not normally distributed, another nonparametric statistical analysis was carried out, using the Kruskal–Wallis *H* test. The other variables were analyzed with their own measurement units. The Levene test was used to analyze homogeneity of variances. Repeated-measures analysis of variances was used to compare the muscle pain between baseline, postexercise, and at 24 and 48 h after exercise. The Bonferroni *post hoc* analysis was used when it was appropriate. The effect size was calculated by η_p^2. Statistical Package for the Social Sciences (SPSS) was used for statistical analysis (IBM, SPSS Statistics, V. 21.0, Chicago, IL, USA). The level of significance was $p < .05$.

3. Results

Table 1 shows descriptive data for the variables associated with recovery for each of the experimental conditions (CnCWI, InCWI, and CG) at different moments of measurement, and statistically significant differences were only found for perceived muscle pain and CMJ ($p < .05$); details are shown in the figures.

Figure 2 shows a significant interaction (F (3,54) = 2.91, p = .016, η_p^2 = .24) with both immersion protocols (CnCWI and InCWI) in significantly reducing pain perception compared with the perceptions of subjects in the CG (passive recovery) in the measurements immediately after immersion (CnCWI vs. CG, $p < .001$) (InCWI vs. CG, p = .009), at 24 h (CnCWI vs. CG, p = .011) (InCWI vs. CG, p = .024), and at 48 h after immersion (CnCWI vs. CG, p = .014) (InCWI vs. CG, p = .022). Statistically

Table 1. Descriptive statistics means and standard deviations of the dependent variables analyzed for the groups continuous cold water immersion (CnCWI), intermittent cold water immersion (InCWI), and control group (CG) (passive recovery) measured before exercise (baseline), immediately after recovery protocol (0 h), and at 24 and 48 h after recovery.

	CnCWI		InCWI		CG	
Variables	Mean	SD	Mean	SD	Mean	SD
Perceived muscle pain (UA) (0 = no pain and 10 = extremely painful)[a]						
Baseline	4.18	1.21	3.42	1.39	4.28	1.38
0 h	2.21	1.07	3.14	1.46	5.71	1.49
24 h	2.42	1.51	2.71	1.38	4.92	1.17
48 h	2.35	1.37	2.5	1.60	4.71	0.95
Thigh muscle volume (ml)						
Baseline	4620.6	840.5	4745.9	1160.4	5176.7	1094.7
0 h	4564.4	842.5	4633.7	1206.9	5025	1199.4
24 h	4650.7	860.6	4715.7	1107.9	4874.5	1098.4
48 h	4597.7	991.6	4668.7	1217.1	4873	1098.7
Countermovement jump (cm)[a]						
Baseline	43.4	4.67	42.58	4.52	44.98	7.12
0 h	42.25	4.66	41.52	4.35	44.64	6.78
24 h	42.5	4.65	41.9	4.27	41.82	7.47
48 h	42.92	4.93	42.37	4.45	41.98	7.56

SD: standard deviation; UA: arbitrary unit.
[a]Significant difference ($p < .05$) in the behavior of this variable.

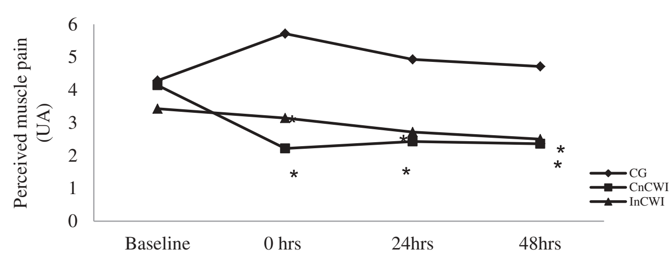

Figure 2. Comparison of perceived muscle pain between experimental groups with respect to the control group.
Note: *: significant differences with respect to control group ($p < .05$), UA: arbitrary unit, CG: control group, CnCWI: continuous cold water immersion, InCWI: intermittent cold water immersion.

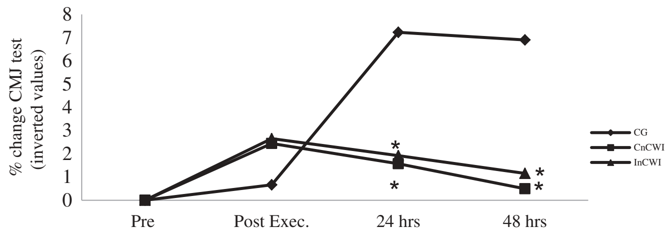

Figure 3. Comparison of changes as analyzed using the CMJ test (%).
Note: * = significant differences with respect to control group (p < 0.05), CG: control group, CnCWI: continuous cold water immersion, InCWI: intermittent cold water immersion.

significant differences were not reported when comparing the baseline value with measurements after immersion in any of the groups. Statistically significant differences were not reported ($p > .05$) at any of the times of measurement when comparing the group that underwent continuous immersions with the group that underwent intermittent immersions.

Figure 3 indicates statistically significant differences in jump capacity via analysis using the CMJ test, at 24 h ($Z = 11.04$, $p = .004$ when comparing the CnCWI and InCWI with the CG [passive recovery] [CnCWI vs. CG, $p = .006$] [InCWI vs. CG, $p = .029$]) and at 48 h after training ($Z = 14.01$, $p < .001$) (CnCWI vs. CG, $p < .001$) (InCWI vs. CG, $p = .017$). No statistically significant differences ($p > .05$) were reported when comparing the groups that underwent continuous immersions with the group that underwent intermittent immersions at any of the measurement times. Regarding the muscle volume, the analysis did not report significant interaction (F (3,54) = 2.42, $p = .058$).

4. Discussion

The present study is intended to analyze the effects on recovery of two CWI protocols including the CnCWI protocol (12-min immersion at 12 ± 0.4°C) and the CWI protocol (4 times × 2-min immersion at 12 ± 0.4°C + 1 min out of water at room temperature) after exercising compared to passive recovery. The main finding is that both immersion protocols proved to be effective for reducing the signs of fatigue and for specifically delaying the onset of muscle soreness (DOMS); they also proved to have positive effects on jumping capacity recovery measured using the CMJ test.

In the case of DOMS, continuous immersions under the protocol of 12 min at 12 ± 0.4°C proved to be effective in reducing muscle pain, both immediately after immersion and at 24 and 48 h after exercise. These results disagree with those of other studies [15,36] but support those reported by [16–18], which indicate that CWIs reduce physiological and functional signs related to DOMS, confirming that using CWI under these protocols is effective. The results also reinforce that protocols in which temperatures range between 11ºC and 15ºC with an immersion time of 10–15 min have a positive effect [8] and that CWI techniques seem to be more effective at accelerating performance recovery in various sports using 5–15 min immersions at a water temperature of 5–20°C [2].

In the case of intermittent immersions under the protocol of 4 times × 2 min of immersion with a water temperature of 12 ± 0.4°C + 1 min out of water at room temperature, the results obtained disagree with those reported by [28]. When used the protocol of 3 × 1 min of immersion at 5 ± 1°C, with 1 min out of the water, they did not report positive effects on DOMS upon comparing the experimental group with the CG.

Our results agree with those reported by [19] who used a protocol of 5 min × 1 10 ± 0.5°C + 1 min out of water at room temperature and reported positive effects of intermittent immersion. These studies agree with the results those reported by [22], who found significant differences both immediately after the immersion protocol and at 24 h after training in comparison to the CG for the group of women in their study using a protocol of 5 × 2 min of immersion with a water temperature of 11 ± 0.7°C + 2 min out of water at room temperature.

Likewise, the authors in [29] reported significant differences at 24 h after treatment between the group of intermittent immersions and the CG, using the protocol of 2 × 5 min of immersion with water temperature at 10°C and 2.5 min out of water at room temperature 21°C ± 0.5. This study is the first to report such differences both immediately and at 24 and 48 h after exercise, indicating that the protocol used was characterized by a 2:1 ratio and is effective for reducing muscle pain.

A possible physiological explanation could be that DOMS reduction may be associated with the reduction of acute inflammation [4], the presence of muscle spasms [13,14], and the effect of the hydrostatic pressure [5]. Another explanatory mechanism is that exposure to cold has demonstrated the potential activation of the transient receptor 8 of melastatin (TRPM8) [37], which is related to the sensations of pain and temperature [38,39]. Once activated, the TRPM8 analgesic effect given by the action of inhibitory interphase neurons [38] improves the perception of DOMS and increases the sensation of recovery [30].

It is also important to indicate that exposure to cold causes changes in the neurotransmitters dopamine and serotonin, which are responsible for regulating mood, sleep, emotions, motivation, perception of pain, and fatigue level. Undergoing CWI protocols could help mitigate central nervous system fatigue [30] and suggests that an increase in the serotonin/dopamine ratio is associated with tiredness and rapid onset of fatigue, while a low serotonin/dopamine ratio favors a better performance through maintenance and physiological activation.

Regarding jumping capacity measured through CMJ, both immersion protocols proved to be more effective than passive recovery, which is in agreement with previous studies [15]. Using a continuous immersion protocol, reported differences were observed between the group that underwent immersions with respect to the CG in terms of performance using the SquatJump test at 48 and 72 h after exercise but not at 24 h after exercise between both groups.

As for intermittent immersion [22], the use of a protocol 5 min after the completion of the match and consisted of five 2-min intermittent immersions of the lower limbs (up to the iliac crest) in a cold water bath (11°C), separated by 2 min rest in ambient air (sitting, room temperature of 20°C), resulted in statistically significant differences 24 h after immersion in the CMJ test with respect to the CG, which is in agreement with the findings of the present study.

Regarding thigh volume, the results obtained in this study coincide with those reported by [40], who also observed that continuous dives did not significantly decrease edema measured at 24, 48, and 72 h posttreatment. Similar reports were given by [4], demonstrating that using a continuous immersion protocol did not result in significant decreases in muscle edema in the immediate posterior measurement. The authors of [4] also indicated that the edema (thigh circumference) indicator varied less throughout the treatment for the cold water group than the compression stockings group and the CG, which are similar to the results of the present study. A possible explanation is that the load to which the players were exposed did not cause sufficient muscle damage to generate significant edema.

The results obtained in the present study allow professionals in sports sciences, such as physical trainers, to aid in choosing the best protocol for their athletes according to their preference, as both protocols are effective. In summary, CnCWI and InCWI protocols have same effect on improving the recovery process in basketball players.

It is necessary to carry out more studies in this area to compare different CWI protocols, including the measurement of biochemical variables such as CPK and lactate dehydrogenase as well as physiological tensiomyographic variables such as reaction time, contraction time, and muscle relaxation time. In addition, it is necessary to test different intermittent immersion protocols that consider immersion time, relationship of the time in and out of water, and different temperatures to increase empirical support for the definition of the most appropriate protocol according to the type of sport. Regarding the immersion time and temperature, the authors of [8] have made a significant contribution to reporting that protocols with temperature ranges between 11ºC and 15ºC and with an immersion time of 10–15 min have a positive effect size compared to protocols with temperature ranges between 5ºC and 10ºC and an immersion time under 10 min. Finally, the limitations of this study are consonance with the sample size, subjects who were not professional players, and a lack of biochemical variable analysis in the study.

5. Conclusion

Considering the effectiveness of both protocols, coaches and trainers could choose CnCWI or InCWI depending on the tolerance and cold preference of the athletes.

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Declaration of interest

The authors have no relevant affiliations or financial involvement with any organization or entity with a financial interest in or financial conflict with the subject matter or materials discussed in the manuscript. This includes employment, consultancies, honoraria, stock ownership or options, expert testimony, grants or patents received or pending, or royalties.

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