Original Article

Comparison of cold water immersion protocols in female handball players after match training

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ABSTRACT

Purpose: Compare the effect of two protocols cold water immersion on indicators of recovery in female handball players. Methods: 12 female handball players (Age: 14 ± 0.7 years, body mass: 58.44 ± 7.8 kg, Height: 161± 7.1 cm, fat %: 21.5± 3) were involved in a “cross-over” experimental design. After three training sessions (Avg heart rate 183 ± 9, 180 ± 8 and 180 ± 8b/pm respectively), participants were placed a continuous cold water immersion protocol (*n*=12), (12 min water temperature 14± 0.5C°), intermittent cold water immersion protocol (*n*=11), (4 x 2 min water temperature 14 ± 0.5C° + 1min out of water) and control group (CG) with passive recovery (*n*=9). Countermovement jump test (CMJ), Visual Analog Scale (VAS-Pain) and thigh volume were measured. Results: Both cold water immersion protocols were effective in reducing the pain immediately post immersion, 24 and 48 hours after training compared with the CG ($F_{(4,116)}$ = 6.84, p < 0.001. ωp^2: 0.32). CMJ ($F_{(4,116)}$ = 1,79, p =.11, ωp^2: 0.02) and thigh volume ($F_{(4,116)}$ = 0.77, p =.59, ωp^2: -0.007) did not report statistically significant changes at any time of measurement. Conclusions: Both CWI protocols are effective to reduce delayed on set muscle soreness at all times post training in female handball players. CWI should be included after training sessions to enhance players’ recovery for the next training day. CWI protocol could be used according to individual preferences due to both of them have same effect

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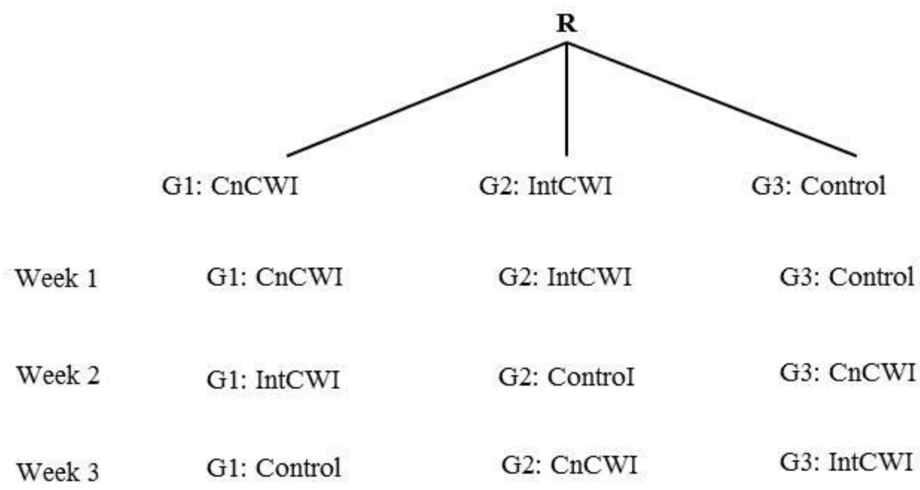
INTRODUCTION

An adequate recovery from exercise is essential to maintain performance throughout training and competitions (Brown et al., 2017). In recent years, the use of cold water immersion (CWI) has become a recovery method most used by specialists in sports sciences who seek to minimize fatigue and improve the recovery processes (Calleja-González et al., 2016, Versey, Halson, & Dawson, 2013). Several reviews (Burgess & Lambert, 2010; Versey, Halson, & Dawson, 2013; Wilcock, Cronin, & Hing, 2006) as well as meta-analyses (Graham, 2017; Hohenauer et al., 2015; Leeder et al., 2012; Machado et al., 2016; Sánchez-Ureña et al., 2015) have demonstrated the beneficial effect of these techniques in recovery, while another metanalysis reports no significant effect in recovery (Higgins, Greene, & Baker, 2016; Murray & Cardinale, 2015). The physiological mechanisms proposed for the use of CWI are attributable to cold induced vasoconstriction of blood vessels, muscle tissue cooling and increases in hydrostatic pressure. The combination of these mechanisms lead to a reduction in blood flow, decreased oedema formation and inflammation, decreased cell permeability and a reduction in secondary oxidative metabolism (Graham, 2017, Leeder et al., 2012; Wang & Siemens, 2015). Other physiological mechanisms proposed for the use of CWI are attributable to cold exposition that has demonstrated potential activation of the transient 8 receptor of melastatin (TRPM8) (Wang y Siemens, 2015). On this arguments, experimental studies indicate that CWI generates a series of physiological changes including reductions in skin and core body temperatures (Peiffer et al., 2009; Yanagisawa et al., 2007), acute inflammation (Wilcock, Cronin, & Hing, 2006), muscle spasms and sensations of pain (Vaile, Gill, & Blazevich, 2007; Sánchez-Ureña et al., 2017), localized edema (Vaile, Halson, Gill, & Dawson, 2008), fatigue perception (Rowsell et al., 2009), and creatine phosphokinase (CPK) levels (Ascensao et al., 2011; Crowe, O'Connor, & Rudd, 2007; Vaile, Halson, Gill, & Dawson, 2008), physiological and functional symptoms related to delayed-onset muscle soreness (DOMS) (Elias et al., 2013; Montgomery et al., 2008; Stanley et al., 2012), as well as improvement in recovery perception (Delextrat et al., 2012; Stanley et al., 2012). However, other studies have reported that this type of recovery technique has no effect or even detrimental effects on recovery (Crowe et al., 2007; Peiffer et al., 2009). Most of the studies referenced previously have compared CWI under control or passive recovery conditions, using continuous immersions. However, few studies have used intermittent immersion and they have concluded that this form of immersion does not have any effect on recovery and performance (Rowsell et al., 2009, 2011; Sellwood et al., 2007). Furthermore, other studies (Deletrat et al., 2012; Ingram et al., 2009; Sánchez- Ureña et al., 2017), reports positive effects on recovery using CWI intermittently. To the best of our knowledge, there are no studies on the use of CWI in female handball players. Based on this situation, the main purpose of this study was to compare the effect of two CWI protocols in the recovery in youth female handball players.

MATERIALS AND METHODS

Study 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 a continuous cold-water immersion (CnCWI), subjects in experimental group 2 received an intermittent cold water immersion (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.



Note. R: random assignment

Figure 1. Random treatment assignments and weekly work diagram during the study.

Participants

12 female handball players (age: 14 ± 0.7 years, weight: 58.44 ± 7.8 kg, height: 161 ± 7.1 cm, body fat: 21.5 ± 3.5%). On average, players have been practicing handball three times per week for three years. Their participation in the study was voluntary and an informed consent form was signed by their parents or guardians. 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.

Measurements

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 three sites (triceps, suprailiac, abdomen,) (Jackson y Pollock, 1990), using a Lange skinfold caliper from Beta Technology (Cambridge, UK). These measurements were taken under the International Society for the Advancement of Kinanthropometry protocol (Stewart et al., 2011), and all participants were measured by an experienced researcher.

Recovery and performance indicators

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 (Rowsell et al., 2011; Sánchez- Ureña et al., 2017; Vaile, Gill, & Blazevich, 2007).

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 (Eston & Peter, 1999). The formula developed by Katch & Kacth (1974), was used to calculate muscle volume as follows:

$$Vol = h=12 \times \Pi \times [C12 + C22 + (C1) \times (C2)]$$

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

Jumping performance

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%) Markovic et al. (2004), All variables were measured before (baseline) and immediately after the recovery protocol (0 h) as well as at 24 and 48 h after treatment.

Internal load

The heart rate (HR) was monitored using a Polar Team System (Polar Electro Iberia, Barcelona, España).

Water temperature

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

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.

Fatigue protocol

Subjects underwent three 60-minute training match, (Average HR per match (183 ± 9 bpm, 180 ± 8 bpm and 180 ± 8 bpm, respectively). Each training match was 60 minutes in duration (two periods of 30 minutes with 10 minutes of break).

Recovery protocols

Participants rotated through the following three conditions of the study: CnCWI protocol (12-min immersion with temperature at 14 ± 0.5°C), CWI protocol (4 times × 2-min immersion with temperature at 14 ± 0.5°C + 1 min out of water at room temperature), and CG (passive recovery, 14-min sitting down at 20C° (room temperature).

These protocols were selected because the temperature range between 5ºC and −20ºC and the time of immersion, 5–15 min, were recommended by Versey et al. (2013), as well as Machado et al. (2016), 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.

Statistical Analysis

Descriptive statistics (mean and standard deviation) were calculated for all variables of interest. Assumptions of normality and homogeneity of variances were assessed by Shapiro Wilk's test and Levene test, compound symmetry "Box M" and sphericity "Mauchley", respectively. Mixed ANOVA was used to compare all variables. Bonferroni post hoc analysis was used when it was appropriated. All data were analyzed using SPSS package, version 21.0. Significance was set at $p < 0.05$ level.

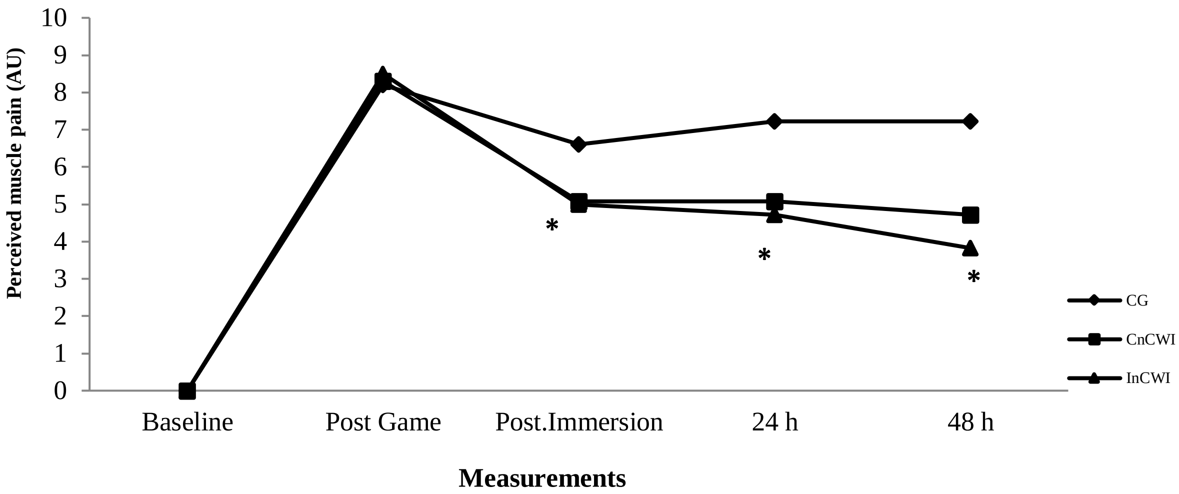
RESULTS

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), post training, post immersion, and at 24 and 48 h after recovery.

	Baseline	Post Training	Post Immersion	24 h	48 h
	X ± SD	X ± SD	X ± SD	X ± SD	X ± SD
Thigh Volumen. (ml)					
CG	5009 ± 515	5150 ± 525	5136 ± 550	5124 ± 557	5171 ± 728
CnCWI	4949 ± 535	5119 ± 545	4944 ± 560	4947 ± 560	4974 ± 583
InCWI	4967 ± 766	5125 ± 600	4956 ± 751	4937 ± 591	4959 ± 656
Jump height in CMJ (cm)					
CG	35,9 ± 5,3	32,3 ± 4,3	31,6 ± 9,8	35,5 ± 5,5	35,4 ± 4,7
CnCWI	36,3 ± 5,4	33,6 ± 4,8	32,3 ± 9,4	34,3 ± 9,6	35,5 ± 3,8
InCWI	35,8 ± 5,2	33,2 ± 4,9	31,4 ± 9,9	36,5 ± 6,7	36,3 ± 5,6

Note: X: means; SD: standard deviation; CMJ: counter movement jump

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, not statistically significant differences were in thigh volume ($F_{(4,116)} = 0.77$, p =.59, ωp^2: -0.007) and Jump height in CMJ ($F_{(4,116)} = 1,79$, p =.11, ωp^2: 0.02).



*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 2. Comparison of perceived muscle pain between experimental groups with respect to the control group.

Figure 2 shows a significant interaction ($F_{(4,116)} = 6.84$, $p < 0.001$. ωp^2: 0.32) 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 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.

DISCUSSION

This study is intended to analyze the effects on recovery of two CWI protocols including the CnCWI protocol (12- min immersion at 14 ± 0.5°C) and the CWI protocol (4 times × 2-min immersion at 14 ± 0.5°C + 1 min out of water at room temperature) after exercising compared to passive recovery in youth female handball players.

The main finding is that both immersion protocols proved to be effective for reducing the signs of fatigue, specifically delaying the onset of muscle soreness (DOMS); but not 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 14 ± 0.5°C proved to be effective in reducing muscle pain, both immediately after immersion and at 24 and 48 h after exercise, coinciding with that reported by (Elias et al., 2013; Sánchez-Ureña et al., 2017; Stanley et al., 2012), which indicate that CWIs reduce physiological and functional signs related to DOMS, confirming that using CWI under these protocols is effective. The results also give solvency that protocols in which temperatures range between 11ºC and 15ºC with an immersion time of 10–15 min have a positive effect (Machado et al., 2015) 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 (Versey et al., 2013), however these results disagree with those of other studies (Glasgow, Ferris, & Bleakley, 2014; Vaile et al., 2008).

In the case of intermittent immersions under the protocol of 4 times × 2 min of immersion with a water temperature of 14 ± 0.5°C + 1 min out of water at room temperature, the results obtained disagree with those reported by Sellow et al. (2007), they 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 Rowsell et al. (2009), 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 Delextat et al. (2012), 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.

Also, Ingram et al. (2009), 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.

This results, are in same line with a similar study by Sánchez-Ureña et al. (2017), reported significant differences both protocols immediately after the immersion protocol, at 24 h and 48 h after training in comparison to the CG for the group using a continuous protocol 12 min of immersion with a water temperature at 12 ± 0.5° C and intermittent protocol 4× 2 min of 12 ± 0.5° C + 1 min out of water at room temperature.

According with Wilcock et al. (2006), between a possible physiological reason could be that DOMS reduction may be associated with the reduction of acute inflammation, reduce the presence of muscle spasms (Vaile et al., 2007; Washington et al., 2000), and the effect of the hydrostatic pressure (Leeder et al., 2012). Another explanatory mechanism is that exposure to cold has demonstrated the potential activation of the transient receptor 8 of melastatin (TRPM8) (Wang & Siemmes, 2015), which is related to the sensations of pain and temperature (Knowlton et al., 2013; Proudfoot et al., 2006). Knowlton et al. (2013), indicated once activated the TRPM8 analgesic effect given by the action of inhibitory interphase neurons improves the perception of DOMS, increases the sensation of recovery (Ihsan, Waston, & Abbiss, 2016).

It is also important to indicate that exposure to cold causes changes in the neurotransmitters dopamine and serotonin, which are responsible for regulating the perception of pain, and fatigue level. Undergoing CWI protocols could help decrease central nervous system fatigue 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 (Ihsan et al., 2016).

Regarding jumping capacity measured through CMJ, both immersion protocols not proved to be more effective than passive recovery, these results are agreement with previous studies such as Vaile et al. (2008)

in the measured at 24 h, they reported not differences. However, are in disagree whit they reporter at 48 h reported differences were observed between the groups that underwent immersions with respect to the CG in terms of performance using the Squat Jump test, using a continuous immersion protocol. Too are disagree with reported by Sanchez-Ureña et al. (2017), who observed significant differences between immersion group versus CG at post immersion, 24 h and 48 h measured using a continuous protocol 12 min at 12 ± 0.4°C.

In reference to intermittent immersion, this results are in disagree with reported by Delextrat et al. (2012), they used 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. Likewise, are in contrast with reported by Sanchez-Ureña et al. (2017), who observed significant differences between immersion group versus CG at post immersion, 24 h and 48 h measured using an intermittent protocol 4 x 2 min immersion at12 ± 0.4 °C + 1 min out of water), Important to point out bout studies was in basketball players.

To explain the behavior of the results obtained Takeda et al. (2014), indicate that CMJ has usually been considered as an indicator of neuromuscular performance, since after exercise-induced muscle damage, a decrease in CMJ is a result of impaired neuromuscular function and efficiency, due to the reduction of both, the frequency as the intensity, which the nerve impulse reaches the muscle. However, (Higgins et al., 2016; Pruscino, Halson, & Hargreaves, 2013), they point out that the recovery of neuromuscular function depends not only on issues related to reducing the damage induced by exercise, but is also influenced by other physiological factors such as muscle activation, muscle coordination, level of fiber recruitment in motor plate by the nervous system.

Regarding thigh volume, the results obtained in this study coincide with those reported (Montgomery et al., 2012; Sánchez- Ureña et al., 2017), who also observed that continuous dives did not significantly decrease edema measured at 24 and 48h post treatment. Similar reports were given by Wilcock et al. (2006), demonstrating that using a continuous immersion protocol did not result in significant decreases in muscle edema in the immediate posterior measurement. In case of intermittent protocols Sánchez- Ureña et al. (2017), reported similar results in post immersion, 24 and 48 h post fatigue.

Wilcock et al. (2006), 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 had similar effects on improving the recovery of DOMS in handball players. However, more studies are necessary with in handball players boutsex and preferable in elite athletes where are analyzed biochemical variables such as CPK and lactate dehydrogenase as well as physiological tensiomyographic variables such as reaction time, contraction time, and muscle relaxation time.

CONCLUSION

Considering the effectiveness of protocols for reduce the pain sensation, coaches and trainers could choose CnCWI or InCWI before training sessions, depending on the tolerance and cold preference of the handball players.

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