

# The effects of tow protocol cold water immersion on the post match recovery and physical performance in well-trained handball players

Mokhtar M.<sup>1ABDE</sup>, Adel B.<sup>1BCDE</sup>, Wahib B.<sup>2ABC</sup>, Hocine A.<sup>3BC</sup>, Othman B.<sup>1CD</sup>, Mohamed S.<sup>2CDE</sup>

<sup>1</sup>Laboratory of Optimizing Research Programmes on Physical and Sports Activities, Institute of Physical Education and Sport, University of Mostaganem, Algeria

<sup>2</sup>Laboratory of Applied Sciences to Human Movement Institute of Physical Education and Sport, University of Mostaganem, Algeria

<sup>3</sup>Institute of Physical Education and Sport, University of Oran, Mostaganem, Algeria

Authors' Contribution: A – Study design; B – Data collection; C – Statistical analysis; D – Manuscript Preparation; E – Funds Collection.

## Abstract

**Purpose:** The purpose of this study is to compare two cold water immersion (CWI) protocols, continuous and fractionated, to optimize the recovery of Handball players after on recovery from exercise resulting in exercise-induced muscle damage.

**Material:** Ten male Handball players (age:  $15 \pm 1.4$  years, mass index:  $67.2 \pm 5.1$  kg, height:  $176.6 \pm 7.30$ ) voluntarily participated in the study. After three 90-minute training sessions (average heart rate  $160 \pm 15.81$ ,  $156 \pm 5.53$  and  $156 \pm 12.24$  bpm) per week, participants were divided into 03 groups. The first experimental group (GE1) in continuous immersion (CWIC) of (12 minutes,  $12 \pm 0.4^\circ$  C), a second experimental group (GE2) in fractional immersion (CWIF) of (4 x 2 min at  $12 \pm 0.4^\circ$  C + 1 min out of water) and a control group (GC) in passive recovery. Body mass indices (BMI), countermovement (Countermovement jump) and muscle pain (Intensity of pain in the thighs) were measured.

**Results:** The results concerning the percentage differences in the variation of the CMJ occurred respectively at 24h ( $Z = 12.62$ ,  $p = 0.004$ ) and 48h ( $Z = 16.22$ ,  $p < 0.001$ ) compared to the control group. In addition, the results for muscle volume did not report any significant interaction ( $F(5.64) = 3.42$ ,  $p = 0.078$ ). The results of both protocols showed their effectiveness in reducing pain intensity by 24 and 48 hours after intense training ( $F(3.54) = 2.91$ ,  $p = 0.016$ ,  $p_2 = 0.24$ ).

**Conclusions:** In conclusion, continuous and fractionated cold water immersion is beneficial for neuromuscular recovery 24 hours after intense exercise. The results also demonstrate a rapid recovery of handball players from their physical potential required in high level competitions.

**Keywords:** cold water, immersion, recovery, handball, physical performance.

## Introduction

There is Cold water immersion (CWI) is a popular form of cryotherapy and considered one of the most effective for reducing tissue temperature and sustained cooling after removal [1] and speed up the recovery process [2, 3].

Different approaches to these methods [3, 4], as well as the results [4–7] have shown a beneficial effect of these techniques in recovery. In contrast, other studies have reported no significant effect on recovery [8, 9].

More specifically, experimental studies indicate that CWI generates a series of physiological changes including, the reduction of core body temperature [10, 11], acute inflammation [12], muscle spasms, and pain sensations [13], localized edema [12], as well as symptoms related to delayed onset muscle pain [14–17]

The perception of fatigue and levels of creatine phosphokinase (CPK), another study to realize by [10], whose aim was to examine the effects of 20-minute ( $14^\circ$  C) immersion on neuromuscular function, recommendations were made to suggest that temperature and duration Optimal CWI for performance-based exercise recovery and management of exercise-induced muscle damage are at  $10\text{-}15^\circ$  C and  $5\text{-}15$  min [3, 21].

Most of these studies compared CWI under control or passive recovery, using continuous dips [17, 21–23]. On the other hand, CWI has also been used through the fractional method. The results concluded that this form of immersion has no effect on the athlete's recovery and performance [24, 25], In addition, another study [19] reports positive effects on recovery using CWI intermittently.

These contradictory results make necessary the deeper exploration of these approaches to be able to bring objective and weak answers. Moreover, despite the wide dissemination and use of this recovery technique [3], to our humble knowledge [26], only one study has explored the use of this technique in Handball players [7]. The protocol to use was that of the split CWI. The results showed a positive effect on handball recovery. However, no study has explored the effects of the two methods on recovery among university Handball players in team sports.

The advanced physiological mechanisms when using fractional immersions show a pumping effect caused by vasoconstriction and vasodilatation, which occur due to temperature change. This pumping effect stimulates the transport of waste and nutrients into the body [8, 27]. In contrast, continuous immersions are advocated as a result of increased exposure to cold and the effects of vasoconstriction and hydrostatic pressure which together

facilitate processes such as, rapidly decreasing body temperature, and acceleration of processes associated with decreased pain [28].

*Hypothesis:* This study set out to test the hypothesis that, we assume that the response of the recovery indicators varies significantly depending on the type of CWI recovery protocol.

*Purpose:* Therefore, the main objective of this study is to compare the effects of two recovery protocols by CWI after a state of intense fatigue in highly-trained university Handball players

### Materials and Methods

#### Participants

The subjects who voluntarily participated in this experiment were Hand Ball players between 14 and 15 years of age (15±1.4 years of age) and a body weight of 67.2 ± 5.1 kg, with a height of 176 ± 3.02 cm. Their sporting experience was (5±2 years) on average. They trained three times a week. Each training session lasts 1 hour and a half. In addition, the entire team regularly participated in one competition once a week, for a total of 12 competitions during the pre-competitive period (Fig. 1). The experimental procedures, the associated risks and benefits were explained to each player through a consent form signed by the parents.

Subjects were homogeneously distributed A balanced design was applied in which subjects in Experimental Group 1 received the abstract (CWI.C), subjects in Experimental Group 2 received the (CWIF) and subjects in the Control Group received the a (GC). This population was passively recovered, as shown in Figure 1, and this study was conducted prior to the competition period. The study was designed in accordance with the recommendations for clinical research in the Declaration of Helsinki [29]. The protocol was reviewed and approved by a committee of experts from the Institute of Physical

Education and Sport of the University of Mostaganem (Algeria).

#### Study Design

Body composition and anthropometric measurements:

The mass index was determined using a model (Tanita BC-1500, Japan 2015) with an accuracy of ± 0.1 kg. The height was measured using a wall stadiometer. The Percentage of fat was calculated using a skin fold caliper, data from 7 sites (chest, medial-axillary subscapular, triceps, suprailiac, abdomen and thigh) [30, 31] were evaluated. All measurements were made with an anthropometric measurement calculation tool [32]. The water temperature was monitored and recorded using a DeltaTrak digital thermometer, model 12207 (Lima, Peru) at 1-minute intervals.

*The Performance and Recovery Indicators:*

Perceived pain:

The visual analog scale (VAS 0-10) was used to measure the pain perceived by the subjects. In this case, zero (0) indicates no pain and ten (10) indicate extreme pain. To determine the level of pain, subjects were asked to perform the 90-degree chase test and indicate the perceived muscle pain in the thigh. This method has already been used in pain perception after intense exercise [14, 18, 19, 25].

The circumference and volume of the thigh were measured using an anthropometric tape measure. Circumference was measured at two locations on the leg, under the buttock and above the knee. A marker was used to ensure the reliability of the re-test (before the recovery protocol and at 24 and 48 hours respectively after recovery). These data allow the calculation of thigh volume, which is an indicator of inflammation and muscle damage [10]. The formula updated by [33–36] was used to calculate muscle volume as Follows:

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

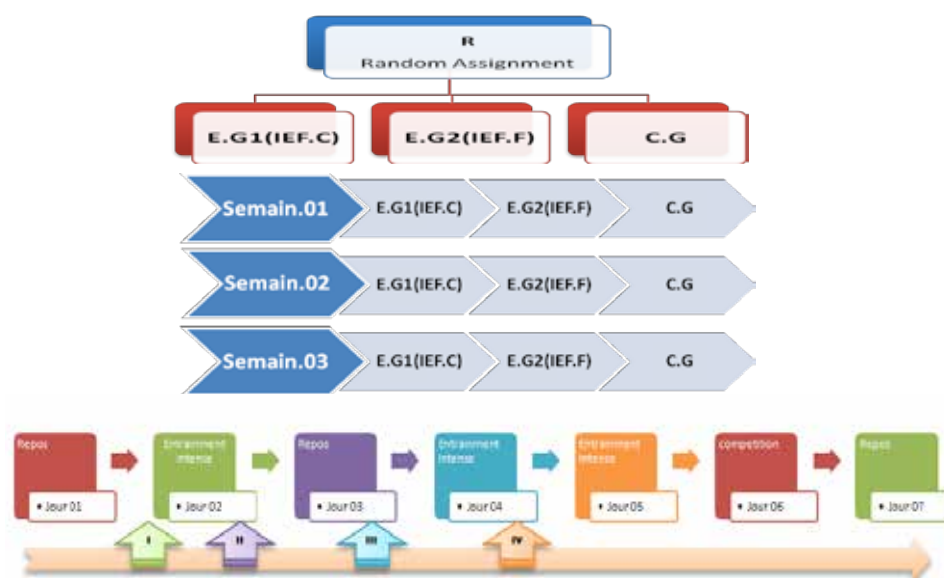


Figure 1. Shows the random assessment of the study

Note: h =high thigh; Π =3, 14; C1=Sub-gluteal circumference; C2= above knee circumference.

The counter-movement jump test (CMJ):

The measurements were made using a force platform. Three tests were performed with a recovery time of 2 minutes, and the best jump was recorded for each measurement episode. The jump countermovement test (CMJ) has an intra-class correlation reliability (CIC=0.98) [37]. All variables were measured before and immediately after the recovery (from 0 hours) and at 24 and 48 hours after cold water immersion.

#### Statistical Analyses

Descriptive statistics (mean and standard deviation) were calculated for all variables. The normality of the data was assessed using the Shapiro-Wilks test. The results indicated normality for all variables except muscle volume and MJF performance, which were analyzed in terms of percentage change from the previous value. Since the values of these two variables were not normally distributed, another non-parametric statistical analysis was performed, using the Kruskal-Wallis H test. The other variables were analyzed with their own units of measurement. The Levene test was used to analyze the homogeneity of variances. Repeatedly measured ANOVAs were used to compare post-exercise muscle pain at 0, 24 and 48 hours after exercise. Bonferroni post hoc analysis was used.

#### Results

Table 1 above presents descriptive data for the variables associated with recovery for each of the experimental conditions (CWI C, CWI F, and GC) at different measurement times. Statistically significant differences do not appear for pain perception and counter-jump movement ( $p < .05$ ); details are presented in (Figure 2).

Figure 2 above shows a significant interaction ( $F(3.92) = 3.62, p = 3.16, p = .24$ ) with the two immersion protocols (CWI.C CWI.F) and significantly reducing pain

perception compared to GC (passive recovery) perceptions in measurements immediately after immersion (CWI.C Vs CG,  $p < .001$ ) (CWI.F Vs CG,  $p = .009$ ), at 24 hours (CWI.C Vs CG,  $p = .021$ ) (CWI.F Vs CG,  $p = .024$ ) and 48 hours after immersion (CWI.C Vs CG,  $p = .017$ ) (CWI.F Vs CG,  $p = .032$ ).

Statistically significant differences were not reported when comparing the reference value with the post-immersion measurements. In addition, statistically significant differences were not reported ( $p < 0.05$ ) at any of the measurement times when comparing the continuous immersion group with the split immersion group. Change CMY test CMY 0% (CWI.F \* 1 inverted values) CWI.C 2 Pre-Post Exec. 24 hours 48 hours of significant difference with respect to the control group ( $p < 0.05$ ), CG: control group.

Figure 3 above shows statistically significant differences in jump ability by analysis using the MJF test at 24 hours ( $Z = 12.62, p = 0.004$  when CWI.C; CWI.F comparison and with GC (passive recovery) (CWI.C vs CG,  $p = .006$ ) (CWI.F vs GC,  $p = 0.029$ ) and 48 hours after training ( $Z = 16.22, p < 0.001$ ), (CWI.C Vs. CG,  $p < 0.001$ ) (CWI.F vs CG,  $p = 0.017$ ). In addition, no statistically significant differences ( $p < 0.05$ ) were reported when comparing the two groups that were continuously immersed with the fractionated group. Concerning muscle volume, the analysis did not show any significant interaction ( $F(3.54) = 2.42, p = 0.058$ ).

#### Discussion

The main purpose of conducting this study was to examine the effects of two cold-water immersion protocols: the CWI C protocol (12 min immersion at  $12 \pm 0.4^\circ\text{C}$ ) and the CWI F protocol (4 times x 2 min immersion at  $12 \pm 0.4^\circ\text{C} + 1$  min out of water) after intense exercise on recovery. The main finding of this study is that both immersion protocols are effective in reducing signs of fatigue and delaying the onset of muscle pain. The analyses also showed positive effects on the recovery

**Table 1.** The mean scores of experimental and control groups

Variables	Perceived pain				Muscle think volume				Counter movement jump			
	baseline	0H	24H	48	baseline (mm):	0H	24H	48	baseline (cm)	0H	24H	48
CWI.C mean	4.32	2.31	2.52	2.26	4726.03	4663.6	4520.9	4566.9	44.2	43.61	43.03	43.94
SD	1.63	1.17	1.61	1.2	850.2	843.8	840.5	983.5	5.6	4.89	4.8	5.06
CWI.F mean	4.86	3.24	2.73	2.55	4735.8	4662.9	4782.1	4703.9	44.7	43.9	43.56	44.64
SD	1.52	1.56	1.48	1.06	1180.5	1213.4	1122.8	1248.1	4.63	4.94	4.06	4.97
G.C mean	4.63	5.81	5.02	4.53	5065.9	4934	4894.3	4886	46.76	46.93	45.6	43.3
SD	1.67	1.59	1.54	0.83	1084.6	1184.2	1102.9	1129.5	7.6	6.95	7.2	7.49

Notes: G.E 1 (CWI.C): Experimental group with the Continuous Cold Water Immersion Protocol. G.E 2 (CWI.F): Experimental group with the Fractionated Cold Water Immersion Protocol. G.C: Group control.

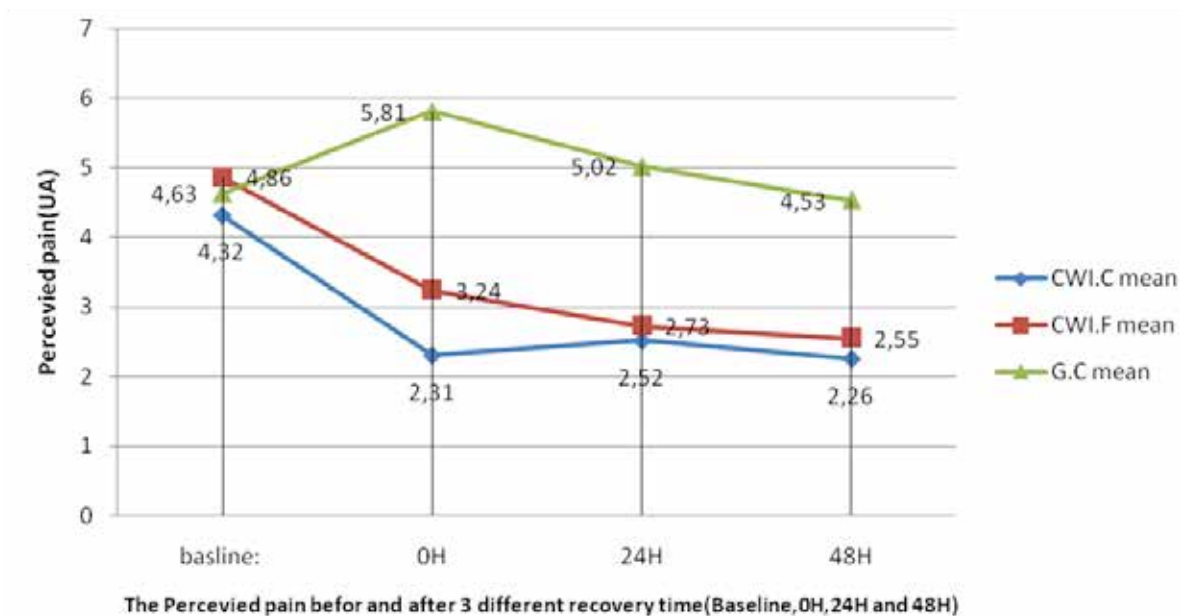


Figure 2. Shows the perception of muscle pain (UA) and its tendency between the 3 groups.

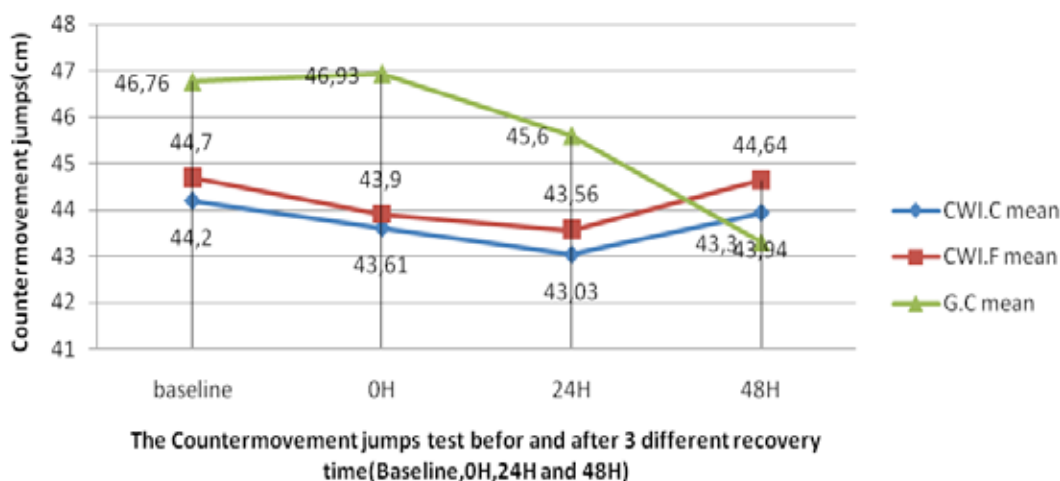


Figure 3. Shows the counter movement jump between the 3 groups CMJ (cm)

of jump capacity measured using the CMJ jump test.

In the case of the study of Simmons [38], continuous immersion in cold water as part of the 12-minute protocol at  $12 \pm 0.4^\circ$ , the latter proved effective in reducing muscle pain immediately after immersion and at 24 and 48 hours after intense exercise. These results are not consistent with the work of Glasgow and Stevens [23, 39] but with those reported by Delextrat, Rowsell and Stanley [16, 17, 40] which indicate that cold water reduces the functional and physiological signs associated with muscle pain [41] and confirm that the use of this protocol for CMJ is effective. These results further reinforce protocols with temperatures ranging from  $11^\circ\text{C}$  to  $15^\circ\text{C}$ , with an immersion time of 10 to 15 minutes that have a positive effect [41] and that MJF techniques appear to be more effective in accelerating performance restoration in different sports by using immersions 5 to 15 minutes at a

water temperature of  $5\text{-}20^\circ\text{C}$  [42].

In addition, in fractional dives under the  $4 \times 2$  min immersion protocol with a water temperature of  $12 \pm 0.4^\circ\text{C} + 1$  min above water at room temperature, the results obtained disagree with those reported by [43]. When used, the  $3 \times 1$  min protocol of immersion at  $5 \pm 1^\circ\text{C}$ , with 1 min out of water, does not report positive effects on DOMS on a comparison of the experimental group with the control group.

Our results are consistent with those reported by Ascensao and al [19] who used a  $5 \text{ min} \times 1$  protocol ( $10 \pm 0.5^\circ\text{C} + 1$  min out of water) at room temperature and reported positive effects of intermittent immersion. These concordances with research results were reported by António Ascensão & Magalhães [44] who found significant differences both immediately after the immersion protocol and 24 hours after training compared

to the control group.

Similarly, Sánchez-Ureña [45] reported significant differences at 24 hours after training between the fractionated immersion group and the control group, using the 2 x 5-minute immersion protocol with water temperature at 10°C and 2.5 minutes out of water at 21°C ± 0.5. This study is the first to report these differences both immediately at 24 and 48 hours after exercise, indicating that the protocol used was characterized by the reversal of the previous protocol.

These physiological results demonstrate that the physiological and functional symptoms associated with Post-Effort Muscle Pain (EPMP) associated with the reduction of acute inflammation [12], as well as the presence of symptoms in the muscle and the effect of hydrostatic [13, 14] pressure [6] have accelerated recovery. Another mechanism could be related to cold exposure that has shown the potential for activation of the transient 8-melastatin receptor [27, 47] which is related to pain and temperature sensation [48, 49]. Once activated, TRPM8 has an analgesic effect given by the action of the interphas neurons the inhibitory interphase [48, 50] and which improves the perception of DMPE and increases the feeling of recovery [28].

It is also important to note that exposure to cold causes changes in the neurotransmitters of dopamine and serotonin, which are responsible for regulating mood, sleep, emotions, motivation, pain perception and fatigue. Cold water immersion may help to reduce central nervous system fatigue [28] and suggests that an increase in serotonin/dopamine ratio is associated with fatigue and the rapid onset of fatigue, while a low serotonin/dopamine ratio promotes better performance through maintenance and physiological activation.

In addition, the jump capacity measured by MJF through the two immersion protocols was found to be more effective than passive recovery. This result is consistent with the studies of Mokrani and Stanley & Peake [17, 51]. Indeed, using a continuous immersion protocol, differences were also observed between this group and the control group in terms of effectiveness using the Squat Jump test 48 hours and 72 hours after exercise but not at 24 hours after exercise the exercise between the two groups.

As with cold water immersion, Ascensão [44] used a five-minute protocol after the end of the competition to 2 split dives of the lower limbs (to the iliac crest) in a cold water bath (11°C), separated by 2 min in ambient air (sitting, ambient temperature 20°C) resulted in statistically significant differences 24 hours after the CMJ test immersion. These results are in line with the

conclusions of our study.

In addition, the results for thigh volume coincide with those reported by Zagatto et al [52] who also observed that continuous immersion did not significantly decrease edema evaluated at 24, 48 and 72 hours after training. Similar conclusions have been reported by Wilcock & Hing [53] showing that the use of a continuous immersion protocol did not lead to a significant decrease in muscle edema in the immediate posterior measurement. Wilcock [53] also indicated that the thigh circumference (edema) which is an indicator varies less throughout cold water training in the continuous immersion and control groups. The results are identical to the results of this study. One possible explanation is that the load to which the players were exposed did not cause sufficient muscle damage to generate oedema. The results obtained in this study allow sport professionals, such as coaches and trainers [54] to choose the best protocol for their athletes according to their preference, given the effectiveness of both protocols.

### **Conclusion**

In the field of sports training and more particularly in the field of active recovery, more work is needed to compare different cold water immersion protocols, including the measurement of biochemical variables such as creatine phosphokinase (CPK) and lactate dehydrogenase (LDH) physiological myographic surfactants as well as other variables such as reaction time [55], contraction and muscle relaxation time. In addition, it is necessary to test different split immersion protocols that take into account immersion times, in-water and out-water relationships and temperature differences to optimize the most appropriate protocol for the type of sport.

### **Acknowledgments**

The authors would like to thank the Handball players who participated in the study for their time and patient. We also want to thank the University coach and his staff and also ADDA abdeidaim for valuable contributions and careful proofreading. Thank you for your inspiration and for being a great friend and colleague.

Disclosure statement of funding: Algerian Olympic Sports Centre and Institute of physical education and sports Sciences.

### **Conflict of interests**

The authors declare that there is no conflict of interests.

### References

1. Vieira A, Siqueira AF, Ferreira-Junior JB, do Carmo J, Durigan JLQ, Blazeovich A, et al. The Effect of Water Temperature during Cold-Water Immersion on Recovery from Exercise-Induced Muscle Damage. *Int J Sports Med.* 2016;37(12):937-43. <https://doi.org/10.1055/s-0042-111438>
2. Calleja-González J, Terrados N, Mielgo-Ayuso J, Delextrat A, Jukic I, Vaquera A, et al. Evidence-based post-exercise recovery strategies in basketball. *Phys Sportsmed.* 2016;44(1):74-8. <https://doi.org/10.1080/00913847.2016.1102033>
3. G. N, Halson SL, Dawson BT. Water immersion recovery for athletes: effect on exercise performance and practical recommendations. *Sports Med Auckl NZ.* 2013;43:1101-1130. <https://doi.org/10.1007/s40279-013-0063-8>
4. Hohenauer E, Taeymans J, Baeyens J-P, Clarys P, Clijisen R. The Effect of Post-Exercise Cryotherapy on Recovery Characteristics: A Systematic Review and Meta-Analysis. *PLoS ONE.* 2015;10. <https://doi.org/10.1371/journal.pone.0139028>
5. Christensen PM, Jacobs RA, Bonne T, Flück D, Bangsbo J, Lundby C. A short period of high-intensity interval training improves skeletal muscle mitochondrial function and pulmonary oxygen uptake kinetics. *J Appl Physiol.* 2016;120(11):1319-27. <https://doi.org/10.1152/jappphysiol.00115.2015>
6. Leeder J, Gissane C, van Someren K, Gregson W, Howatson G. Cold water immersion and recovery from strenuous exercise: a meta-analysis. *Br J Sports Med.* 2012;46(4):233-40. <https://doi.org/10.1136/bjsports-2011-090061>
7. Sanchez-Ureña BA, Barrantes-Brais K, Ureña-Bonilla P, Calleja-González J, Ostojic S. Effect of water immersion on recovery from fatigue: a meta-analysis. *Eur J Hum Mov.* 2015;34:1-14.
8. Higgins TR, Greene DA, Baker MK. Effects of Cold Water Immersion and Contrast Water Therapy for Recovery From Team Sport: A Systematic Review and Meta-analysis. *J Strength Cond Res.* 2017;31(5):1443-60. <https://doi.org/10.1519/JSC.0000000000001559>
9. Murray A, Cardinale M. Cold applications for recovery in adolescent athletes: a systematic review and meta analysis. *Extreme Physiol Med.* 2015;4:17. <https://doi.org/10.1186/s13728-015-0035-8>
10. Peiffer JJ, Abbiss CR, Watson G, Nosaka K, Laursen PB. Effect of cold-water immersion duration on body temperature and muscle function. *J Sports Sci.* 2009;27(10):987-93. <https://doi.org/10.1080/02640410903207424>
11. Yanagisawa O, Homma T, Okuwaki T, Shima D, Takahashi H. Effects of cooling on human skin and skeletal muscle. *Eur J Appl Physiol.* 2007;100(6):737-45. <https://doi.org/10.1007/s00421-007-0470-3>
12. Vaile JM, Gill ND, Blazeovich AJ. The effect of contrast water therapy on symptoms of delayed onset muscle soreness. *J Strength Cond Res.* 2007;21(3):697-702. <https://doi.org/10.1519/00124278-200708000-00008>
13. Washington LL, Gibson SJ, Helme RD. Age-related differences in the endogenous analgesic response to repeated cold water immersion in human volunteers. *Pain.* 2000;89(1):89-96. [https://doi.org/10.1016/S0304-3959\(00\)00352-3](https://doi.org/10.1016/S0304-3959(00)00352-3)
14. Elias GP, Wyckelsma VL, Varley MC, McKenna MJ, Aughey RJ. Effectiveness of water immersion on postmatch recovery in elite professional footballers. *Int J Sports Physiol Perform.* 2013;8(3):243-53. <https://doi.org/10.1123/ijspp.8.3.243>
15. Montgomery PG, Pyne DB, Hopkins WG, Dorman JC, Cook K, Minahan CL. The effect of recovery strategies on physical performance and cumulative fatigue in competitive basketball. *J Sports Sci.* 2008;26(11):1135-45. <https://doi.org/10.1080/02640410802104912>
16. Rowsell GJ, Coutts AJ, Reaburn P, Hill-Haas S. Effects of cold-water immersion on physical performance between successive matches in high-performance junior male soccer players. *J Sports Sci.* 2009;27(6):565-73. <https://doi.org/10.1080/02640410802603855>
17. Stanley J, Buchheit M, Peake JM. The effect of post-exercise hydrotherapy on subsequent exercise performance and heart rate variability. *Eur J Appl Physiol.* 2012;112(3):951-61. <https://doi.org/10.1007/s00421-011-2052-7>
18. Argus CK, Broatch JR, Petersen AC, Polman R, Bishop DJ, Halson S. Cold-Water Immersion and Contrast Water Therapy: No Improvement of Short-Term Recovery After Resistance Training. *Int J Sports Physiol Perform.* 2017;2016-0127. <https://doi.org/10.1123/ijspp.2016-0127>
19. Ascensão A, Leite M, Rebelo AN, Magalhães S, Magalhães J. Effects of cold water immersion on the recovery of physical performance and muscle damage following a one-off soccer match. *J Sports Sci.* 2011;29:217-225. <https://doi.org/10.1080/02640414.2010.526132>
20. Elias GP, Wyckelsma VL, Varley MC, McKenna MJ, Aughey RJ. Effect of water immersion on postmatch recovery in elite professional footballers. *Int J Sports Physiol Perform.* 2013;8:243-253. <https://doi.org/10.1123/ijspp.8.3.243>
21. Machado AF, Ferreira PH, Micheletti JK, de Almeida AC, Lemes ÍR, Vanderlei FM, et al. Can Water Temperature and Immersion Time Influence the Effect of Cold Water Immersion on Muscle Soreness? A Systematic Review and Meta-Analysis. *Sports Med Auckl NZ.* 2016;46(4):503-14. <https://doi.org/10.1007/s40279-015-0431-7>
22. Kwiecien SY, McHugh MP, Howatson G. The efficacy of cooling with phase change material for the treatment of exercise-induced muscle damage: pilot study. *J Sports Sci.* 2018;36(4):407-13.
23. Stevens CJ, Kittel A, Sculley DV, Callister R, Taylor L, Dascombe BJ. Running performance in the heat is improved by similar magnitude with pre-exercise cold-water immersion and mid-exercise facial water spray. *J Sports Sci.* 2017;35(8):798-805. <https://doi.org/10.1080/02640414.2016.1192294>
24. Johnston RD, Gabbett TJ, Jenkins DG. Influence of playing standard and physical fitness on activity profiles and post-match fatigue during intensified junior rugby league competition. *Sports Med - Open.* 2015;1(1):18. <https://doi.org/10.1186/s40798-015-0015-y>
25. Rowsell GJ, Coutts AJ, Reaburn P, Hill-Haas S. Effect of post-match cold-water immersion on subsequent match running performance in junior soccer players during tournament play. *Journal of Sports Sciences.* 2011;29:1-6. <https://doi.org/10.1080/02640414.2010.512640>
26. Belkadi A, Remaoun M, Benbernou O. The Perception of the Use of (Ict) on the Acquisition of New Teaching Skills According to (Teachers, Student Trainees). *In the Physical Education and Sports.* 2017;1: 28-32.
27. Chrara L, A.Raoui R, Belkadi A, Asli H, Benbernou O. Effects of caloric restriction on anthropometrical and specific performance in highly-trained university judo athletes. *Arab Journal of Nutrition and Exercise (AJNE),* 2018;3:105-118. <https://doi.org/10.18502/ajne.v3i3.3669>
28. Ihsan M, Watson G, Abbiss CR. What are the Physiological Mechanisms for Post-Exercise Cold Water Immersion in the Recovery from Prolonged Endurance and Intermittent Exercise? *Sports Med Auckl NZ.* 2016;46(8):1095-109. <https://doi.org/10.1007/s40279-016-0483-3>
29. General Assembly of the World Medical Association.

- World Medical Association Declaration of Helsinki: ethical principles for medical research involving human subjects. *J Am Coll Dent.* 2014;81(3):14-8.
30. Wilhelm Hoppe M, Brochhagen J, Baumgart C, Bauer J, Freiwald J. Differences in Anthropometric Characteristics and Physical Capacities Between Junior and Adult Top-Level Handball Players. *Asian Journal of Sports Medicine*, 2017; In Press. <https://doi.org/10.5812/asjms.60663>
  31. Karan V, Rakovac A, Karan M, Popović M, Klačnja J, Lukač D. Evaluation of body composition and muscular strength in different sports. *Med Pregl.* 2017;70(5-6):150-4. <https://doi.org/10.2298/MPNS1706150K>
  32. Houcine A, Ahmed A, Saddek Z. Designing a Software to Count the Body Composition and Somatotype and its Role in Pursing the Morphological State of Spotsmen. *AASRI Procedia.* 2014;8:38-43. <https://doi.org/10.1016/j.aasri.2014.08.007>
  33. Hammami M, Negra Y, Billaut F, Hermassi S, Shephard RJ, Chelly MS. Effects of Lower-Limb Strength Training on Agility, Repeated Sprinting With Changes of Direction, Leg Peak Power, and Neuromuscular Adaptations of Soccer Players. *J Strength Cond Res.* 2018;32(1):37-47. <https://doi.org/10.1519/JSC.0000000000001813>
  34. Katch VL, Katch FI. A simple anthropometric method for calculating segmental leg limb volume. *Res Q.* 1974;45(2):211-4. <https://doi.org/10.1080/10671188.1974.10615262>
  35. Mudie KL, Gupta A, Green S, Hobara H, Clothier PJ. A Comparison of Vertical Stiffness Values Calculated from Different Measures of Center of Mass Displacement in Single-Leg Hopping. *J Appl Biomech.* 2017;33(1):39-47. <https://doi.org/10.1123/jab.2016-0037>
  36. Tidhar D, Armer JM, Deutscher D, Shyu C-R, Azuri J, Madsen R. Measurement Issues in Anthropometric Measures of Limb Volume Change in Persons at Risk for and Living with Lymphedema: A Reliability Study. *J Pers Med.* 2015;5(4):341-53. <https://doi.org/10.3390/jpm5040341>
  37. Markovic G, Dizdar D, Jukic I, Cardinale M. Reliability and factorial validity of squat and countermovement jump tests. *J Strength Cond Res.* 2004;18(3):551-5. <https://doi.org/10.1519/00124278-200408000-00028>
  38. Simmons G, Cooper S, Research JB, Muse D. Enhancing methods for the delayed onset muscle soreness (DOMS) pain model. *J Pain.* 2018;19(3):S81. <https://doi.org/10.1016/j.jpain.2017.12.196>
  39. Glasgow PD, Ferris R, Bleakley CM. Cold water immersion in the management of delayed-onset muscle soreness: Is dose important? A randomised controlled trial. *Phys Ther Sport.* 2014;15(4):228-33. <https://doi.org/10.1016/j.ptsp.2014.01.002>
  40. Delextrat A, Calleja-González J, Hippocrate A, Clarke ND. Effects of sports massage and intermittent cold-water immersion on recovery from matches by basketball players. *J Sports Sci.* 2013;31(1):11-9. <https://doi.org/10.1080/02640414.2012.719241>
  41. Lauber C, Hickie S, Jargstorff J, West C. Effect of Cold Water Immersion or Contrast Water Therapy on Muscle Soreness After Exercise: 3330 Board #235 June 2 2. *Medicine & Science in Sports & Exercise*, 2017;49:951. <https://doi.org/10.1249/01.mss.0000519594.90624.f3>
  42. Versey NG, Halson SL, Dawson BT. Water immersion recovery for athletes: effect on exercise performance and practical recommendations. *Sports Med Auckl NZ.* 2013;43(11):1101-30. <https://doi.org/10.1007/s40279-013-0063-8>
  43. Ascensão A, Leite M, Rebelo AN, Magalhães S, Magalhães J. Effects of cold water immersion on the recovery of physical performance and muscle damage following a one-off soccer match. *J Sports Sci.* 2011;29(3):217-25. <https://doi.org/10.1080/02640414.2010.526132>
  44. Sánchez-Ureña B, Martínez-Guardado I, Crespo C, Timón R, Calleja-González J, Ibañez SJ, et al. The use of continuous vs. intermittent cold water immersion as a recovery method in basketball players after training: a randomized controlled trial. *Phys Sportsmed.* 2017;45(2):134-9. <https://doi.org/10.1080/00913847.2017.1292832>
  45. Elias GP, Wyckelsma VL, Varley MC, McKenna MJ, Aughey RJ. Effectiveness of water immersion on postmatch recovery in elite professional footballers. *Int J Sports Physiol Perform.* 2013;8(3):243-53. <https://doi.org/10.1123/ijsp.8.3.243>
  46. Wang H, Siemens J. TRP ion channels in thermosensation, thermoregulation and metabolism. *Temperature* 2015;2:178-87. <https://doi.org/10.1080/23328940.2015.1040604>
  47. Knowlton WM, Palkar R, Lippoldt EK, McCoy DD, Baluch F, Chen J, et al. A Sensory-Labeled Line for Cold: TRPM8-Expressing Sensory Neurons Define the Cellular Basis for Cold, Cold Pain, and Cooling-Mediated Analgesia. *J Neurosci.* 2013;33(7):2837-48. <https://doi.org/10.1523/JNEUROSCI.1943-12.2013>
  48. Proudfoot CJ, Garry EM, Cottrell DF, Rosie R, Anderson H, Robertson DC, et al. Analgesia Mediated by the TRPM8 Cold Receptor in Chronic Neuropathic Pain. *Curr Biol.* 2006;16(16):1591-605. <https://doi.org/10.1016/j.cub.2006.07.061>
  49. Abdelkader G, Madani R, Adel B, Bouabdellah S. Sporting events among the disabled between excellence and ideal in motor performance. *Int J Phys Educ Fit Sports.* 2018;7(3):66-71. <https://doi.org/10.26524/ijpefs1837>
  50. Mohamed KS, Mohamed K, Mohammed S, Mokrani D, Belkadi A. The Effect of Heavy Weight Training on Physiological Abilities of Soccer Players Under the Age 21 Years Old. *Acta Fac Educ Phys Univ Comen.* 2019;59(1):33-43. <https://doi.org/10.2478/afepuc-2019-0004>
  51. Zagatto AM, de Paula Ramos S, Nakamura FY, de Lira FS, Lopes-Martins RÁB, de Paiva Carvalho RL. Effects of low-level laser therapy on performance, inflammatory markers, and muscle damage in young water polo athletes: a double-blind, randomized, placebo-controlled study. *Lasers Med Sci.* 2016;31(3):511-21. <https://doi.org/10.1007/s10103-016-1875-1>
  52. Wilcock IM, Cronin JB, Hing WA. Physiological response to water immersion: a method for sport recovery? *Sports Med Auckl NZ.* 2006;36(9):747-65. <https://doi.org/10.2165/00007256-200636090-00003>
  53. Belkadi A, Othman B, Mohamed S, Abdelhafid L, M BH, Gleyse J. Contribution to the Identification of the Professional Skills Profile of Coaches in the Algerian Sport Judo System. *Int J Sports Sci.* 2015;5(4):145-50.
  54. Berria M, Bachir K, Eddine SN, Adel B. Study of LDH adaptations associated with the development of Speed endurance in basketball players U19. *Int J Appl Exerc Physiol.* 2018;7(3):35-43.

---

**Information about the authors:**

**Mokhtar M.;** <https://orcid.org/0000-0002-9832-0840>; mokhtar.mim@univ-mosta.dz; Institute of Physical Education And Sport, University of Mostaganem; 27000 Mostaganem, Algeria.

**Adel B.;** (Corresponding author); <https://orcid.org/0000-0002-8715-2036>; Adel.belkadi@univ-mosta.dz; Institute of Physical Education And Sport, University of Mostaganem; 27000 Mostaganem, Algeria.

**Wahib B.;** <https://orcid.org/0000-0002-4622-4582>; wahib.beboucha@univ-mosta.dz; Institute of Physical Education And Sport, University of Mostaganem; 27000 Mostaganem, Algeria.

**Hocine A.;** <https://orcid.org/0000-0003-2657-1795>; asli.houcine\_sport@yahoo.fr; Institute of Physical Education And Sport, University of Oran; 31000 Oran, Algeria.

**Othman B.;** <https://orcid.org/0000-0003-1883-6917>; benbernouothmane@yahoo.fr; Institute of Physical Education And Sport, University of Mostaganem-University of Mostaganem; 27000 Mostaganem, Algeria.

**Mohamed S.;** <https://orcid.org/0000-0003-3448-5299>; mohamed.sebbane@univ-mosta.dz; Institute of Physical Education And Sport, University of Mostaganem-University of Mostaganem; 27000 Mostaganem, Algeria.

---

Cite this article as:

Mokhtar M, Adel B, Wahib B, Hocine A, Othman B, Mohamed S. The effects of tow protocol cold water immersion on the post match recovery and physical performance in well-trained handball players. *Pedagogics, psychology, medical-biological problems of physical training and sports*, 2019;23(6):288-295.

<https://doi.org/10.15561/18189172.2019.0603>

---

This is an Open Access article distributed under the terms of the Creative Commons Attribution License, which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited (<http://creativecommons.org/licenses/by/4.0/deed.en>).

Received: 30.08.2019

Accepted: 25.09.2019; Published: 30.09.2019