THE ROLE OF COLD WATER IMMERSION AS A POST-EXERCISE RECOVERY METHOD FOR RECREATIONAL ATHLETE BASED ON CREATINE KINASE AND VERTICAL JUMP: A RANDOMISED TRIAL

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Abstract

Background: Recreational sports have a positive influence on health. However, there will be a concern if the training intensity and volume increase without proper recovery. Cold water immersion has been known as one of the post-exercise recovery methods. Assessment of creatine kinase and vertical jump can be used to monitor the condition of post-exercise recovery. **Aim:** To evaluate the role of cold water immersion based on creatine kinase and vertical jump. **Method:** Twenty subjects were randomized to the cold water immersion or passive recovery group. Creatine kinase and vertical jump were measured as a baseline, followed by fatigue protocol (circuit training in gym) and recovery protocol according to each group. The creatine kinase and vertical jump were monitored in three consecutive periods; post-exercise recovery, 24-hour, and 48-hour post-exercise. The mean difference within groups and between groups of creatine kinase and the vertical jump was analyzed using repeated Anova + post-hoc Bonferroni test and T-test, respectively. **Results:** The intervention group showed faster recovery than the control group at 24-hour post-exercise based on vertical jump. Intervention group had higher vertical jump ($p = 0{,}039$) at 24-hour assessment. The intervention group showed faster recovery at 48-hour post-exercise than the control group on creatine kinase. There were also lower ($p < 0{,}01$) creatine kinase in the intervention group at 48-hour post-exercise measurement. **Conclusion:** The use of cold water immersion is recommended as a post-exercise recovery method for the recreational athlete after high-volume and high-intensity training.

Keywords: Recovery, cold water immersion, vertical jump, creatine kinase, exercise

Introduction

Participation in recreational sports are increasing in the urban community. Recreational sports activities, such as running, biking, futsal, badminton, and many others, give health benefits. There will be a problem if training intensity suddenly incrase without proper recovery.[1]

Recovery is related to time, aiming to restore the body physiologically and psychologically after exercise. The fatigue will be developed, especially after high-intensity training, that should be balanced with the recovery process.[2] A good recovery makes a positive adaptation to exercise and increases physical capacity and performance. Inadequate recovery could lead to maladaptation to exercise, decrease performance, and increase risk of injury and illness.[3]

The recovery process and fatigue condition can be monitored by measuring specific parameters. Physical performance aspects related to recovery can be obtained by measuring vertical jump (VJ). A decrease in VJ score is related to fatigue of knee extensor muscles after exercise.[4] Creatine kinase (CK) is a biochemical marker monitored during recovery. CK level increases after high volume and high-intensity exercise, with a predominant eccentric component. It reflects the stress of muscle fibers during training.[5]

Cold water immersion (CWI) is one post-exercise recovery method. The use of CWI to enhance recovery is prevalent in competitive sports, although its effectiveness from previous studies is still inconclusive. The previous studies have high variability in temperature, duration, and timing of CWI, type of exercise, and fitness level of the subject.[6] The benefit of CWI after exercise in recreational athletes has not been studied before. The overuse injury in recreational sports is commonly seen,[7], which is related to a lack of post-exercise recovery.

This study aims to evaluate the role of CWI in recreational athletes based on the evaluation of CK level and VJ score during the recovery period.

Materials and Methods

We conducted a non-blinded randomized controlled clinical trial from February to April 2021 in the sports and exercise studies Indonesian Medical Education and Research Institute (IMERI) center. Consecutive sampling was taken from recreational athletes around Jakarta, Depok, Tangerang, Bogor, and Bekasi. Estimation of sample size was calculated based on the formula of two independent groups, continuous outcome, which produced a minimal of 16 subjects.

Inclusion criteria were male dan female age 20-40 years old, have participated in recreational sports activity for at least the past one year, and willing to participate in the study by signing the informed consent. The exclusion criteria include musculoskeletal problems, chronic and metabolic disease, body mass index (BMI) > 27,9 kg/m^2, and cold hypersensitivity.

Preparticipation examination was done on the subjects, consisting of medical and training history, sleep problem (assessed by using athlete sleep screening questionnaire /ASSQ), level of physical activity and sedentary (International Physical Activity

Questionnaire/IPAQ short form Indonesian version), general physical examination, anthropometry measurement, postural assessment (modified New York Posture Rating Scale/NYPRS) and movement screening (standing flexibility, hurdle step, deep squat, inline lunges, and heel raise). We also measured health-related fitness parameters, consisting of cardiorespiratory fitness (Ebbeling treadmill test), muscle strength (leg dynamometer), and body composition (Tanita MC-780).

The subjects were randomized to either CWI intervention group or passive recovery (PR) control group, stratified by sex and sleep problem. We then measured the baseline of CK level (blood sample was analyzed at laboratory of Clinical Pathology Departement, Cipto Mangunkusumo National Central Hospital) and VJ score (measured as the average height of two countermovement jumps using Takei digital vertical jump mat). The subjects then familiarized training/fatigue protocol before doing it the following day.

The fatigue protocol was circuit training in the gym, consisting of nine exercises focused on lower extremity muscle (figure 1. Fatigue protocol). The rest interval between sets was 30 seconds and 60 seconds rest between exercises for the strength training. Ergocycle was done at 65-70% maximum heart rate (HR max), continuously for 15 minutes. Treadmill interval running intensity was set at 60-65% HR max and 85-90% HR max for duration of 15 minutes. Subjects were wearing a Polar heart rate sensor throughout fatigue and recovery protocol, and the rate of perceived exertion was assessed using the Borg scale after every exercise was completed.

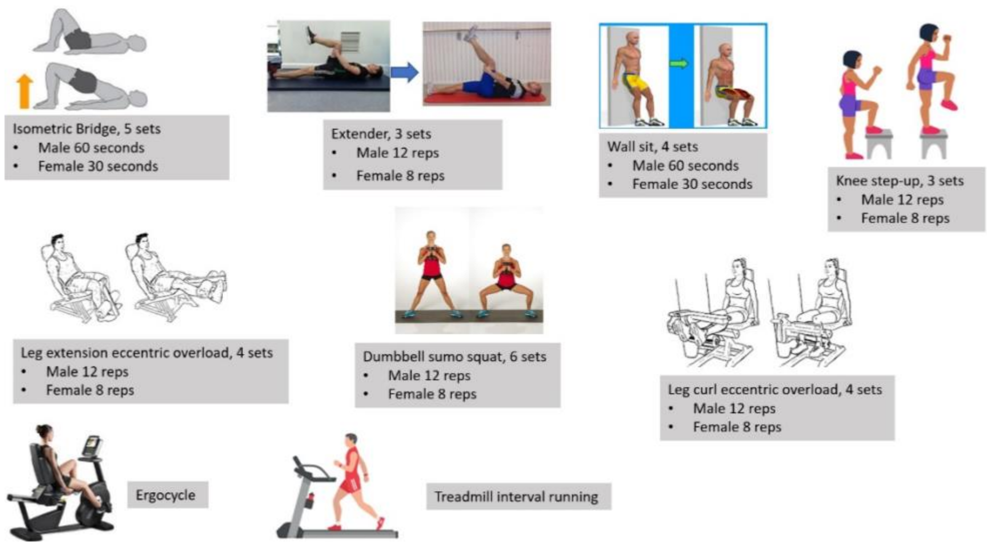

Figure 1. Fatigue Protocol

The recovery protocol was done immediately after the fatigue protocol. Both groups did static stretching of the lower extremity, followed by their respective recovery protocol. The control group was asked to remain to sit for 15 minutes. The intervention group was given CWI using a portable rubber pool 201 x 150 x 51 cm. Subjects receiving the CWI entered the rubber pool, remained in standing position for three minutes, and then submersed to the point of the iliac crest for 12 minutes at a temperature of 11-15°C. Monitoring change of CK level and VJ score were done following recovery protocol (post-exercise recovery), 24-hour and 48-hour post-exercise.

IBM SPSS statistic version 24.0 was used for statistical analysis. The normality of every dependent variable and equality of variance was confirmed using the Shapiro-Wilk and Levene tests. The mean difference within the group was analyzed using repeated Anova + post-hoc Bonferroni test to detect the difference between CK level-VJ score measured at baseline and CK level-VJ score measured at post-exercise recovery, 24-hour, 48-hour in each group. The mean difference between the group was analyzed using an independent T-test to detect the difference between the CK level-VJ score of the two groups measured at every period (baseline, post-exercise recovery, 24-hour, and 48-hour).

Results

The enrollment of subjects can be seen in figure 2 (the CONSORT flow diagram). There were no losses to follow-up data of 20 subjects, but we excluded three subjects from the data analysis because they had a high baseline CK level (CK >1000 U/L). A high baseline level of CK showed a sign of muscle damage.[5] Further evaluation revealed that the three subjects with high baseline CK levels had participated in prolonged and high-intensity exercise two until three days before the baseline CK measurement.

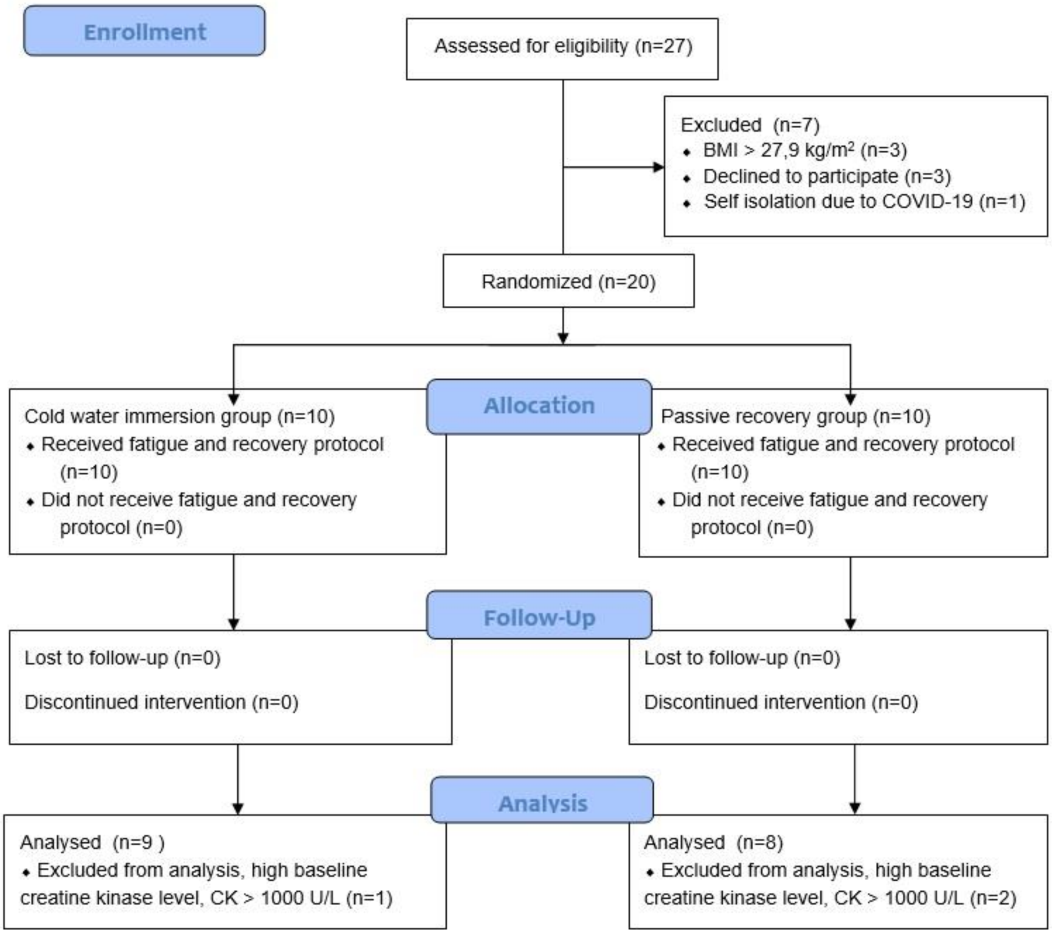

Figure 2. The CONSORT flow diagram

The baseline characteristics of 17 subjects can be seen in the table. There were no significant differences in all parameters between the two groups.

Table 1. Baseline characteristics of subjects

Parameter	Unit/category	Group		p-value
		CWI (n=9)	PR (n=8)	
Age[a]	Years	32,5 ± 5	33,8 ± 4	0,279[c]
Sex[b]	Male	5 (55,6)	5 (62,5)	0,581[d]
	Female	4 (44,4)	3 (37,5)	
Sleep problem	None-mild	8 (88,9)	7 (87,5)	0,735[d]
	moderate-severe	1 (11,1)	1 (12.5)	
Level of physical activity[b]	Moderate	6 (66,7)	5 (62,5)	0,627[d]
	High	3 (33,3)	3 (37,5)	
Sedentary[b]	Yes	4 (44,4)	3 (37,5)	0,581[d]
	No	5 (55,6)	5 (62,5)	
Training frequency (before the pandemic)[b]	Routine	5 (55,6)	2 (25)	0,481[e]
	Fair	1 (11,1)	3 (37,5)	
	Rare	3 (33,3)	3 (37,5)	
Training frequency (during the pandemic)[b]	Routine	5 (55,6)	3 (37,5)	0,370[e]
	Fair	3 (33,3)	2 (25)	
	Rare	1 (11,1)	3 (37,5)	

Body mass index[a]	kg/m^2	23,1 ± 2,2	23,6 ± 2,7	0,312[c]
Muscle mass[a]	kg	43,9 ± 8,3	44,9 ± 10,1	0,414[c]
Fat percentage[s]	%	24,1 ± 7,9	25,9 ± 4,5	0,291[c]
Leg muscle strength[b]	Good	0 (0)	1 (12,5)	0,606[e]
	Fair	3 (33,3)	0 (0)	
	Poor	6 (66,7)	7 (87,5)	
Cardiorespiratory fitness[a]	ml/kg/min	45,3 ± 9,1	43,8 ± 5,6	0,347[c]

a = mean ± standar deviation

b = number (percentage)

c = T-test

d = Fisher exact test

e = Mann-Whitney test

CWI = cold water immersion

PR = passive recovery

Both groups completed all nine exercises in fatigue protocol (p = 0,673, Mann-Whitney test). There were no significant differences in training intensity between the two groups, whether the strength training (CWI Borg scale 3 of 10, PR Borg scale 4 of 10, p = 0,321, Mann-Whitney test) or the aerobic training (CWI 78,5 ± 8,6 % HR max, PR 80,2 ± 6,4 % HR max, p = 0,329, T-test). Both groups had the same level of fatigue based on monitoring of training intensity.

The changes in CK level are shown in figure 3. There was no significant difference in CK level between CWI and PR at baseline (p = 0,153, T-test). Both groups had significantly increased CK levels at post-exercise recovery measurement. At 24-hour post-exercise assessment, subjects who got CWI and PR had not reached recovery point, although the CK level of subjects in the CWI group was significantly lower than subjects in the PR group (p = 0,004, T-test). The repeated ANOVA test and post-hoc Bonferroni showed that the CWI group had no statistically significant difference in CK level compared to their baseline value at 48-hour post-exercise measurement, while the PR group had (CWI p = 0,062, PR p = 0,001). This result indicates that the CWI group had recovered faster (at 48-hour post-exercise) than the PR group, with a significantly lower CK level than the PR group (p = 0,018, T-test).

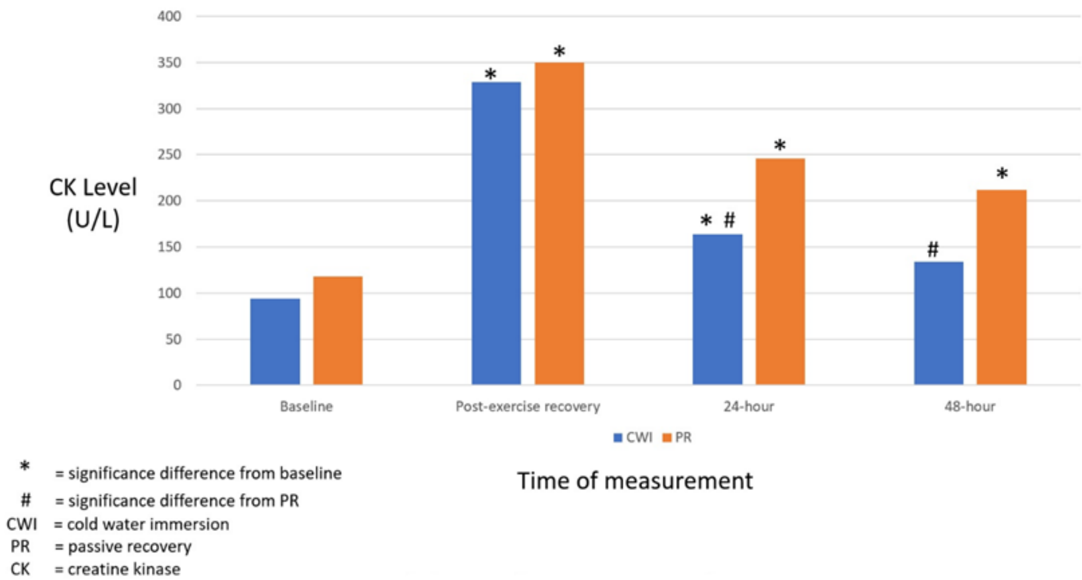

Figure 3. Changes of CK level

Figure 4 shows the change of VJ score in both groups. There was no significant difference between-group difference of VJ score at baseline (p = 0,275, T-test). VJ scores significantly decreased in both groups at post-exercise recovery measurement compared to their respective baseline, despite the CWI group having a higher VJ score than the PR group (p = 0,041, T-test). The repeated ANOVA test and post-hoc Bonferroni showed that the CWI group had no statistically significant VJ score than their baseline at 24-hour post-exercise measurement. In contrast, the PR group still showed a statistically significant difference to the baseline score (CWI p= 0,474, PR p = 0,003). This result indicates that the CWI group had recovered faster than the PR group at 24-hour post-exercise based on changes of VJ score, with a significantly higher VJ score than the PR group (p = 0,039, T-test). Both groups had recovered at 48-hour post-exercise measurement, and there was no statistically significant difference.

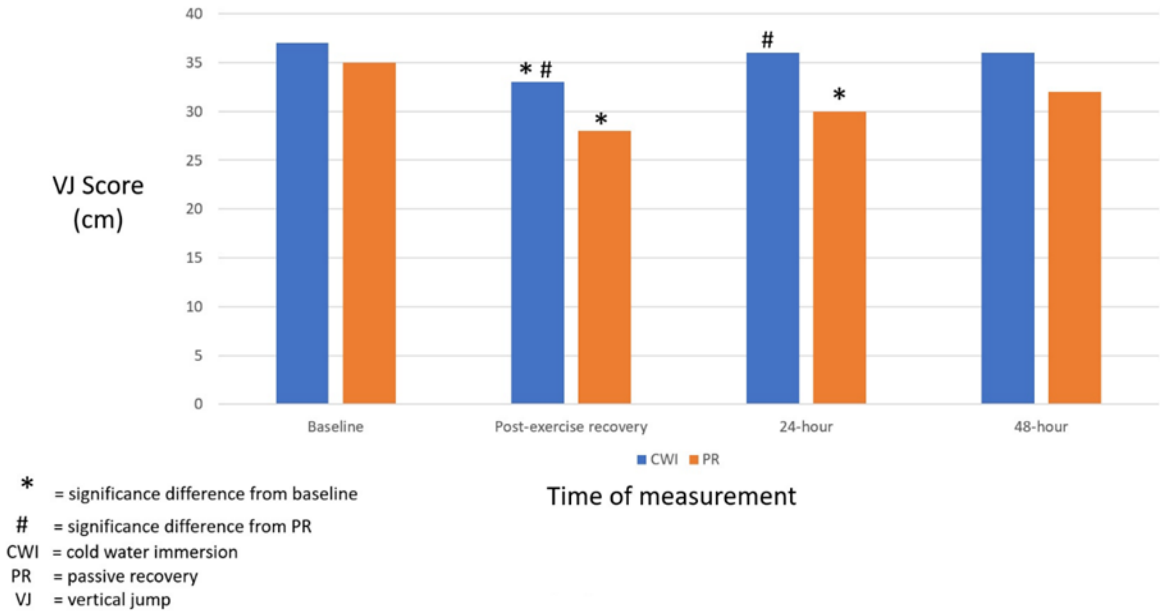

Figure 4. Changes of VJ Score

Discussion

The main findings of this present study showed that 11-15°C CWI intervention for 15 minutes in a recreational athlete could make the recovery process faster than PR at 24-hour post-exercise based on VJ score and at 48-hour post-exercise based on CK level. The results obtained in this study are similar to several previous studies that identified the effect of post-exercise CWI by measuring the VJ score and CK level.

Bouzid et al. also found that CWI can accelerate recovery 24 hours after exercise based on changes in VJ score and 48 hours after exercise based on changes in CK level. Bouzid et al. gave CWI intervention of 10°C for 10 minutes to a male professional soccer athlete after Loughborough Intermittent Shuttle Test (LIST) protocols.[8]

Fonseca et al., who conducted a study on trained male jiu-jitsu athletes, found that CWI can accelerate recovery 24 hours after training based on changes in VJ score. They did not find any significant post-exercise recovery effect between CWI and control based on CK level measurement.[9]

Pooley et al. showed that post-exercise CWI could also speed up recovery in elite junior male soccer athletes. In this study, recovery occurred 48 hours after the match in the group receiving CWI compared to the static stretching group, based on changes in VJ score and CK level.[10]

Measurement of VJ aims to assess muscle power. Muscle power is one skill-related fitness component.[11] Fatigue of the lower extremity muscles after exercise will affect the results of the VJ score. Therefore, it is often used to monitor fatigue conditions in training. The average jump height will decrease up to 120 hours after high-intensity exercise.[4]

Muscle CK bind to myofibrillar structures (M line) in the sarcomere, a region that connects thick filaments (myosin). This region plays a role in maintaining stability during muscle contraction. The high eccentric load can lead to rupture of the muscle sarcomere and increase serum CK. A rise in serum CK may occur to 300-500 U/L levels after high volume or high-intensity exercise.[12] Both subjects in the CWI and PR group of this study showed an increase of serum CK to the level above 300 U/L shortly after completing the fatigue protocol / post-exercise recovery measurement (CWI 329±49 U/L, PR 350±119 U/L). CK activity will be back to baseline in four to 10 days after high-intensity exercise.[12]

The decrease in VJ score and an increase in CK level after high-intensity exercise is influenced by the process of exercise-induced muscle damage (EIMD). Form of exercises that can cause EIMD are generally long duration exercises, exercises with dominant eccentric muscle contraction, or unaccustomed exercises for specific individuals.[13] All these aspects have been implemented in this present study's fatigue protocol. Muscle fiber damage in the EIMD occurs due to mechanical and metabolic processes. The mechanical process originates mainly from the load of the eccentric contraction, which causes tension (stress) in the tiny muscle fibers (microtear). Metabolic processes occur due to increased muscle temperature, impaired cellular respiration in mitochondria, decreased pH, and increased production of free radicals. These could disrupt calcium ion homeostasis in muscle cells, resulting in increased membrane permeability and leakage of CK into circulation.[13] EIMD will defect the functional work of the muscle contractile protein. Failure of the excitation-contraction coupling mechanism will impact the power generated from the VJ movement.[14]

CWI will reduce muscle edema and increase elimination of debris through a vasoconstrictive effect, increase hydrostatic pressure and decrease muscle temperature. Decreased tissue temperature will reduce muscle metabolism and minimize the damage from hypoxia.[15] Adequate tissue oxygenation will increase the activity of motor units in muscle tissue. CWI also limits the contractile protein damage due to EIMD by reducing the permeability of muscle cell membranes. Lower levels of muscle tissue damage (microtear) with CWI intervention may be associated with restoration of VJ score.[8] Reduction of permeability of muscle cell membranes and increase in debris removal will decrease the CK level rapidly. This process is part of the vasoconstrictive effect and increase in hydrostatic pressure of CWI intervention.[15]

The implication and importance of this present study are related to faster recovery after high-intensity training with CWI intervention. Professional athletes generally have a tight training and matches schedule during competition. Athletes who recover faster are expected to be better equipped to train or compete on the next schedule. They will have minimal fatigue and so the risk of injury.[17] Recreational athletes generally condense their recreational sports activities in one or two-day between their daily routines. They are also at risk of experiencing fatigue due to inappropriate exercise volume and intensity.[1] Specific post-exercise recovery interventions such as CWI can be beneficial in accelerating recovery. The faster recovery allows a recreational athletes to return to their work or daily routines in a fitter condition after training. It also reduces the risk of illness and injury due to accumulated fatigue.

The study's strength lies in its subjects, an untrained participant composed of male and female. This variation is different from several previous studies conducted on trained subjects in particular sports or exercise, and they were homogeneous (all subjects were male). This study can provide a new perspective that untrained individuals, male and female, can also get benefit from post-exercise CWI. The other advantage is that the water temperature during the recovery protocol is well monitored, and there is no loss to follow-up data. Despite untrained subjects, there is no incidence of injury during fatigue protocol. The familiarization session and training supervision contribute to zero injury cases in this study.

There was some limitation. Some nutrients that can affect response to recovery, especially those related to controlling EIMD, could not be evaluated during this study. Although the subjects were advised not to consume pain-relieving drugs, coffee, and alcohol during the study period and to continue their daily dietary habits, their nutritional intake was not recorded. Physical activity cannot be fully controlled before the baseline of the VJ score and CK level measurements. They were advised and reminded not to do any form of physical exercise and not to take other recovery methods at home (massage, active recovery, TENS, hydrotherapy, stretching) during the recovery period.

Conclusions

Cold water immersion can accelerate post-exercise recovery in recreational athletes compared to passive recovery. The intervention of CWI makes a recovery faster than PR at 24-hour after exercise based on changes in the vertical jump score. CWI makes faster recovery than PR at 48-hour after exercise based on CK value changes.

Competing Interests

There are no competing interests in this study

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