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The effect of different temperature in land and water after a bout of high intensity training (HIT) on hs-CRP, coagulation factors, and muscle damage indices in professional martial artists

Roya Besharati[1]
Department of Physical Education and Sport Sciences, Ra.C., Islamic Azad University, Rasht, Iran

Nasibe Ezedin [2]
Department of Physical Education and Sport Sciences, Ra.C., Islamic Azad University, Rasht, Iran

Mona Mehdizadeh Haghighi[3]
Department of Physical Education and Sport Sciences, Ra.C., Islamic Azad University, Rasht, Iran

Anahita Shabani[4]
General Practitioner, Medicafit Corrective Exercise & Sport Medicine Clinic, Rasht, Iran

ABSTRACT

Introduction: Enhancing health and physical fitness is a key component of combat readiness in professional athletes. Over the centuries, many groups such as firefighters, military forces, rescue workers, etc. have implemented various strategies to prevent injuries and improve the physical preparedness of their personnel. This study aimed to compare the effect of different temperature in land and water immersion (15°C, and 30°C) after a bout of high intensity training (HIT) on high sensitive CRP (hs- CRP), coagulation factors, and muscle damage markers in professional martial artists (PMA).

Material & Methods: Twelve healthy male PMA (mean age: 21.53 ± 1.73 years; height: 174.33 ± 8.43 cm; weight: 69.53 ± 7.73 kg) participated in this study. During three weeks, participants engaged in one session of HIT per week, each lasting one hour and includes wearing clothes and carrying a 6kg backpack. Post-exercise recovery was conducted using one of the three following active recovery protocols: dry-land, immersion in water (15°C, and 30°C) respectively. Blood samples were collected before, immediately, and 10 minutes after training recovery to measure hs-CRP, coagulation markers, and muscle damage markers. Statistical analyses were performed using SPSS version 24, with statistical significance set at $p<0.05$.

Results: No significant differences were found among the three recovery methods in any of the measured variables, including hs-CRP, fibrinogen, prothrombin, partial thromboplastin time, creatine kinase (CK), aspartate aminotransferase (AST), alanine aminotransferase (ALT), and troponin ($p>0.05$). However, significant time-dependent changes were observed in creatine phosphokinase levels, which increased immediately post-exercise and post-recovery compared to baseline in all three sessions ($p<0.05$). Notably, in the third session, CPK levels significantly decreased after recovery compared to Immediately post-exercise ($p<0.05$).

Conclusion: The findings suggest that there is no significant difference between land active recovery and water immersion at 15°C or 30°C in hs-CRP levels, coagulation factors, or muscle cell damage markers in PMA. All three recovery methods appear to elicit similar physiological responses in the context of a bout of intense training in professional athletes. The data from this study showed that increasing physical fitness to the highest possible level is likely to increase the body's resistance to sudden changes in temperature (such as immersion in cold and hot water) including inflammatory, coagulation, and cellular damage factors following intense exercise.

Keywords: High intensity training, hs-CRP, Coagulation factors, muscle damage markers, athlete, ambient temperature, cold and warm water immersion.

***Correspondence:** hasty.sport@yahoo.com
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1. Introduction

"Changes in body temperature during or after sports exercises or work activities in firefighters, military personnel, and similar professions can have varying effects on the human body. The primary goal of athletes and coaches is to reach peak athletic performance. Optimal and efficient execution of sports skills is the result of the complex interaction of physiological, genetic, biomechanical, and anthropometric factors, and ultimately the selection of an effective method for recovery to the baseline state. Recovery from physical activity is a process through which the body returns to its pre-exercise condition. Although recovery naturally occurs over time, athletes and coaches are interested in accelerating this process to reduce the time between training sessions(1). Martial arts, like other sports, require proper recovery principles to reduce injuries and achieve optimal performance. One of the main concerns of taekwondo coaches and athletes is the limited time between training sessions and competitions for physiological recovery and returning to the pre-activity state during consecutive days of competition(2). Studies have reported that in this high-contact sport, the lower limbs experience the highest incidence of injuries, with contusions, bruises, sprains, and strains being the most common types of injuries(2, 3). Therefore, coaches strive to shorten the recovery period through various methods so that athletes can regain optimal performance and prepare quickly for the next competition, while also reducing the risk of musculoskeletal injuries. Following intense physical activity, structural damage can be observed in the muscles, which serves as a limiting factor for muscular performance (4). Muscle soreness after physical activity occurs in two phases: immediately after exercise—due to tissue edema or the accumulation of metabolic by products—and delayed onset muscle soreness (DOMS), which is associated with inflammatory responses and muscle damage. Intense activities often lead to the early release of muscle damage markers, indicating muscular stress or injury (5). High training volumes and intense competitions—especially with limited recovery time—place significant stress on the musculoskeletal system and generally lead to symptoms of overtraining, fatigue, and reduced physical performance(6). In addition, strenuous training and competitions can lead to muscle damage. Muscle damage stimulates the release of inflammatory mediators and enzymes into the plasma. Creatine kinase is recognized as one of the key markers of muscle membrane disruption. Its levels increase as a result of muscle damage following intense and prolonged exercise. High intensity and repeated contractions during physical activity trigger inflammatory responses within the muscle (7). Damage to active skeletal muscle leads to a decrease in energy reserves, accumulation of metabolic byproducts from physical activity, fatigue, and reduced performance. Under these conditions, the need for proper recovery becomes essential—serving as a critical component of the overall training plan in sports. The primary function of recovery is to help the athlete continue training, reduce injuries caused by training or competition, and ultimately achieve better performance in the next session or competition without reaching the stage of overtraining(8). Recovery includes a variety of methods such as nutritional strategies, static stretching, massage, adequate sleep, active recovery, passive recovery, cryotherapy, and cold-water immersion(9). Cold-water immersion is one of the popular recovery methods used by coaches and athletes to accelerate the process of performance recovery after training and competition(10). Some studies have reported the benefits of this method after activity, showing that it may reduce muscle damage, decrease muscle soreness, and aid in muscle performance recovery(11). Cold-water immersion can be performed in two ways: localized immersion and whole-body immersion (with the head not submerged). In the localized method, the muscles and limbs that have been active and need recovery are placed in cold water(12, 13). Two important variables in this method are water temperature and immersion duration. The temperature and duration of immersion may vary depending on the type of exercise and the variable being measured (14, 15). Several studies have demonstrated that cold water immersion is more effective in reducing muscle damage compared to other recovery methods (16, 17). Given the intense nature of combat training and the increased risk of systemic inflammation, muscle damage, and physiological dysfunction, identifying and comparing the effectiveness of different recovery strategies is crucial for improving physical condition, reducing damage biomarkers, and maintaining the health and performance of professional combat Athletes .The challenge in this research is the lack of scientific consensus and sufficient evidence regarding the relative effectiveness of various recovery strategies (such as cold water immersion, massage, active recovery, sleep, nutritional supplementation, or cryotherapy) in reducing systemic inflammation, muscle damage (e.g., elevated markers like CK, myoglobin, and IL-6), and improving performance in professional martial artists, particularly under conditions of intense training and actual competitions. Given the primary challenge of this research—namely, the lack of scientific consensus and sufficient evidence regarding the relative effectiveness of various recovery strategies (such as cold water immersion, massage, active recovery, sleep, nutritional supplementation, or cryotherapy) in reducing systemic inflammation, muscle damage (e.g., elevated markers like CK, myoglobin, and IL-6), and improving performance in professional martial artists, particularly under conditions of intense training and actual competitions—it can be concluded that the existing findings are often contradictory and inconsistent. These inconsistencies largely stem from differences in study methodologies, studied populations, intensity and type of interventions, and real-world competition conditions, which limit the generalizability of the results. Therefore, the interpretation of current results should be approached with great caution, and there is an urgent need for higher-quality further research, including larger randomized controlled trials involving professional martial artists, longitudinal designs that simulate real competition conditions, and up-to-date systematic reviews or meta-analyses to achieve a more valid scientific consensus.

2. Methodology

2.1. Materials and methods

This pre and post-test quasi-experimental design study, involving 12 volunteer PMA assigned to a group. During three weeks, participants performed one session per week of combined resistance and aerobic HIT. Blood samples were collected at three time points: before, immediately training, and following recovery. Recovery methods varied across three weeks: land-based recovery, cold water immersion at 15°C, and warm water immersion at 30°C (table 1).

Table 1. *Experimental Protocol*

Phase	Session 1(week one)	Session 2(week two)	Session 3(week three)
Pre-exercise	Blood sampling	Blood sampling	Blood sampling
Exercise	Resistance + Aerobic HIT	Resistance + Aerobic HIT	Resistance + Aerobic HIT
Immediately post-exercise	Blood sampling	Blood sampling	Blood sampling
Recovery method	Active land-based recovery	Cold water immersion (15°C)	Warm water immersion (30°C)
Post-recovery	Blood sampling	Blood sampling	Blood sampling

2.2. Participants

The statistical population of study were selected from Professional taekwondo athletes (PMA) of Rasht clubs, Guilan province, Iran. Following initial assessments and the posting of a recruitment notice in various clubs, 15 volunteers expressed interest in participating. Inclusion criteria included full physical health (confirmed by a medical professional), being under 25 years of age, and having an acceptable level of physical fitness. After screening and eligibility assessments, 12 physically fit PMA were selected as the final participants and completed the study. Three athletes were excluded due to medical reasons: one person for high blood pressure, one for musculoskeletal pain and one for impaired lipid profile. Prior to the main study, a pilot test was conducted on two athletes to assess the feasibility of the training and recovery protocols, monitor heart rate responses, and ensure the appropriateness of the procedures. Participants underwent training once a week for three consecutive weeks. Each session lasted one hour and involved performing exercises while wearing attire and carrying a 6-kilogram weighted bag. Following each training session, recovery was administered using one of three active recovery methods: dry-land recovery, immersion in water at 15°C, and 30°C respectively. Blood samples were collected from the left cubital vein by a laboratory technician under the researcher’s supervision immediately before training, immediately after training, and 10 minutes following the completion of each recovery method. The samples were analyzed for hs-CRP levels, coagulation factors, and markers of muscular damage. Training sessions were held between 3:00 PM and 4:00 PM. Ambient temperature ranged from approximately 20 to 23°C, and humidity levels were recorded between 89% and 93%. Throughout the duration of the study, participants were instructed to avoid any intense martial arts training outside the scheduled sessions.

2.3. Measurements

Height was measured using a wall height meter Stadiometer. Participants were measured without shoes, and height was recorded in centimeters. This measurement was conducted only during the initial test. Weight was measured using a digital scale (XK3190–A12E, China) and recorded in kilograms. Participants were weighed with minimal clothing. They were advised not to consume heavy meals or large amounts of water for at least three hours prior to the measurement.

Blood samples were collected from participants at three time points: before, immediately, and 10 minutes post-recovery. Under standardized environmental control conditions, including ambient temperatures between 20°C and 23°C, sufficient lighting, and relative humidity ranging from 89% to 93%. Blood collection was performed between 15:00 and 16:30. A volume of 5 cc of venous blood was drawn from the cubital vein using sterile Supa-brand syringes. Depending on the type of analysis, the blood samples were collected in test tubes containing anticoagulants or in plain tubes without anticoagulants. Serum or plasma was used for analysis as appropriate to the specific test.

In the present study, serum levels of hs-CRP were measured using a diagnostic kit (Pars Azmoon Co). The measurement was performed using the ELISA method with an Coagulometer (Stago-R Evolution (France) automatic coagulation analyzer). Results were reported in micrograms per milliliter (µg/mL). Blood plasma was used for the analysis, which was obtained from test tubes containing anticoagulant. The level of creatine phosphokinase (CPK) was measured using the COBAS-MIRA Plus autoanalyzer (Roche, Germany) based on an enzymatic colorimetric method. The results were reported in units per liter (U/L). ALT and AST levels were measured using an enzymatic method with the CRONIX AT-801 autoanalyzer (Germany). The results were expressed in units per liter (U/L). Serum samples were obtained from blood collected in plain tubes without anticoagulants.

Fibrinogen levels, as a coagulation marker, were measured using diagnostic kits from Diagnostica (France) and the Stago coagulometer (France). Prothrombin time (PT) and partial thromboplastin time (PTT) were measured in seconds, while fibrinogen concentration was reported in milligrams per deciliter (mg/dL). Troponin levels were measured using a specific troponin kit from Eastbiopharm and the ELISA method (ELISA reader, Italy). Results were reported in nanograms per milliliter (ng/mL). Blood samples collected in anticoagulant-containing tubes were used, and plasma was analyzed.

2.4. Intervention

Resistance Training protocol consisted of six exercises: crunches, burpees, squats, planks, push-ups, and pull-ups at 85% 1 Reptation Maximum (1RM), performed over a duration of 30 minutes. The first 10 minutes were dedicated to stretching and warm-up exercises. The resistance training involved performing each of the six exercises in 3 set of 10 second with a 45-second rest interval between sets. Most commonly, 1RM is determined directly using trial and error testing. The participant lifts progressively heavier free weights, resting for several minutes between each attempt (5min), until the maximum weight for which the participant can complete one full repetition is determined. Following the resistance training, and after two-minute rest period, aerobic exercise training was performed at an intensity greater than 80 percent of maximum heart rate (220 – age) that control with Polar Heart Rate Monitor (RC3 GPS Fitness Watch) over a distance of 1.6 kilometers.

After completing the training in each session, participants performed active stretching and recovery exercises training for 15 minutes in land. In the second session, they underwent immersion in water at 15°C, and in the third session, immersion was conducted in water at 30°C. The ambient temperature ranged approximately between 20°C and 23°C, with humidity levels between 89% and 93%. Additionally, air temperature, humidity, and water temperature were continuously monitored throughout the sessions.

2.5. Statistical Methods

Descriptive statistics were used to present the anthropometric and physiological characteristics of the participants in separate tables. The Kolmogorov–Smirnov test was applied to assess the normality of the data distribution. Subsequently, repeated measures analysis of variance (ANOVA) was conducted, followed by the Bonferroni post hoc test. The results of Mauchly’s Test of Sphericity for the variables type of recovery, measurement time, and their interaction (recovery type × time) indicated that the assumption of sphericity was met for all three variables ($p > 0.05$). Therefore, to assess the effect of these variables on hs-CRP levels, the Greenhouse-Geisser correction under sphericity conditions was applied. All statistical analyses were performed using SPSS software version 22, and graphs were created using Microsoft Excel 2013. A significance level of $p < 0.05$ was considered statistically significant.

3. Results

The characteristics of PMA including age, height, weight, and body mass index (BMI), were presented in the table 2.

Table 2. *Descriptive Characteristics of Participants (n = 12)*

Variable	Mean ± Standard Deviation
Age (years)	21.53 ± 1.73
Height (cm)	174.33 ± 8.43
Weight (kg)	69.53 ± 7.73
BMI (kg/m²)	23.28 ± 1.48

The blood variables of the athletes, including inflammatory, coagulation, and muscle damage markers, measured at different stages of the testing protocol, are presented in the table 3.

Table 3. *Descriptive Statistics of Inflammatory, Coagulation, and Cellular Damage Markers in PMA (n = 12)*

Marker Category	Variable	Measurement Time	Active Dry-Land Recovery (Mean ± SD)	Water Immersion at 15°C (Mean ± SD)	Water Immersion at 30°C (Mean ± SD)
Inflammatory Marker	hs-CRP (µg/mL)	Before exercise	875.36 ± 386.00	837.36 ± 322.61	874.00 ± 331.84
		Immediately after	1129.27 ± 480.06	1044.90 ± 502.71	939.09 ± 392.17
		After recovery	1037.09 ± 500.02	942.72 ± 274.09	880.52 ± 437.81
Coagulation Markers	Fibrinogen (mg/dL)	Before exercise	250.21 ± 20.43	253.94 ± 12.06	249.25 ± 30.06
		Immediately after	252.13 ± 31.41	254.98 ± 18.21	250.09 ± 25.08
		After recovery	249.19 ± 25.12	234.27 ± 16.42	231.44 ± 19.65
	PT (sec)	Before exercise	12.13 ± 0.32	12.04 ± 0.15	12.08 ± 0.18
		Immediately after	12.22 ± 0.41	12.13 ± 0.32	12.31 ± 0.46
		After recovery	12.35 ± 0.39	12.27 ± 0.41	12.31 ± 0.46
	PTT (sec)	Before exercise	36.00 ± 4.87	36.54 ± 2.26	35.40 ± 3.58
		Immediately after	38.90 ± 3.41	37.45 ± 4.94	37.09 ± 4.39
		After recovery	38.73 ± 4.12	37.09 ± 4.18	36.81 ± 4.13
Cellular Damage Markers	CPK (U/L)	Before exercise	198.81 ± 54.66	231.90 ± 34.38	204.81 ± 33.06
		Immediately after	226.09 ± 51.82	276.63 ± 37.35	246.09 ± 42.19
		After recovery	214.36 ± 67.43	265.72 ± 42.66	230.72 ± 48.39
	AST (U/L)	Before exercise	27.72 ± 5.25	27.18 ± 4.35	28.36 ± 10.92
		Immediately after	30.27 ± 6.13	31.81 ± 9.10	30.54 ± 12.11
		After recovery	29.45 ± 7.56	29.72 ± 11.55	29.57 ± 13.35
	ALT (U/L)	Before exercise	26.54 ± 8.12	26.09 ± 8.80	25.36 ± 7.82
		Immediately after	26.36 ± 7.05	27.63 ± 7.36	25.54 ± 9.04
		After recovery	21.72 ± 8.07	25.81 ± 10.82	25.81 ± 8.27
	Troponin (ng/mL)	Before exercise	0.21 ± 0.021	0.30 ± 0.027	0.21 ± 0.029
		Immediately after	0.32 ± 0.054	0.39 ± 0.030	0.26 ± 0.025
		After recovery	0.31 ± 0.037	0.36 ± 0.028	0.25 ± 0.028

To assess the normal distribution of the research variables, the Shapiro- wilk test was used. The results indicate that all measured variables follow a normal distribution ($p > 0.05$).

To examine the differences between active recovery in land, water immersion at 15°C and 30°C on hs-CRP levels, an ANOVA repeated measurement was used. The results (Figure1) indicated that there was no significant effect of recovery type on hs-CRP levels in PMA ($p > 0.05$).

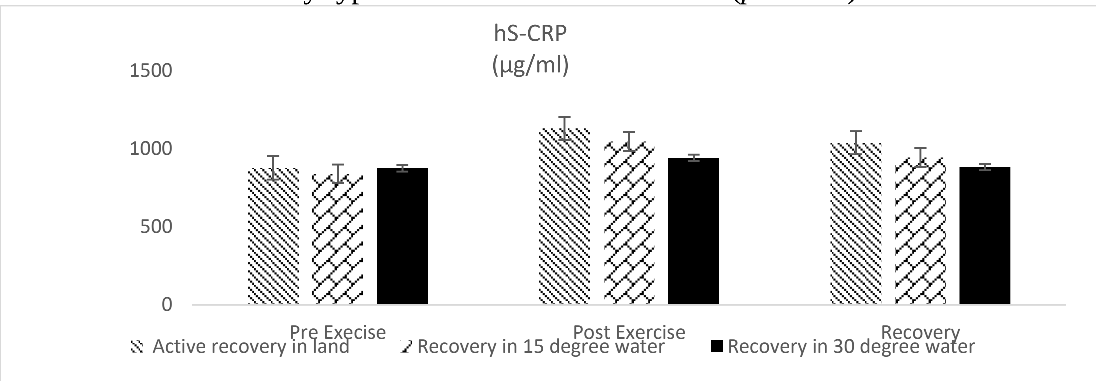

Figure1. Comparison of hs-CRP levels at different time points between active recovery in land, and immersion in 15°C and 30°C water among PMA (n=12)

To investigate the differences between active recovery in land and immersion in 15°C and 30°C water on fibrinogen, PT, and PTT levels, a repeated measures ANOVA indicated no significant effects of recovery method, measurement time, or their interaction on fibrinogen, PT, and PTT levels (p > 0.05). Thus, no significant differences were found between active land recovery and water immersion at 15°C and 30°C on coagulation markers in PMA (Figure 2,3,4).

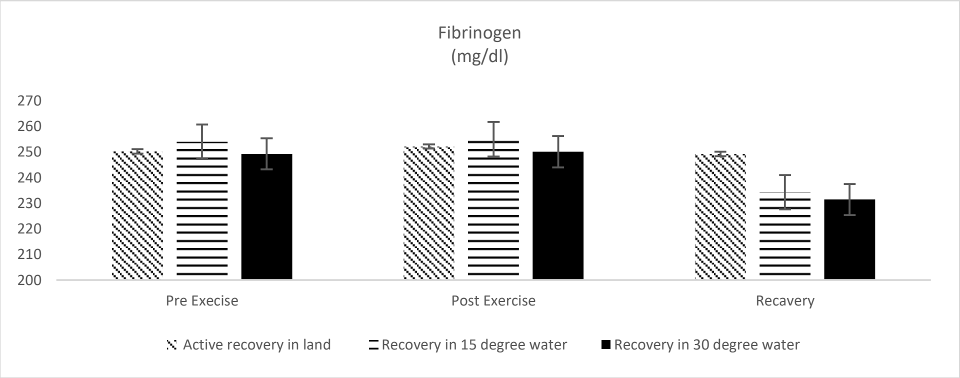

Figure 2. Differences in fibrinogen levels at various measurement times between active land recovery and immersion in 15°C and 30°C water in PMA (n=12)

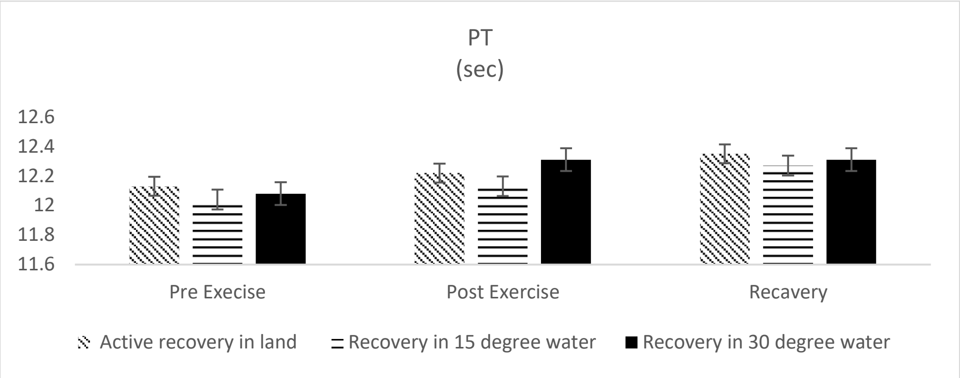

Figure 3. *Differences in PT levels at different measurement times between active recovery* on land and water immersion at 15°C and 30°C in PMA (n = 12)

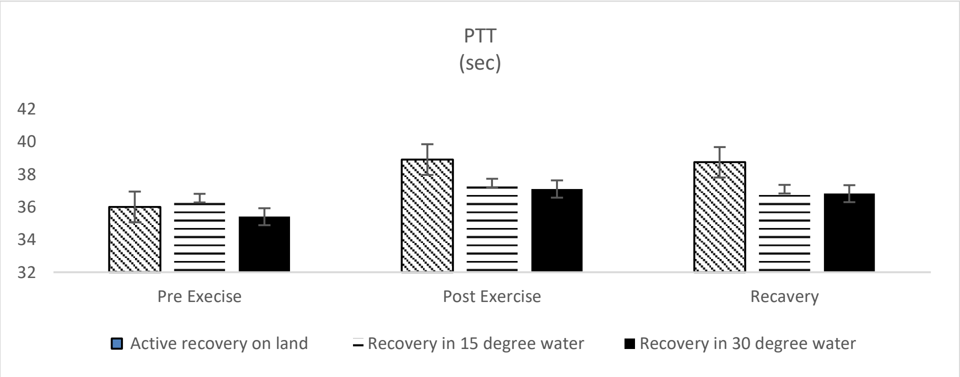

Figure 4. Differences in PTT levels at different measurement times between active recovery *on land and water immersion at 15°C and 30°C in combat athletes (n = 12)*

The results did not have a significant effect on Cellular Damage Markers contain: CPK, ALT, AST, and Troponin levels. (Figure 5,6,7,8)

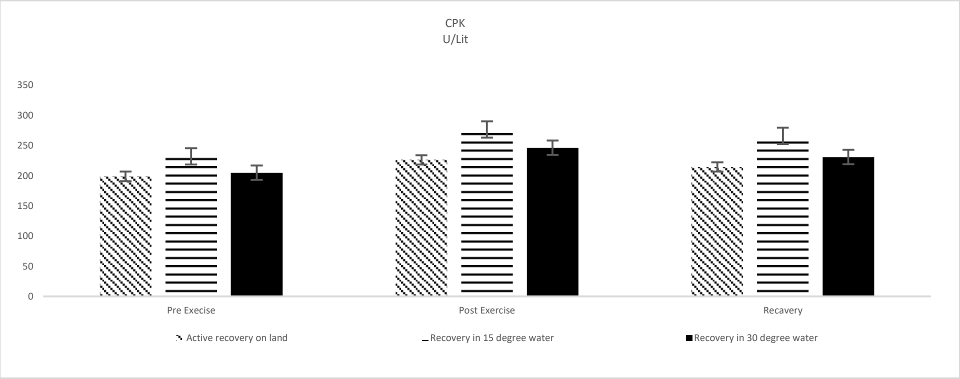

Figure 5. CPK levels at different measurement times between active recovery on land and water immersion at 15°C and 30°C in PMA (n = 12)

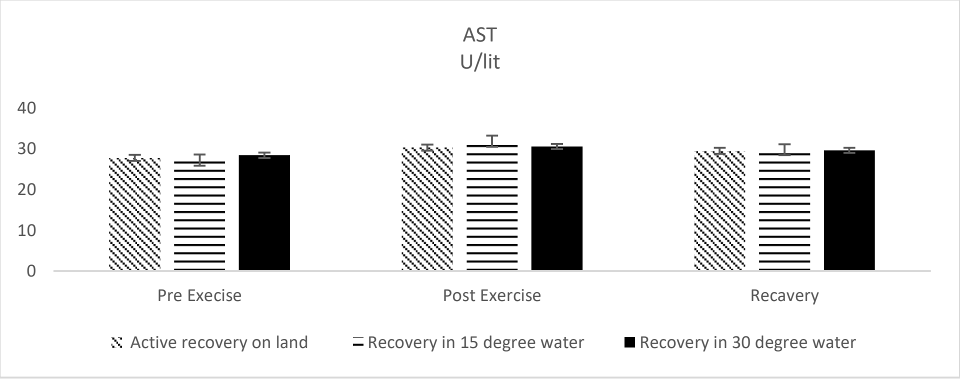

Figure 6. AST levels at different measurement times between active recovery on land and water immersion at 15°C and 30°C in PMA (n = 12)

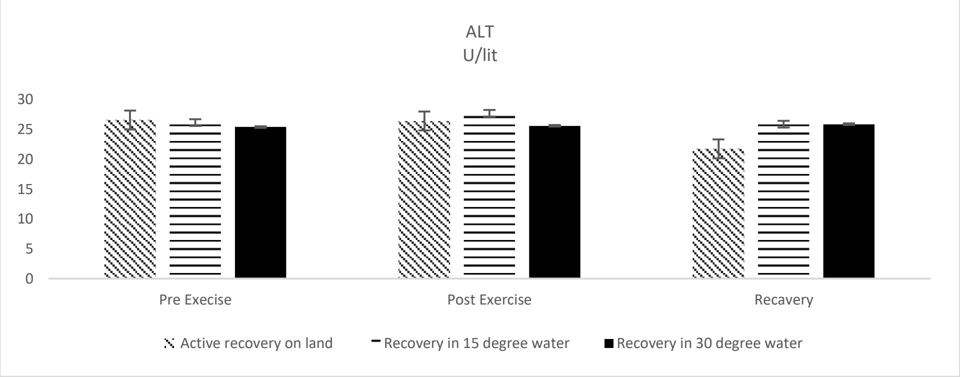

Figure 7. ALT levels at different measurement times between active recovery on land and water immersion at 15°C and 30°C in PMA (n = 12)

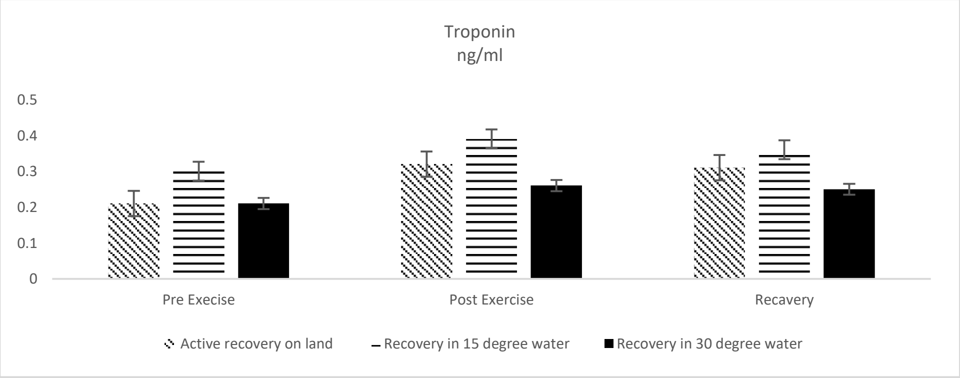

Figure 8. Troponin levels at different measurement times between active recovery on land and water immersion at 15°C and 30°C in PMA (n = 12)

4. Discussion

The purpose of the present study was to examine the effects of different recovery temperatures in land and water environments following a bout of HIT on hs-CRP, coagulation factors, and muscle damage indices in PMA. The findings are discussed in relation to existing evidence on exercise-induced inflammation, muscle damage, and temperature-based recovery strategies.

HIT is known to provoke a transient systemic inflammatory response, commonly reflected by elevations in hs-CRP (18, 19). This response is largely mediated by muscle fiber disruption, increased cytokine release, particularly interleukin-6, and hepatic synthesis of acute-phase proteins (20).Several studies support the use of cold water immersion (CWI) as a recovery modality to attenuate post-exercise inflammation. The proposed mechanisms include reduced tissue temperature, vasoconstriction, and decreased leukocyte migration, which may collectively limit the inflammatory cascade(14). Meta-analytical findings suggest that CWI may modestly reduce inflammatory markers within 24–48 hours following strenuous exercise when compared with passive recovery (21).In contrast, other investigations report no significant differences in hs-CRP responses between cold water immersion, thermoneutral water immersion, and land-based recovery(11, 22). Peake et al. (2017) demonstrated that while CWI reduced perceived muscle soreness, it did not significantly alter systemic inflammatory markers, including CRP. Such inconsistencies may be explained by variations in exercise type, recovery duration, immersion temperature, and athletes' training status(13).Collectively, these findings suggest that although cold water immersion may influence subjective recovery, its effectiveness in consistently reducing hs-CRP following high-intensity exercise remains equivocal.

Exercise-induced muscle damage (EIMD) is typically characterized by increased circulating levels of creatine kinase (CK), lactate dehydrogenase (LDH), and myoglobin, particularly following eccentric or HIT (23). Martial arts involve repeated explosive actions and physical contact, making athletes particularly susceptible to muscle damage(18).A substantial body of literature supports the use of cold water immersion to attenuate muscle damage markers and accelerate recovery. Cooling-induced reductions in muscle temperature and metabolic activity may limit secondary muscle damage and inflammatory-mediated degradation (24). Systematic reviews and meta-analyses have reported lower CK concentrations and faster restoration of muscle function following CWI compared with land-based recovery(25).Conversely, several studies have found no significant differences in muscle damage markers between cold water immersion and other recovery modalities(16). Furthermore, growing evidence suggests that chronic use of CWI may impair long-term training adaptations by suppressing anabolic signaling pathways such as mTOR(11, 26). Roberts et al. (2015) reported attenuated gains in muscle hypertrophy and strength when cold water immersion was used regularly following resistance training(27). Therefore, while CWI appears beneficial for short-term recovery in competitive contexts, its long-term use should be strategically periodized.

Acute bouts of HIT have been shown to transiently activate the coagulation system, leading to increased fibrinogen levels, elevated D-dimer, and shortened clotting times(28). These changes are considered adaptive responses to vascular and endothelial stress.Research examining the influence of post-exercise temperature manipulation on coagulation factors is limited. Cold exposure may theoretically enhance coagulation via vasoconstriction and hem concentration, whereas warm water immersion may promote vasodilation and improved blood rheology. However, most studies indicate that exercise-induced coagulation changes are short-lived and normalize within hours, regardless of recovery modality. The scarcity of data in elite athletic populations underscores the need for further research, particularly given the repeated exposure of professional martial artists to high-intensity exercise stimuli(29).

Water-based recovery offers additional physiological benefits, including hydrostatic pressure and buoyancy, which may enhance venous return and metabolite clearance compared with land-based recovery. Cold water immersion remains one of the most widely used recovery strategies due to its analgesic and anti-inflammatory properties (30).However, recent evidence suggests that warm or contrast water immersion may be equally effective—or even superior—for restoring muscle performance without excessively suppressing inflammation (31, 32). These findings highlight the importance of tailoring recovery strategies to specific performance goals, competition schedules, and training phases (29).

The data from this study showed that increasing physical fitness to the highest possible level is likely to increase the body's resistance to sudden changes in temperature (such as immersion in cold and hot water) including inflammatory, coagulation, and cellular damage factors following intense exercise. Considering the findings of the present study as well as the conflicting results reported in some previous research, it is recommended that future investigations be designed and conducted with examination of longer-term effects (up to 72 hours post-exercise). Since some inflammatory markers such as hs CRP and coagulation factors require more time to exhibit changes after exercise, measuring these indicators at extended time points (24, 48, and 72 hours) could provide a more comprehensive understanding of the effects of recovery interventions. Utilizing larger sample sizes, existence of control group, and comparing across different demographic groups (military personnel, elite athletes, firefighter personals etc.) can enhance the generalizability of the results. Assessing inflammatory cytokines like IL 6, TNF α, and IL 10 or oxidative stress markers might offer greater sensitivity in detecting differences between recovery methods.Since physiological responses to recovery may differ between males and females, and environmental conditions such as ambient temperature or humidity can influence the effectiveness of water immersion, controlling for these variables in future studies is essential.

5. Conclusion

In conclusion, recovery temperature and environment play an important role in modulating physiological responses following HIT. Cold water immersion may provide short-term benefits for reducing muscle damage and perceived soreness, whereas its effects on hs-CRP and coagulation factors remain inconsistent. The results of our study showed that in highly physically fitness athletes, changes in ambient temperature in the short term have fewer effects on coagulation, cellular damage, and inflammation factores.

Personalized and goal-oriented recovery strategies are therefore recommended for professional martial artists.

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References

1. Leeder J, Gissane C, Van Someren K, Gregson W, Howatson G. Cold water immersion and recovery from strenuous exercise: a meta-analysis. British journal of sports medicine. 2012;46(4):233-40. DOI: 10.1136/bjsports-2011-090061
2. Lv Q, editor Research on the physical fatigue recovery and Training Method of Taekwondo Athletes. 2015-1st International Symposium on Social Science; 2015: Atlantis Press. DOI: 10.2991/ISSS-15.2015.32
3. Lystad RP, Alevras A, Rudy I, Soligard T, Engebretsen L. Injury incidence, severity and profile in Olympic combat sports: a comparative analysis of 7712 athlete exposures from three consecutive Olympic Games. British journal of sports medicine. 2021;55(19):1077-83. DOI: 10.1136/bjsports-2020-102958
4. Wiese-Bjornstal DM. Psychology and socioculture affect injury risk, response, and recovery in high-intensity athletes: a consensus statement. Scandinavian journal of medicine & science in sports. 2010;20:103-11. DOI: 10.1111/j.1600-0838.2010.01190.x
5. Bessa A, Nissenbaum M, Monteiro A, Gandra PG, Nunes L, Bassini-Cameron A, et al. High-intensity ultraendurance promotes early release of muscle injury markers. British journal of sports medicine. 2008;42(11):889-93. DOI: 10.1136/bjsm.2007.041228
6. Crewther BT, Cook CJ. Effects of different post-match recovery interventions on subsequent athlete hormonal state and game performance. Physiology & behavior. 2012;106(4):471-5. DOI: 10.1016/j.physbeh.2012.03.018
7. SEDAGHAT M, RASHIDI M, IZADI M. The Effect of Creatine Supplementation on CK, LDH after A Session Intense Exercise. 2018. DOI: 10.29252/jsmt.5.2.45
8. Weerapong P, Hume PA, Kolt GS. The mechanisms of massage and effects on performance, muscle recovery and injury prevention. Sports medicine. 2005;35(3):235-56. DOI: 10.2165/00007256-200535030-00004
9. Rey E, Lago-Peñas C, Casáis L, Lago-Ballesteros J. The effect of immediate post-training active and passive recovery interventions on anaerobic performance and lower limb flexibility in professional soccer players. Journal of human kinetics. 2012;31:121. DOI: 10.2478/v10078-012-0013-9
10. Park E-H, Choi S-W, Yang Y-K. Cold-water immersion promotes antioxidant enzyme activation in elite taekwondo athletes. Applied Sciences. 2021;11(6):2855. DOI: 10.3390/app11062855
11. 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 Medicine. 2016;46(8):1095-109. DOI: 10.1007/s40279-016-0483-3
12. An J, Lee I, Yi Y. The thermal effects of water immersion on health outcomes: an integrative review. International journal of environmental research and public health. 2019;16(7):1280. DOI: 10.3390/ijerph16071280
13. Peake JM, Roberts LA, Figueiredo VC, Egner I, Krog S, Aas SN, et al. The effects of cold water immersion and active recovery on inflammation and cell stress responses in human skeletal muscle after resistance exercise. The Journal of physiology. 2017;595(3):695-711. DOI: 10.1113/JP272881
14. Bleakley CM, Davison GW. What is the biochemical and physiological rationale for using cold-water immersion in sports recovery? A systematic review. British journal of sports medicine. 2010;44(3):179-87. DOI: 10.1136/bjsm.2009.065565
15. Broatch JR, Petersen A, Bishop DJ. Postexercise cold water immersion benefits are not greater than the placebo effect. Medicine & Science in Sports & Exercise. 2014;46(11):2139-47. DOI: 10.1249/MSS.0000000000000348
16. Bailey D, Erith S, Griffin P, Dowson A, Brewer D, Gant N, et al. Influence of cold-water immersion on indices of muscle damage following prolonged intermittent shuttle running. Journal of sports sciences. 2007;25(11):1163-70. DOI: 10.1080/02640410600982659
17. Hohenauer E, Costello JT, Deliens T, Clarys P, Stoop R, Clijsen R. Partial-body cryotherapy (− 135° C) and cold-water immersion (10° C) after muscle damage in females. Scandinavian journal of medicine & science in sports. 2020;30(3):485-95. DOI: 10.1111/sms.13596
18. Amtmann JA. Self-reported training methods of mixed martial artists at a regional reality fighting event. The Journal of Strength & Conditioning Research. 2004;18(1):194-6. DOI: 10.1519/1533-4287(2004)018<0194:STMOMM>2.0.CO;2
19. Pedersen BK, Febbraio MA. Muscle as an endocrine organ: focus on muscle-derived interleukin-6. Physiological reviews. 2008. DOI: 10.1152/physrev.90100.2007
20. Nieman D. Exercise immunology: future directions for research relatedto athletes, nutrition, and the elderly. International journal of sports medicine. 2000;21(Sup. 1):61-8. DOI: 10.1055/s-2000-1450

21. Hohenauer E, Taeymans J, Baeyens J-P, Clarys P, Clijsen R. The effect of post-exercise cryotherapy on recovery characteristics: a systematic review and meta-analysis. PloS one. 2015;10(9):e0139028. DOI: 10.1371/journal.pone.0139028
22. Stanley J, Peake JM, Buchheit M. Consecutive days of cold water immersion: effects on cycling performance and heart rate variability. European journal of applied physiology. 2013;113(2):371-84. DOI: 10.1007/s00421-012-2445-2
23. Clarkson PM, Hubal MJ. Exercise-induced muscle damage in humans. American journal of physical medicine & rehabilitation. 2002;81(11):S52-S69. DOI: 10.1097/00002060-200211001-00007
24. Eston R, Peters D. Effects of cold water immersion on the symptoms of exercise-induced muscle damage. Journal of sports sciences. 1999;17(3):231-8. DOI: 10.1080/026404199366019
25. 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 medicine. 2016;46(4):503-14. DOI: 10.1007/s40279-015-0431-7
26. Fyfe JJ, Broatch JR, Trewin AJ, Hanson ED, Argus CK, Garnham AP, et al. Cold water immersion attenuates anabolic signaling and skeletal muscle fiber hypertrophy, but not strength gain, following whole-body resistance training. Journal of Applied Physiology. 2019. DOI: 10.1152/japplphysiol.00032.2018
27. Roberts LA, Raastad T, Markworth JF, Figueiredo VC, Egner IM, Shield A, et al. Post-exercise cold water immersion attenuates acute anabolic signalling and long-term adaptations in muscle to strength training. The Journal of physiology. 2015;593(18):4285-301. DOI: 10.1113/JP270570
28. El-Sayed MS, El-Sayed Ali Z, Ahmadizad S. Exercise and training effects on blood haemostasis in health and disease: an update. Sports medicine. 2004;34(3):181-200. DOI: 10.2165/00007256-200434030-00004
29. Kellmann M, Beckmann J. Sport, recovery, and performance. J Beckmann–Abingdon, UK: Routledge. 2018. DOI: 10.4324/9781315268142
30. Halson SL. Recovery techniques for athletes. Sports Science Exchange. 2013;26(120):1-6.
31. Versey NG, Halson SL, Dawson BT. Water immersion recovery for athletes: effect on exercise performance and practical recommendations. Sports medicine. 2013;43(11):1101-30. DOI: 10.1007/s40279-013-0063-8
32. Vaile J, Halson S, Gill N, Dawson B. Effect of cold water immersion on repeat cycling performance and thermoregulation in the heat. Journal of sports sciences. 2008;26(5):431-40. DOI: 10.1080/02640410701567425