Effect of Post-Exercise Cold Water Immersion Recovery Protocol on Cardiovascular Adaptations and Exercise Capacity in Athletes: A Randomized Controlled Trial

AlZahraa Bahy Mohamed[1], Zeinab Mohamed Helmy[2], Sherin Hassan Mohamed[3], El-Sayed Essam El-Sayed Felaya[2]

[1]Physical Therapy for Cardiovascular/Respiratory Disorder and Geriatrics, Faculty of Physical Therapy, Ahram Canadian University, Egypt.

[2]Physical Therapy for Cardiovascular/Respiratory Disorder and Geriatrics, Faculty of Physical Therapy, Cairo University, Egypt.

[3]Physical Therapy for Cardiovascular/Respiratory Disorder and Geriatrics, Faculty of Physical Therapy, Beni-Suef University, Egypt.

Corresponding author: AlZahraa Bahy Mohamed, Phone: 01021999573, **E-mail:** zahrabahy@gmail.com

ABSTRACT

Background: Muscle injuries caused by exercise, including edema, pain, weakness, as well as functional loss of mobility, greatly affect the capacity to carry out subsequent exercise, which in turn reduces physical activity and sports participation. Being a cryotherapy tool, cold-water immersion is one of several post-exercise recovery techniques that have grown in popularity to help in recovery after training and competitions.

Aim of the study: to examine the impact of post exercise cold water immersion on cardiovascular adaptations and exercise capacity in basketball players.

Subjects and Methods: In total, 60 male basketball players aged from 18–28 years were randomized into two equal groups (n = 30). The experimental group (A) received both cold water immersion and traditional recovery protocols, whereas the control group (B) received traditional recovery protocol only. The protocol was applied three times per week for four consecutive weeks. The dependent variables, namely, heart rate, blood pressure, oxygen saturation, cardiac enzymes, and exercise capacity were assessed at the beginning and the end of trial.

Results: There was a significant increase in resting O_2, immediate after exercise O_2, Harvard step test score, and Cooper test score, while significant decline was found in resting heart rate (HR) immediate following exercise HR, HR recovery time, resting SBP, immediate after exercise SBP and resting DBP of group A in comparison with that of group B.

Conclusion: Cold-water immersion was an effective post-exercise recovery protocol for cardiovascular adaptations, exercise capacity enhancement, and reduce risk of injury in subsequent basketball training and competition.

Keywords: Exercise-induced muscle injuries, Basketball players, Exercise capacity, Cold water immersion

INTRODUCTION

It was usual for elite athletes to suffer from post-exercise injuries. Despite some variation in the type of lesions seen across sports, most injuries were the result of a mixture of factors, making it extremely difficult to identify a single cause [(1)].

It has been reported that time lost due to illness and injuries is an important component in athletic success when it comes to cardiorespiratory fitness as well as injury prevention. As a result, reducing in-season injuries in athletes may be possible through the detection of modifiable risk variables in youth players by aerobic fitness testing conducted either before or during the sports season. Individuals who aren't as fit are more likely to feel fatigued quickly from the same amount of work, which could make them more susceptible to injuries [(2)].

The regulation of the heart rate (HR) throughout exercise and recovery is regulated by a balance of parasympathetic as well as sympathetic activity. Fewer parasympathetic neurons are believed to be the cause of the diminished heart rate reserve (HRR) following exercises [(3)]. An athlete's ability to compete or train at a high level again depends on their ability to recover adequately after exercise. This includes both physiological as well as psychological mechanisms. The complexity of the recovery process following training and competition was high, and it often varied according on the type of exercise and other environmental stresses. Athletes utilized a variety of well-known strategies to speed up the recovery process. Their usage would rely on the type of activity accomplished, the time until the subsequent training session or event and tool and/or personnel accessible. Athletes often utilize aquatic therapy, active recovery, stretching, compressive garments, massage, sleep, as well as nutrition as primary means of recovery [(4)].

By regulating inflammation as well as cellular stress, cold water immersion (CWI) as a recovery approach may have reduced the long-term adaptive reactions to resistance training. Cryotherapy, which includes icing or cold-water immersion, was long thought to lower the metabolic rate as well as inflammation in tissues surrounding an affected skeletal muscle location by decreasing blood flow and temperature in the muscle. The idea was that this prevented surrounding cells from

Received: 06/06/2023
Accepted: 07/08/2023

ischemia following damage, thereby lowering the possibility of further cell damage or death [5].

It seems that CWI improved cardiovascular recovery parameters like venous return as well as cardiac output while also improving the heart's ability to return to baseline neuronal activity. The only cryotherapy methods known to cause cardiovascular alterations were those that exposed a high percentage of the body to the cold water [6].

The benefits of immersion in water include a decrease in exercise-induced edemas, an improvement in the venous return of the heart, and an improvement in extracellular fluid transport to the bloodstream. Due to an increase in cardiac output, the body was able to better use the oxygen and waste products that were produced during exercise. It is hypothesized that decreased neuromuscular transmission and improved energy conservation brought about by water immersion's buoyant impact may further reduce fatigue [7].

This study aimed to introduce an effective recovery protocol post exercise like cold water immersion in basketball players, which decreases risk of post training muscular injury, induces cardiovascular adaptations, and improves exercise capacity, thereby achieving higher level of fitness of such players in the next basketball training sessions and competitions.

Methods

Participants and design of the study:

A randomized controlled trial was carried-out from May 2022 to June 2023 at Al-Zamalek club, Giza, Egypt. The study was conducted on 60 male basketball players who aged 18–28 years and were randomized into two groups equal in number (n = 30), experimental (A) and control (B) groups. Measurements were assessed at two time periods: pre and post the four weeks duration of the study. All the participants received the same post exercise traditional recovery protocols.

Individuals who fulfilled the following criteria were considered for participation in the study: The men's ages varied from 18 to 28 years old, and their BMIs were between 18.5 and 24.9. Their resting heart rates and blood pressures were within normal ranges, and their flexibility, muscular strength, as well as endurance were all similarly good, as determined by the findings of the sit-and-reach, push-up, as well as jogging tests, respectively. The participants were excluded if they had one of the following criteria: heart problems or history of heart surgeries, any sport injuries that would limit their performance, type 1 diabetes, hypersensitivity to cold water or ice, obesity or overweight, which would limit their fitness, any lung or kidney problems and exercise induced broncho-constriction.

Randomization:

Computerized randomization was used in the current study. Research randomizer (https://www.randomizer.org/) is a free online tool that allows for randomization of participants into different treatment groups. The software was configured with the following parameters: 2 treatment groups, an allocation ratio of 1:1. The randomizer was blinded to the group of the participant, also the statistical analyzer was blinded, the investigator could not be blinded to the group of the participant.

Intervention:

Post-exercise cold water immersion recovery protocol:

To ensure accurate HR readings, the training terminated with a 7-minute submaximal run that generated the necessary HR steady-state signal [8]. Thereafter, the participants finished the traditional recovery protocol then they were asked to completely submerge their bodies, excluding the neck as well as head, in a temperature-controlled bath (~ 10°C) for 15 minutes [9]. Under direct supervision, the participants remained in the seated position whilst the water was continuously circulated [10].

Post-exercise traditional recovery protocol:

Immediately after the basketball strenuous training, all participants performed a 30 minutes of traditional post-exercise recovery protocol, which included cooling down exercises in the form of low-intensity exercises such as light jogging and walking, upper body stretches, and head-to-knee forward bends. Also, they received massage therapy like effleurage, petrissage, friction, and tapotement techniques [11].

Outcome measures:

Vital signs post-exercise recovery:

After 30 minutes of rest, basal readings of heart rate and oxygen saturation (SpO_2), and blood pressure parameters were recorded by pulse oximeter and sphygmomanometer respectively. The participants were allowed to do strenuous basketball training for 60 minutes.

Following performed recovery protocols, these parameters were recorded every 2 minutes until returned to the resting values [12]. After that, the recovery time was calculated in minutes and was recorded for each participant.

Cooper’s test:

The distance obtained from this field exercise test was converted from metres into kilometres and the subsequent equation was utilized to predict the VO_2max [13]: VO_2max (ml·kg-1 ·min-1) = (22.351 x distance covered in kilometres) - 11.288 [14]. This estimated VO_2max was calculated to determine the exercise capacity of such basketball players.

Harvard step test:

Researchers have thought of this step test as a field-based, practical way to measure aerobic fitness. The following equation was used to get the fitness index score: Physical Fitness Index (PFI) (long form) = (100 x test duration in seconds) divided by (2 x sum of heartbeats in the recovery periods) [15].

Cardiac enzymes

Creatinine phosphokinase enzyme and cardiac troponin T were detected at laboratory field by Cobas e 602 module and Cobas 411 for immunoassay tests, 8000 modular analyzer series was used to detect cardiac troponin T (cTnT) and creatinine phosphokinase (CK Mb) in the blood (Sun rise company, China) [16].

Blood sampling for cTnT and CK-Mb measurements were done before starting the strenuous basketball training then it was repeated after passive resting period of 24 (24h) hours from the completion of post-exercise recovery protocols [17]. This test was done only in regard to first strenuous basketball training at the beginning of the study.

Total Quality Recovery Action Scale:

Total quality recovery action (TQRact) Scale was a valid alternative for evaluating the state of recovery in players, TQRact was an easily applicable field test and provided information in the evaluation and training of professional players [18]. Twelve unique recovery behaviors were recorded, organized into four main categories: Hydration and Nutrition, Sleep and Rest, Relaxation and Emotional Support, and Warming Up and Stretching. Each action was given a score between one and twenty Recovery Points (RPs) according to its relative importance. Every recovery behavior was listed, and players were requested to indicate whether they would employ it by answering yes or no [19]. Then the total score was summed and recorded for each player.

Power analysis:

G*power V3.1 was used to calculate the sample size prior to conducting the study using data obtained from pilot study conducted on 3 subjects per group. The effect size was 0.95 with alpha level set at 0.05 and 0.95 power, the resultant sample size was 60 in total and 30 per group [20].

Assessment of eligibility:

Potential participants were assessed according to inclusion criteria as shown in figure 1

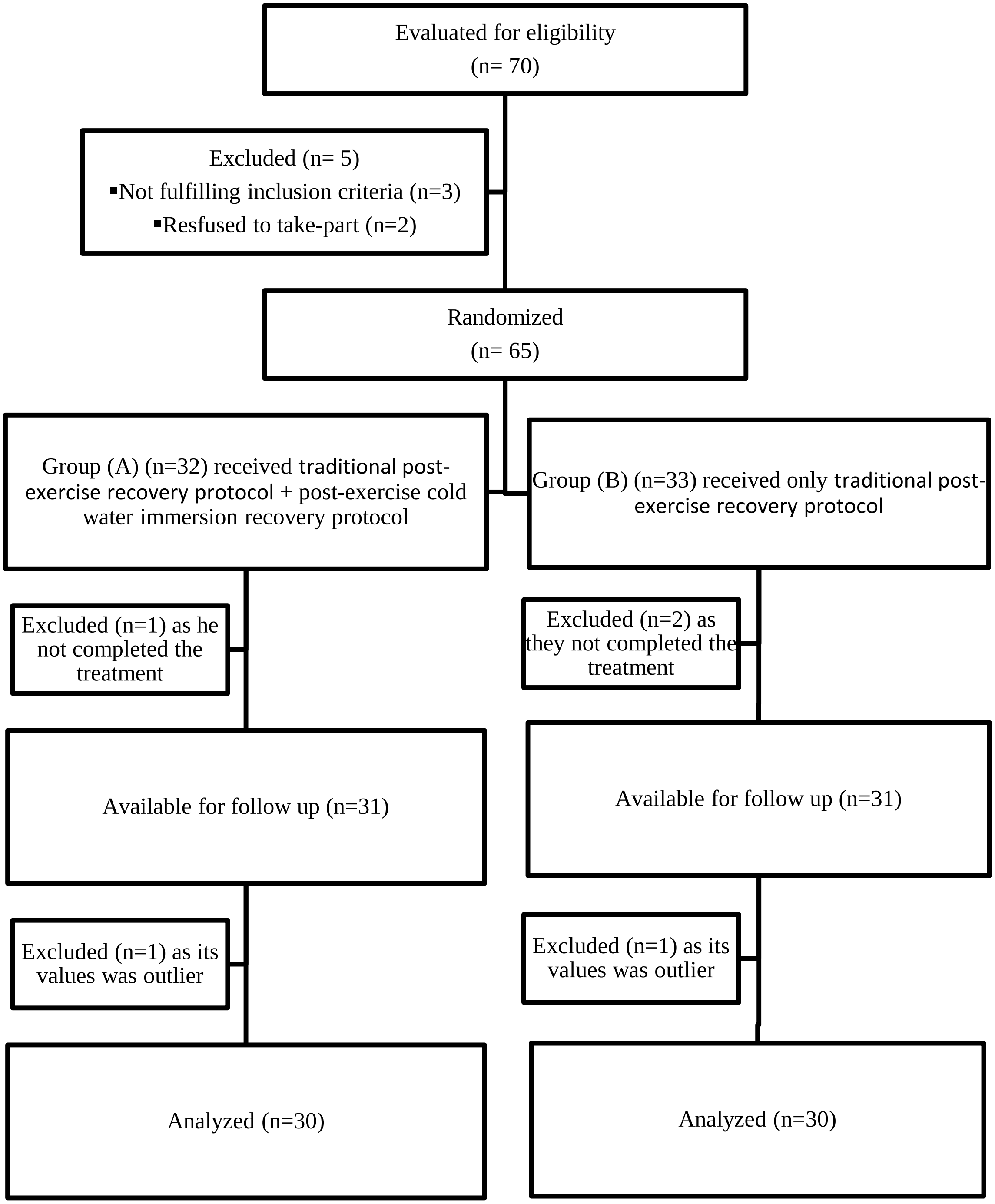

Figure (1): Flowchart of the study

Ethical approval:

The study was approved by the Faculty of Physical Therapy at Cairo University's Ethical Committee prior to start, with the number P.T.REC/012/003249. All participants signed a consent form before participating in the study, and the researchers explained the study's goal, nature, as well as risks to them. This work has been carried out in accordance with The Code of Ethics of the World Medical Association (Declaration of Helsinki) for studies involving humans.

Statistical analysis

Data were collected in data collection form and then organized in a large data collection sheet to be prepared for analysis.

Descriptive statistics were utilized to summarize and describe the key characteristics of the data. The measures of central tendency, such as the mean as well as standard deviation, were computed for each variable within different groups and time points. Additionally, percentages of improvement or change were calculated to assess the impact of the interventions [21].

No intention to treat analysis was used. Data were cleaned from outliers using the equation of interquartile range (IQR) [22], normality was checked using Shapiro-Wilk test to determine the test to be conducted, this indicated that all data were normal and homogeneous [23].

SPSS V28 was used to analyze data of all outcome measures using mixed model ANOVA [24].

Mixed-model ANOVA was performed to examine the main effects of time and group, in addition to their interaction, on the dependent variables. The dependent variables included resting HR, immediate after exercise HR, HR recovery time, resting O_2 **saturation**, immediate after exercise O_2, resting SBP, immediate after exercise SBP, resting DBP, immediate after exercise DBP, troponin T, CPK, Harvard step test score, Cooper test score, and TQRact scale total score. Time (Pre vs. Post) and Group (Group A vs. Group B) were used as the independent variables. The F-statistic and p-value were calculated for each main effect and interaction.

Pairwise comparisons, had been conducted to determine specific group differences. The mean difference (MD) and p-value were reported for each pairwise comparison. The level of significance was controlled at $P < 0.05$.

RESULTS

Demographic characteristics of the participants

The descriptive and inferential statistics of the demographics for the sample between Group A and Group B suggest that there were no significant differences in age, weight, height, and BMI between the two groups (Table 1).

Table (1): Descriptive and inferential statistics of the demographics of the sample between groups

Variable	Group A (N=30)	Group B (N=30)	P value
Age/Years	23.86±2.77	22.93±3.15	0.23
Weight/Kg	76.57±4.67	75.8±4.69	0.53
Height/meter	1.85±0.04	1.83±0.04	0.058
BMI/kg/m2	22.4±0.85	22.55±0.64	0.443

Data are presented as mean ± standard deviation

In summary, the mixed model ANOVA revealed significant effects of time, Group A, Group B, and their interaction on the outcome variable. These findings suggest that both time and the two groups, A and B, have a significant impact on the outcome ($P < 0.01$), and there was also an interaction effect between time and group.

Statistical analysis of HR, HR recovery time, O_2 saturation, and blood pressure:

Within group analysis indicated a significant difference among pre- and post-treatment values of group (A) for resting HR, immediate after exercise HR, HR recovery time, resting O_2, immediate after exercise O_2, resting SBP, immediate after exercise SBP, and resting DBP. However, group (B) revealed non-significant difference. Also, both groups (A) and (B) showed non-significant for immediate after exercise DBP (Table 2, 3).

Table (2): Mixed MANOVA within and between group comparison for HR, HR recovery time, and O2 saturation.

Variable	Group A	Group B	MD	Sig
Pre-Resting HR	87.93±8.24	85.07±7.55	2.862	0.338
Post-Resting HR	72.5±7.87	84.27±7.87	-11.767*	<0.001
% of imp	DE -17.55%	DE -0.94%		<0.001
MD	15.429*	0.8		
Sig	<.001	0.178		
Pre-Immediate after exercise HR	126.64±13.52	124.33±11.49	2.31	0.623
Post-Immediate after exercise HR	109.43±15	128.87±9.9	-19.438*	<0.001
% of imp	DE -13.59%	IN 3.65%		<0.001
MD	17.214*	-4.533*		
Sig	<.001	0.026		
Pre-HR recovery time	32.64±9.87	25.73±9.46	6.91	0.065
Post-HR recovery time	25±8.55	23.67±7.19	1.333	0.652
% of imp	DE -23.41%	DE -8.01%		<0.001
MD	7.643*	2.067		
Sig	<.001	0.051		
Pre-Resting O_2	91±3.23	90.53±3.54	0.467	0.715
Post-Resting O_2	85.5±2.98	90±3.66	-4.500*	0.001
% of imp	DE -6.04%	DE -0.59%		<0.001
MD	5.500*	0.533		
Sig	<.001	0.082		
Pre-Immediate after exercise O_2	87.71±3.6	87.4±3.58	0.314	0.816
Post-Immediate after exercise O_2	84.71±3.75	86.6±3.48	-1.886	0.172
% of imp	DE -3.42%	DE -0.92%		<0.001
MD	3.000*	0.8		
Sig	<0.001	0.058		

HR: heart rate

Table (3): Mixed MANOVA within and between group comparison for blood pressure.

Variable	Group A	Group B	MD	Sig
Pre-Resting SP	114.71±6.98	114.67±5.63	0.048	0.984
Post Resting SP	111.43±4.85	115±5.55	-3.571	0.077
% of imp	DE -2.86%	IN 0.29%		0.004
MD	3.286*	-0.333		
Sig	<.001	0.68		
Pre-Immediate after exercise SP	152.57±6.16	147.73±6.87	4.838	0.057
Post-Immediate after exercise SP	146.21±6.52	146.07±6.98	0.148	0.954
% of imp	DE -4.17%	DE -1.12%		0.002
MD	6.357*	1.667		
Sig	<0.001	0.091		
Pre-Resting DP	75.57±4.89	75.33±5.26	0.238	0.901
Post-Resting DP	73.36±4.92	74.93±4.93	-1.576	0.397
% of imp	DE -2.92%	DE -0.53%		0.001
MD	2.214*	0.4		
Sig	<0.001	0.255		
Pre-Immediate after exercise DP	79.14±4.93	77.53±4.53	1.61	0.368
Post-Immediate after exercise DP	77.43±4.16	77.33±4.45	0.095	0.953
% of imp	DE -2.16%	DE -0.26%		0.111
MD	1.714*	0.2		
Sig	0.015	0.757		

Statistical analysis of troponin T and CPK:

Within group analysis indicated a significant difference among pre- and post-treatment values of both groups (A) and (B) for troponin T and CPK (Table 4).

Between groups analysis showed that there was no significant difference of percentage of improvement (%) among both groups (A) and (B) for troponin T and CPK (Table 4).

Table (4): Mixed MANOVA within and between group comparison for troponin T and CPK.

Variable	Group A	Group B	MD	Sig
Pre-Troponin T	8.59±2.27	9.47±2.22	-0.256	0.523
Post-Troponin T	5.36±0.97	5.61±1.14	-0.888	0.297
% of imp	DE -37.6%	DE -40.76%		0.328
MD	-3.229*	-3.860*		
Sig	<0.001	<0.001		
Pre-CPK	687.57±292.51	766.8±271.5	-79.229	0.456
Post-CPK	441.5±157.54	448.47±183.35	-6.967	0.914
% of imp	DE -35.79%	DE -41.51%		0.229
MD	246.071*	318.333*		
Sig	<0.001	<0.001		

Table of the cardiorespiratory fitness test

-Statistical analysis of Harvard step test and Cooper test scores:

Within group analysis indicated a significant difference between pre- and post-treatment values of group (A) for Harvard step test and Cooper test scores. However, group (B) showed non-significant difference (Table 5).

Between groups analysis indicated that there was significant difference of percentage of improvement (%) between both groups (A) and (B) for Harvard step test and Cooper test scores (Table 5).

Table (5): Mixed MANOVA within and between group comparison for Harvard step test and Cooper test scores.

Variable	Group A	Group B	MD	Sig
Pre-Harvard test score	36.29±13.33	33.8±15	2.486	0.642
Post-Harvard test score	43.07±12.22	34.2±14.44	8.871	0.086
% of imp	IN 18.68%	IN 1.18%		<0.001
MD	-6.786	0.333		
Sig	<0.001	0.401		
Pre-Cooper test score	42.86±5.34	46.24±7.17	-3.376	0.164
Post-Cooper test score	47±4.93	46.58±7.28	0.42	0.858
% of imp	IN 9.66%	IN 0.74%		<0.001
MD	-4.136*	-0.34		
Sig	<0.001	0.27		

Statistical analysis of total quality recovery action scale scores:

Within group analysis indicated a significant difference among pre- and post-treatment values of group (A) and (B) for total quality recovery action scale scores (Table 6).

Between groups analysis indicated that there was no significant difference among both groups (A) and (B) for Total quality recovery action scale scores (Table 6).

Table (6): Mixed MANOVA within and between group comparison for total quality recovery action scale scores.

Variable	Group A	Group B	MD	Sig
Pre-TQRAS	16.5±1.56	16.4±2.06	0.1	0.885
Post-TQRAS	19±1.04	18.4±1.24	0.6	0.171
% of imp	IN 5.15%	IN 12.2%		0.329
MD	-2.500*	-2.000*		
Sig	<0.001	<0.001		

DISCUSSION

At the end of 12 recovery sessions, CWI recovery protocol along with the traditional protocol showed a significant improvement in this group's performance and cardiorespiratory fitness in the subsequent exercise bouts, also showed a significant decreased incidence of post exercise injury.

This study's primary discovery was the increased benefit of adding CWI recovery protocol to the recovery programs of all athletes in order to improve cardiorespiratory fitness and reduce further injuries.

Following a vigorous and/or eccentric exercise, indicators of skeletal muscle damage that exercise causes can remain elevated for a few days in adults [(25)]. After a variety of long periods of exercise, adult athletes have also shown biomarkers of heart muscle injury [(26)].

Although there were a variety of strategies taken by athletes to speed up the recovery process after training and competition, the effectiveness of each approach varied according to the characteristics of the exercise as well as environmental factors. Active recovery, aquatic therapy, stretching, compressive garments, massage, sleep, as well as nutrition were among the most popular ways for athletes to recover from injuries. One of the most effective post exercise recovery protocols was cold water immersion that induced cardiovascular adaptations and improved exercise performance in basketball players who participated in the present study [(4)].

The findings of the present study came in agreement with a study conducted by **Seco-Calvo and colleagues** who investigated the effect of CWI on post-exercise recovery in basketball players. They found that CWI significantly reduced markers of muscle damage and inflammation, including creatine kinase levels and perceived muscle soreness. The authors concluded that CWI could enhance recovery and aid in maintaining performance during subsequent training or competition, and that's what the present study found through CPK and troponin t results which showed a significant difference among pre- and post-treatment values of both groups (A) and (B), and this proved the effect of CWI on enhancing muscle injury and inflammation which always occur after the high intensity exercises. [(27)].

The impact of active recovery (AR) on the hemodynamic and autonomic reactions following exercise in healthy individuals was the subject of another investigation by **Soares and colleagues**. The exercise programs included a 5-minute warming up, a 30-minute exercise on the cycle ergometer with an intensity ranging from 60 to 70% of the heart rate reserve, and a 5-minute recovery period. In the AR, participants maintained a cycling effort ranging from 30% to 35% of their heart rate reserve during the recovery phase. Both active and passive recovery sessions had the same impact on all HRV markers following exercise. In conclusion, in healthy young males, the autonomic as well as hemodynamic responses following moderate-intensity aerobic exercise were unaffected by exercise including active recovery [(28)].

In their review and meta-analysis, **Machado and colleagues** found that the best way to recover from exercise-induced fatigue was CWI (11–15°C) for 11–15 minutes. According to the meta-analysis, CWI performs passive recovery with regard to of both short-term and long-term benefits. For both the immediate as well as delayed effects, water temperatures between 10 and 15 °C was the best. The optimal duration for immersion, in terms of both immediate as well as delayed effects, was 10–15 minutes [(29)]. And that was the duration of CWI in the current study which gained the most beneficial results in the study group.

As a form of cryotherapy, including icing or CWI, decreased the metabolic rate as well as inflammation in tissues within and surrounding the area of injury in skeletal muscle, which may have decreased long-term adaptive reactions to resistance exercise by regulating inflammation as well as cellular stress, lowering temperature and blood circulation in skeletal muscle. The idea was that this prevented surrounding cells from ischemia following injury, thereby lowering the possibility of further cell damage or death [(5)].

One theory explaining superiority of CWI suggests that the cold water used in the recovery protocol triggers physiological responses due to the temperature difference. The cold water stimulates vasoconstriction, reducing blood flow to the extremities and promoting the removal of metabolic waste products. This vasoconstriction may also help to alleviate inflammation and swelling in the muscles, thereby aiding in the recovery process [(7)].

During basketball high intensity exercise, heart rate of players increased to meet the elevated oxygen and energy demands of their body. CWI speeded-up the recovery of heart rate by promoting the removal of metabolic byproducts and enhancing blood flow to the working muscles. This improved recovery of heart rate following exercise indicated a faster return to pre-exercise physiological conditions [(30)]. It seems that CWI improved cardiovascular recovery measures like venous return as well as cardiac output while also improving the heart's ability to return to baseline neuronal activity **[6].**

However, a study conducted a comparison between the impact of CWI as well as active recovery on regulating inflammation and cellular stress following resistance exercise. The study concluded that CWI is not superior to active recovery in terms of decreasing inflammation or cellular stress in the muscles after a session of resistance exercise. The study indicated that the pain-relieving effects of immersing in cold water following exercise are not related to alterations in the production of inflammatory neurotrophins. The researchers' findings indicate that the significant variations in cardiac output, temperature, as well as microvascular circulation in muscle following CWI compared to active recovery do not play a significant role in causing local inflammation as well as cellular stress in human muscle following exercise. However, they proposed that intermittent utilization of cold-water immersion could aid athletes in accelerating their recovery among training sessions **[5].**

In a study carried out by **Mostafa and colleagues**, the researchers compared the impact of two recovery methods, CWI and massage, upon the performance of young male soccer players after a strenuous exercise session. The study consisted of three groups: cold water immersion (CWI), massage (M), as well as passive recovery (P). The subjects' outcome measurements, which comprised of tests of 20 m sprint, 40 m sprinting, agility, vertical jumping, as well as repeat sprint's ability (RSA), were collected. The rate of variation in 20 m sprint as well as Sargent jump performances did not differ significantly among the individuals of the three groups ($P>0.05$). Furthermore, the agility of the CWI recovery group showed a significant improvement in comparison to the massage recovery group ($P = 0.003$). Nevertheless, the recovery group that received massage demonstrated a significantly enhanced repeat sprint performance compared to the recovery group that received CWI ($p = 0.01$). The findings of this study indicated that the combined implementation of CWI and massage recovery procedures produced better results compared to the individual application of each protocol **[31].**

CONCLUSION

It is recommended to add the cold-water immersion recovery protocol to the traditional post-exercise recovery protocol for basketball players to maximize the attained benefits. This improved their performance, cardiorespiratory fitness in subsequent exercise bouts, and decreased the incidence of post-exercise injury. As a result, they could continue their following training and competition at the same or higher level of exercise tolerance needed for such players.

- **Acknowledgments:** We thank all the players for their participation in the current study.

- **Funding:** There was no funding source.
- **Conflict of interest:** The authors declare that they have no conflict of interest.

REFERENCES

1. **Meeuwisse W, Tyreman H, Hagel B *et al.* (2007):** A dynamic model of etiology in sport injury: the recursive nature of risk and causation. Clin J Sport Med., 17(3): 215–219.
2. **Watson A, Brickson S, Brooks A *et al.* (2017):** Preseason aerobic fitness predicts in-season injury and illness in female youth athletes. Orthopaedic Journal of Sports Medicine, 5(9): 513-518.
3. **Pierpont L, Adabag S, Yannopoulos D (2013):** Pathophysiology of exercise heart rate recovery: a comprehensive analysis. Annals of Noninvasive Electrocardiology, 18(2): 107–117.
4. **Halson L (2014):** Monitoring training load to understand fatigue in athletes. Sports Medicine, (Auckland, N.Z.), 44 (2): S139–S147.
5. **Peake M, Roberts A, Figueiredo C *et al.* (2017):** 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, 595(3): 695–711.
6. **Buchheit M, Peiffer J, Abbiss C *et al.* (2008):** Effect of cold-water immersion on postexercise parasympathetic reactivation. Am J Physiol Heart Circ Physiol., 296(2): 421–427.
7. **Wilcock I, Cronin J, Hing W (2006):** Physiological response to water immersion: A method of recovery. Sports Medicine, 36(9): 747-765.
8. **Al Haddad H, Laursen P, Chollet D *et al.* (2010):** Effect of cold or thermoneutral water immersion on postexercise heart rate recovery and heart rate variability indices. Auton Neurosci., 156(1): 111–116.
9. **Lindsay A, Othman I, Prebble H *et al.* (2016):** Repetitive cryotherapy attenuates the in vitro and in vivo mononuclear cell activation response. Experimental physiology, 101(7): 851–865.
10. **Fong F, Lin W, Amico J (2020):** Does cryotherapy after exercise reduce delayed onset muscle soreness in active adults? Evidence-Based Practice, 23(9): 30-31.
11. **Weerapong P, Hume A, Kolt S (2005):** The mechanisms of massage and effects on performance, muscle recovery and injury prevention. Sports medicine, (Auckland, N.Z.), 35(3): 235–256.
12. **Bhavsar S, Abhange R, Afroz S (2014):** Effect of different musical tempo on post-exercise recovery in young adults. Journal of Dental and Medical Sciences, 13(5): 60-64.
13. **Bandyopadhyay A (2015):** Validity of Cooper's 12-minute run test for estimation of maximum oxygen uptake in male university students. Biology of sport, 32(1): 59–63.

14. **Bandyopadhyay A (2021):** Cooper's 12 min run test: Its validity in Indian swimmers and volleyball players. Indian Journal of Physiology and Pharmacology, 64(4): 265-271.
15. **Elsaidy W (2011):** Evaluating the validity and reliability of Harvard Step Test to predict VO2max in terms of the step height according to the angle of knee joint angle. Theories & Application, 1(2): 126-132).
16. **Flowers K, Hunt C, Collinson P (2020):** Interanalyzer analytical variation of a high-sensitivity cardiac troponin T assay can exceed the cutoff of the European Society of Cardiology 1-hour algorithm for ruling out non–ST-segment elevated myocardial infarction. Clinical Chemistry, 66(3): 495-496.
17. **Çakir E, Şenel Ö, ArslanoĞlu E (2019):** The effect of cold water immersion on cardiac troponin T and myoglobin levels. Neuroendocrinology Letters, 40(1): 22-28.
18. **Osiecki R, Rubio T, Coelho R *et al.* (2015):** The Total Quality Recovery Scale (TQR) as a proxy for determining athletes recovery state after a professional soccer match. Journal of Exercise Physiology Online, 18(3): 27-32.
19. **Moreno J, Rodas G, Ramos J *et al*. (2015):** Individual recovery profiles in basketball players. The Spanish Journal of Psychology, 18(24): 1-10.
20. **Kang H (2021):** Sample size determination and power analysis using the G*Power software. Journal of Educational Evaluation for Health Professions, 18, 17-23.
21. **Jopling M (2019):** Using qualitative data. In book: Practical Research Methods in Education, 3, 55-66.
22. **Vinutha H, Poornima B, Sagar B (2018):** Detection of outliers using interquartile range technique from intrusion dataset. In book: Information and decision sciences, 2:511-518.
23. **Gerald B (2018):** A brief review of independent, dependent and one sample t-test. International Journal of Applied Mathematics and Theoretical Physics, 4(2): 50-54.
24. **Sahai H, Ageel M (2012):** The analysis of variance: fixed, random and mixed models. https://books.google.com.eg/books?hl=ar&lr=&id=mkbtBwAAQBAJ&oi=fnd&pg=PR9&dq=24.%2509Sahai+H,+Ageel+M+(2012):+The+analysis+of+variance:+fixed,+random+and+mixed+models.+Springer+Science+%2526+Business+Media).&ots=unjQS8CGtw&sig=O36uRKKI_ioBDvjJ-BzP7cylPLg&redir_esc=y
25. **Brancaccio P, Limongelli M, Maffulli N (2006):** Monitoring of serum enzymes in sport. British Journal of Sports Medicine, 40(2): 96–97.
26. **Papamichail A, Androulakis E, Xanthopoulos A *et al.* (2023):** Effect of training load on post-exercise cardiac biomarkers in healthy children and adolescents: A systematic review of the existing literature. Journal of Clinical Medicine, 12(6): 522-529.
27. **Seco-Calvo J, Mielgo-Ayuso J, Calvo-Lobo C *et al.* (2020):** Cold water immersion as a strategy for muscle recovery in professional basketball players during the competitive season. Journal of Sport Rehabilitation, 29(3): 301-309.
28. **Soares H, Oliveira P, Cavalcante R *et al.* (2017):** Effects of active recovery on autonomic and hemodynamic responses after aerobic exercise. Clinical Physiology and Functional Imaging, 37(1): 62–67.
29. **Machado F, Ferreira H, Micheletti K *et al.* (2016):** Can water temperature and immersion time influence the effect of cold-water immersion on muscle soreness? A systematic review and meta-analysis. Sports Medicine ,46(4): 503–514.
30. **Yeung S, Ting H, Hon M *et al.* (2016):** Effects of cold water immersion on muscle oxygenation during repeated bouts of fatiguing exercise: a randomized controlled study. Medicine, 95(1): 332-339.
31. **Mostafa B, Javadikia M, Hejazi K *et al.* (2016):** The recovery effect of cold water immersion and massage on the physical performance of young male soccer players. Report of Health Care, 2(1): 46-54.