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Cold water immersion as an effective recovery method: its impact on heart rate and lactate levels post exercise

La inmersión en agua fría como método de recuperación eficaz: su impacto en la frecuencia cardíaca y los niveles de lactato después del ejercicio

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Abstract. The study's purpose. This study aims to analyze the effect of the recovery method using cold water immersion (CWI) with different temperatures and administration times. Material and Methods. Thirty-two student-athletes participated in this study. They were divided into four groups, carried out acute physical training with an intensity of 95%, and were given recovery treatments such as CWI during and after physical exercise CWI with temperature 15^0 Celsius (CWI DP 15), CWI with temperature 15^0 Celsius after practice physical (CWI P 15), CWI with temperature 10^0 Celsius after practice physical (CWI P 10), and the Static Rest (SR) group. Analysis descriptive, paired samples t-test, and two-way ANOVA direction used in data analysis. This is that all data were normally distributed ($p \geq 0.05$) and homogeneous ($p \leq 0.05$). The results of the heart rate analysis found that no There is a significant difference between group CWI DP, CWI P 15, and CWI P 10 with the current control group Exercise phase. Meanwhile lactate, there is a difference in concentration of lactate in the CWI DP 15 group against a control group in phase Immediately Post-exercise with a p-value of 0.021; the 10min post-exercise phase is difference significant concentration lactate groups CWI DP15, CWI P15, and CWI P 10 against control group with p- value 0.001, in the 120min post-exercise phase there is difference lactate group CWI P 15 against control group with The p-value is 0.001, in the 24 hours post-exercise phase there is difference concentration lactate CWI DP 15 group against control with p-value 0.0024. Cold Water Immersion (CWI) has been shown to significantly accelerate heart rate recovery (HRR), reduce blood lactate levels, and improve athlete performance, indicating that it may be beneficial in recovery protocols.
Keywords: Recovery Strategy, Cold Water Immersion, Lactate

Resumen.El objetivo de la investigación. El propósito de esta investigación es examinar el impacto de la técnica de recuperación a través de inmersión en agua fría (CWI) con variaciones en temperaturas y duración de la aplicación. Sección de Material y Métodos. En la investigación, estuvieron involucrados treinta y dos estudiantes que también son atletas. Los participantes fueron divididos en cuatro grupos y sometidos a un entrenamiento físico agudo con una intensidad del 95%. Posteriormente, se les aplicaron tratamientos de recuperación, tales como inmersión en agua fría (CWI) durante y después del ejercicio físico, inmersión en agua fría con una temperatura de 15 grados Celsius (CWI DP 15) y inmersión en agua fría con una temperatura de 15 grados Celsius después de la práctica. El grupo de estudio se dividió en tres subgrupos: el grupo de inmersión en agua fría (CWI P 15), el grupo de inmersión en agua caliente con temperatura de 100 grados Celsius después de la práctica física (CWI P 10) y el grupo de descanso estático (SR). En el análisis de datos, se emplea un enfoque descriptivo, la prueba t de muestras pareadas y el análisis de varianza (ANOVA) bidireccional para examinar diferentes aspectos de los datos. Todos los datos presentaban una distribución normal ($p \geq 0,05$) y homogeneidad ($p \leq 0,05$). Los resultados del estudio de la frecuencia cardíaca indicaron que no existe una disparidad significativa entre el grupo CWI DP, CWI P 15 y CWI P 10 en comparación con la etapa de ejercicio del grupo de control actual. Existe una diferencia en la concentración de lactato entre el grupo CWI DP 15 y un grupo control en la fase Inmediatamente. Por otro lado, el lactato también muestra variaciones significativas en ambos grupos. Tras el ejercicio, se observó un valor de p de 0.021. Se encontró una diferencia significativa en la concentración de lactato entre los grupos CWI DP15, CWI P15 y CWI P 10 en comparación con el grupo de control, con un valor de p de 0.001 a los 10 minutos post-ejercicio. Por otro lado, a los 120 minutos post-ejercicio se identificó una diferencia en la concentración de lactato entre el grupo CWI P 15 y el grupo de control. En la fase de 24 horas posterior al ejercicio, se observa una diferencia en la concentración de lactato entre el grupo tratado con inmersión en agua fría (CWI DP 15) y el grupo de control, con valores de p de 0,001 y 0,0024 respectivamente. La inmersión en agua fría (CWI) ha demostrado acelerar de manera significativa la recuperación de la frecuencia cardíaca (HRR), disminuir los niveles de lactato en sangre y mejorar el rendimiento de los atletas. Estos resultados sugieren que la CWI puede ser beneficiosa en los protocolos de recuperación. La inmersión en agua fría es una estrategia de recuperación que puede ayudar a reducir los niveles de lactato en el cuerpo.
Palabras clave: Estrategia de recuperación, Inmersión en agua fría, Lactato

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Introduction

Interval training methods, including Tabata and high-intensity interval training (HIIT), effectively improve various physical fitness components in athletes and students(Munandar et al., 2021; Putrov et al., 2021). Interval training itself is believed to increase performance and endurance(Eigendorf et al., 2018; Paquette et al., 2017). Furthermore, it enhances metabolic function and the efficiency of the vascular system, which are critical for the preservation of optimal athletic performance.

Effective recovery regimens are crucial for athletes to maintain consistent high-level performance and prevent adverse consequences(Kellmann et al., 2018; Terrados et al., 2019). Deficient recuperation will have an adverse effect on the performance of athletes in following training and competition(Nixdorf et al., 2018; Sousa et al., 2024). The negative impacts that occur when there is a lack of recovery include overtraining, decreased performance(Gill, 2006) and delayed-onset muscle soreness (DOMS)(Amir et al., 2017). Therefore, optimizing the recovery strategy is crucial to maintaining peak performance, minimizing the risk of injury, and ensuring long-term athletic success. In this context, monitoring blood lactate and heart rate becomes very important. Blood lactate activity levels indicate metabolic stress, while heart rate indicates cardiovascular strain and recovery efficiency.

Muscle function impairment is mostly observed during the initial high-intensity interval training, resulting in fatigue and a decline in performance(Tripp et al., 2024). This is because interval training is carried out due to the inability of the heart and lungs to supply oxygen levels during the activity (Martínez-Lagunas et al., 2014). Lactate dehydrogenase undergoes allosteric transitions and dissociation in response to pH changes, which regulate lactate generation(Iacovino et al., 2022). Lactate can be used as a very important fuel source in performing anaerobic exercise (S. Lee et al., 2023). Blood lactate concentration after exercise can be used as a predictor of how effective the decline in recovery performance is in athletes after exercise(Manojlović & Erčulj, 2019) and blood lactate in peak exercise is a better indicator of energy metabolism and performance in short-term high-intensity exercise(Takei et al., 2018). So that lactate at the end of exercise can be an indicator of the body's level of fatigue.

Recently, much research has focused on efforts to increase the recovery process in order to accelerate the return of the body's physiological systems to normal conditions after exercise (Bastos et al., 2012; Brophy-Williams et al., 2011; Parouty et al., 2010; Peiffer et al., 2009; J. Vaile et al., 2011). Cold water immersion (CWI) is currently becoming a popular recovery method in several sports, both used by elite and amateur athletes (Broatch et al., 2014; Pournot et al., 2011; Stanley et al., 2014). his recovery method is more widely used because the costs are quite low, and the technique is quite easy to use (Bleakley & Davison, 2010). CWI is performed when athletes immerse their bodies in cold water after exercising. CWI has also been shown to help reduce muscle inflammation, speed up recovery, and reduce muscle soreness after exercise (Bieuzen et al., 2013; Leeder et al., 2012). CWI is proven to have physiological and biochemical effects that improve the immune system, hemodynamics and motor function, as well as psychological effects that are reported to increase positive emotions and reduce negative emotions so that athletes are in a better mood, alert and able to control themselves. Positive emotions are reflected in increased energy, concentration and good cooperation(Yankouskaya et al., 2023).

This research aims to find out how effective the use of the CWI method is between sets in Tabata training. Due to this, in recent years, many studies have focused on the use of post-exercise recovery methods (Amir et al., 2017; Poignard et al., 2023; Roberts et al., 2014; Sánchez-Ureña et al., 2017; White et al., 2014). Therefore, this study will provide an understanding of whether administering CWI during breaks in Tabata training can help control lactate concentrations and improve athlete performance during training.

Thus, this research hopes to provide new insights for coaches, athletes, and sports scientists into recovery strategies in interval training that can help improve athlete performance and better understand the impact of recovery on athletes' physiological aspects. The results of this study are expected to provide a valuable contribution to the development of more effective training methods and a deeper understanding of the impact of recovery on athlete performance.

Material and Methods

Study Design

This experimental research uses a pre and post-control design. The research subjects were divided into 4 groups, namely (1) the cold water immersion group which was given during the training session break and after the training session ended with an ice temperature of 15^0 (CWI DP15), (2) CWI group given at time after 4 session training end with temperature 15^0 (CWI P15), (3) CWI group given at time after 4 session training end with temperature 10^0 (CWI P10), (4) Control group with only do static Rest (SR).

Subjects

32 male students who actively exercise for 2 hours per week participated in this study (subject characteristics are show in table 2). Inclusion criteria included students aged 18 – 19 years and active status who did physical activity for at least 2 hours per week. Furthermore, the exclusion criteria in this study were those who were under 18 years of age and had a history of injury.

Research Instruments

The research instruments used in this study were Accutrend Plus Meter, Kinovea Software, Ice Water, Body composition scale, stopwatch, and Polar Verity Sense.

Procedure

All students will do physical training using the Tabata method for 4 training sessions; the rest between sessions is 4 minutes, and the intensity used in this Tabata training is 85% - 90% of the maximum heart rate. Before the study, everyone provided written informed consent.

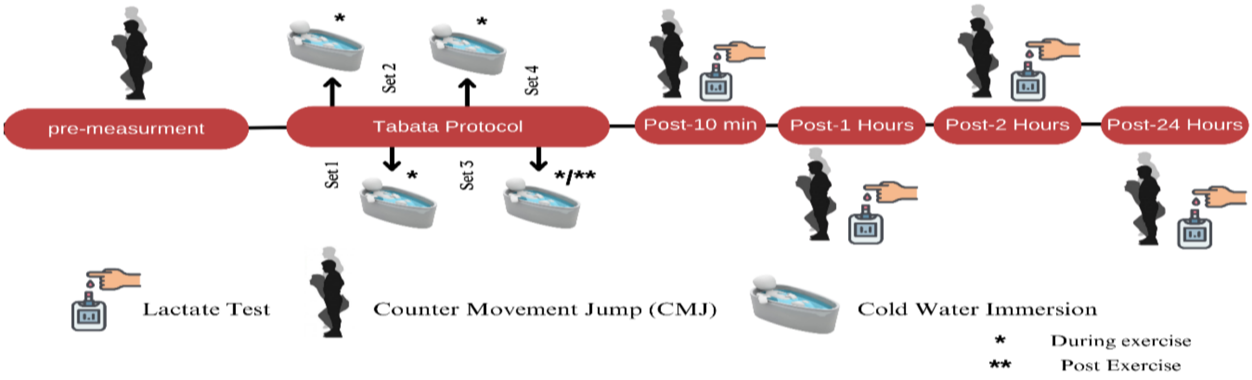

Figure 1. CWI Protocol

Participants will carry out an initial test by measuring the jump height in the counter jump with swing (CMJ) movement. CMJ was taken before exercise, after exercise, 10 minutes, 1 hour, 2 hours and 24 hours after exercise. Researchers used Kinovea software to calculate the jump height analysis. Heart rate recovery (HRR) is calculated at different times, but it is calculated 3 minutes after physical exercise (Dellal et al., 2015). Polar verity sense is used to make it easier to monitor the increase and decrease in heart rate during exercise and heart rate recovery. After the exercise, participants will check their lactic acid levels. The Accutrend plus meter is used to calculate lactic acid levels yourself. Lactate intake is carried out 10 minutes, 1 hour, 2 hours and 24 hours after exercise. This study's acute exercise using the Tabata training method used a work: rest ratio of 20 seconds:10 seconds and lasted 4 minutes. This Tabata exercise has an intensity of 85%- 95%. Rest between sets for 4 minutes. In one set, there are four training movements: 1. Lateral jump hurdle 2. High knee 3. Lunges 4. Jump high touch. These movements are done twice repeatedly.

Table 1.
Tabata Training Program

	Duration	Set 1	Set 2	Set 3	Set 4
Work	20 seconds	Lateral jump hurdle	Lateral jump hurdle	Lateral jump hurdle	Lateral jump hurdle
Rest			10 seconds		
Work	20 seconds	High knees	High knees	High knees	High knees
Rest			10 seconds		
Work	20 seconds	Lunges	Lunges	Lunges	Lunges
Rest			10 seconds		
Work	20 seconds	Jump high touch	Jump high touch	Jump high touch	Jump high touch
Rest			10 seconds		
Work	20 seconds	Lateral jump hurdle	Lateral jump hurdle	Lateral jump hurdle	Lateral jump hurdle
Rest			10 seconds		
Work	20 seconds	High knees	High knees	High knees	High knees
Rest			10 seconds		
Work	20 seconds	Lunges	Lunges	Lunges	Lunges
Rest			10 seconds		
Work	20 seconds	Jump high touch	Jump high touch	Jump high touch	Jump high touch
Rest			10 seconds		

Statistical Analysis

IBM SPSS version 26 software was used to analyze data for this study (Chicago, IL, USA). Descriptive statistics were used to provide context for the participants and research data. The Shapirow-Wilk test method was used to test the normality of this research data. To fulfil the criteria for one-way ANOVA and two-way ANOVA tests, homogeneity and normality of variance tests were carried out. An LSD post hoc test with a significance level of 5% was used for follow-up tests. Data are shown as mean±SD.

Ethics

Experimental procedures were followed in accordance with the Declaration of Helsinki. Ciputra University Institutional Review Board, with number 107/EC/KEPK-FKUC/III/2024, provides institutional ethical approval.

Results

Table 2.
Characteristics Sample

Age (years)	19±5,432
Height (cm)	167±3,112
Weight (kg)	65±6,176
Muscle	50.91 ± 2.073
BMI	22±2,357
Body Fat	17.03 ± 5.093
Water	56.91 ± 3.505
Proteins	21.8±1.309
Basal Metabolic	1.55 ± 0.095
Visceral Fat	5.75±2.764
Bone Mass	2.75 ± 0.091

Based on the table 3, the CWIDP15 and Control groups completed the Tabata training by achieving an average heart rate of up to 85% of the maximum heart rate. Meanwhile, the CWIP15 and CWIP10 groups approached achieving a heart rate of 85% of the maximum heart rate after completing the Tabata training session. These results indicate that both groups have sufficient aerobic capacity to approach or achieve their target heart rate during high-intensity training such as Tabata.

Graph 2 shows that there is no difference in training heart rate in each group, so it can be assumed that each group member has entered the Tabata training zone determined by the researcher. Furthermore, there was a difference in the recovery heart rate only in the group giving ice during and after the control group (sig. < 0.05), while there was no difference with the other groups. In the second and third minutes of recovery, it was seen that the during and post-ice treatment groups were different from the control group.

Table 3.
Description results treatment to Pulse Heartrate

No		Indicator	Mean ±St. Dev	Min	Max
1	CWI DP 15	Pulse Heart Exercise	173 ±4.54	168	179
		Pulse Recovery minute First	145 ±6.23	139	153
		Pulse Recovery minute second	125 ±7.07	119	133
		Pulse Recovery minute third	118 ±8.13	108	126
2	CWI P 15	Pulse Heart Exercise	166 ±12.44	149	178
		Pulse Recovery minute First	150 ±15.88	128	168
		Pulse Recovery minute second	141 ±11.63	127	154
		Pulse Recovery minute third	133 ±14.52	116	149
3	CWI P 10	Pulse Heart Exercise	164 ±10.14	150	173
		Pulse Recovery minute First	148 ±12.59	131	161
		Pulse Recovery minute second	131 ±9.83	117	140
		Pulse Recovery minute third	123 ±9.55	112	134
4	Controls	Pulse Heart Exercise	176 ±8.37	169	186
		Pulse Recovery minute First	163 ±8.44	155	174
		Pulse Recovery minute second	137 ±8.46	142	162
		Pulse Recovery minute third	143 ±10.75	133	157

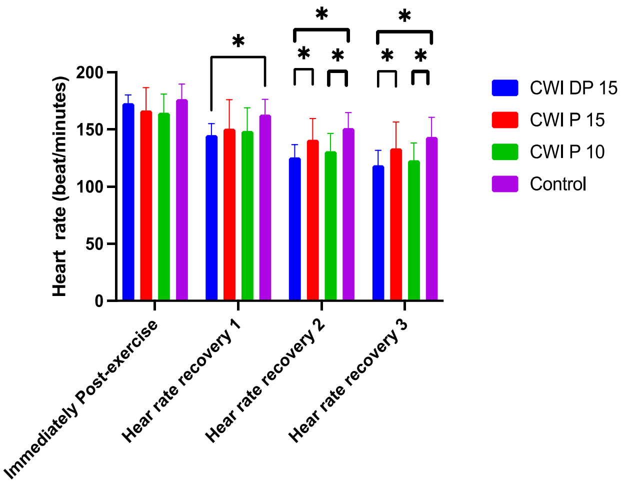

Figure 2. Heart Rate Activity

Table 5.
Analysis of blood lactate (mmol/L) between groups (CWI DP15 vs CWI P15 vs CWI P10 vs Control)

	CWI DP15 (n=8)	CWI P15 (n=8)	CWI P10 (n=8)	Controls (n=8)	p - Value
Immediately Post-exercise	10.3±1.78*	12.9±2.05	11.8±1.40	13.6±2.87	0.021
10min post-exercise	6.4±3.11*	4.6±0.96*	4.4±0.73*	9.4±1.53	0.001
60min post-exercise	2.5±0.56	2.3±0.68	3.4±1.34	2.5±0.68	0.015
120min post-exercise	1.8±0.39	1.5±0.56*	2.8±0.42	3.5±1.36	0.001
24 hours post-exercise	2.6±0.75*	3.8±1.37	3.2±0.59	4.8±2.24	0.024

Description: (*) Significant at control ($p \leq 0.05$). Data are presented as means. P-value was obtained by one-way ANOVA test.

Table 6.
This results in an average tall jump in the countermovement jump.

Counter Movement Jump		
Group	Time	Mean ±St. Dev (cm)
CWI DP 15	Pre-exercise	65.60
	120min post-exercise	58.21
	24 hours post-exercise	58.38
CWI P 15	Pre-exercise	59.79
	120min post-exercise	49.09
	24 hours post-exercise	51.28
CWI P 10	Pre-exercise	59.67
	120min post-exercise	46.05
	24 hours post-exercise	50.93
Control	Pre-exercise	52.60
	120min post-exercise	51.42
	24 hours post-exercise	51.48

The table shows the change in mean jump height in Counter Movement Jump (CMJ) before exercise and 24 hours after exercise. The CWIDP15 group decreased from 65.60 cm to 58.38 cm, while the CWIP15 group decreased from 59.79 cm to 51.28 cm. The CWIP10 group also showed a decrease from 59.67 cm to 50.93 cm. In contrast, the control group experienced a smaller decrease from 52.60 cm to 51.48 cm. Overall, all groups showed a decrease in jump height 24 hours after exercise, with the CWIDP15 group experiencing the smallest decrease compared to the other groups.

Table 7.
Changes in countermovement jump after doing acute training

Counter Movement Jump			
		Sig.	t
CWI DP15	Pre-post 1 Hour	0.005*	7,246
	Pre-Post 24 Hours	0.021*	4,493
CWI P 15	Pre-post 1 Hour	0.001*	15,926
	Pre-Post 24 Hours	0.060	2,942
CWI P 10	Pre-post 1 Hour	0.002*	21,577
	Pre-Post 24 Hours	0.125	2,554
control	Pre-post 1 Hour	0.838	-222
	Pre-Post 24 Hours	0.978	0.029

Description: (*) Significant ($p \leq 0.05$). P-value was obtained by paired sample t-test.

Discussion

The participant completed the acute protocol exercise with high use intensity (85% - 95%). No. There is a difference in pulse heart practice in the four groups as in graph 2, so in research, all samples have been practised on conditions intensity maximum (85%). There is an interesting average decline in pulse heart recovery in the 3rd minute of the DP 15 and P10 group, on average, which is the same decrease and lower than the P15 and the control groups. Although group P15 had the same decline as the control group, all three CWI delivery effects decreased heart rate. More recovery was good from group Control. In the same study (Yang et al., 2019), the data shows decreased heart rate recovery in both groups (CWI and Static Rest), and the CWI group showed a more significant decline than the Static Rest group.

The results of the study suggested that the CWI group experienced a more significant decrease in HRR than the Control group. In the past, HRR has been used as a metric to assess the training condition and autonomic function of athletes(Daanen et al., 2012; C. M. Lee & Mendoza, 2012) even (Gocentas et al., 2018) the HRR is an indication of performance that has specificity for each associated player's performance. Moreover, HRR is also a sign of exhaustion that happens in athletes after engaging in physical exercise(Daanen et al., 2012; Halson, 2014). The reduction in heart rate recovery (HRR) speed throughout the exercise session is crucial since it is connected to the athlete's preparation for further practice in the next programme. In their research,(Watson et al., 2017) demonstrated a reduction in connection speed in heart rate recovery (HRR) among competitive athletes. When implementing high-intensity aerobic interval training, it is vital to consider the duration of recovery and the work-recovery ratio(Watson et al., 2017). Withdraws CWI DP15 0 to provide diverse drops and enhance the quality of goods from the SR group.

Besides detecting a decrease in the researcher's HRR, the indicator of lactate blood can be seen in the effect of granting CWI. Interestingly, giving CWI gives differences in tolerance lactate blood at post-exercise, 10 minutes, 1 hour, 2 hours, and 24 in all groups. Accumulation of lactate blood indicates fatigue due to physical exercise (Barnett, 2006). Accumulation lactate in the group granting CWI DP15 was far lower and different from CWI P 15, CWI P10, and control groups.

A study (Wilcock et al., 2006) discloses that pressure hydrostatic can reduce time transportation metabolites, including lactate, accumulating during exercise through fluid transfer extracellular to the intravascular area and increasing bulk heart. CWI DP15^{0} group with temperature 15^{0} given at intervals exercise at each session, p this is what makes it possible accumulation low lactate consequence pressure hydrostatic. Immersion in fluid cold causes peripheral vasoconstriction, centralizing centralizing circulation (Weenink & Wingelaar, 2021).

Engaging from the study: This accumulation of lactate blood after 10 minutes after exercise physique in the CWI group is far better than the SR group. CWI is more effective in recovery after exercise not exceeding 15 minutes than the non-CWI (Joanna Vaile et al., 2008a). The percentage decline rate of lactate blood 2 hours after exercise shows that the CWI group experienced a decline above 70 % of concentration lactate blood after exercise, whereas CWI15 ^{0} experienced the highest decline, i.e., 88%, compared to the SR group.

Researchers also analyzed the performance of athletes by calculating countermovement jump (CMJ) achievements before the exercise was done, 1 hour after the exercise was carried out and 24 hours after the exercise was done. Table 5 shows that the use of CWI affects the improvement recovery of the subject and further influences achievements in the tall leap after 24 hours. The same with research (Sánchez–Ureña, 2017)in-depth research evaluation results of the use of CWI in increased recovery and performance in the tall jump 24 hours and 48 hours after practice, as CWI provides enhanced health in athletes (Tabben, 2018).

According to this study, CWI yielded superior outcomes in comparison to SR. CWI can enhance the expression of PGC-1a, improving control of energy metabolism in mitochondria (Allan, 2017). The study revealed that the CWI group had superior recovery heart rate reductions and more substantial blood lactate level decreases than the static rest group. The findings of this study will offer several choices for coaches and players on the implementation of recovery protocols using CWI DP15, CWI P15, and CWI P10. This aligns with other research indicating that cold water immersion (CWI) is efficacious in expediting the recuperation of athletes(Peiffer et al., 2009; Xiao et al., 2023). The data shown here corroborate the conclusions of (Daanen et al., 2012; Gocentas et al., 2018) who asserted that Heart Rate Recovery (HRR) is a crucial metric for evaluating the recovery of athletes. Nevertheless, this work expands the comprehension by demonstrating a distinct impact of CWI in decreasing blood lactate, a finding that aligns with the research conducted by(Wilcock et al., 2006).

This study did not examine the long-term effects of cold-water immersion (CWI), so its findings may only apply to short-term recovery. Additionally, the limited number of subjects may limit the generalisability of the results, especially in the context of practical application to a broader population. Finally, while this study demonstrates the effectiveness of CWI in reducing blood lactate levels and heart rate recovery, the physiological mechanisms underlying these effects remain fully understood and require further research, such as measuring muscle damage and inflammation.

Conclusion

This study has confirmed that Cold Water Immersion (CWI) is effective in reducing blood lactate levels and speeding up heart rate recovery (HRR) after high-intensity physical exercise. Compared to the group that remained at rest, the group that underwent cold water immersion (CWI) showed a greater reduction in heart rate recovery (HRR), indicating that they were better prepared for the following exercise. In addition, CWI resulted in a more pronounced reduction in blood lactate accumulation, indicating a decrease in muscle fatigue. The CWI group exhibited a significant enhancement in countermovement jump (CMJ) performance assessments 24 hours post-exercise, thus validating the efficacy of CWI in enhancing athletes' performance and recovery. To determine the most efficient protocols for athlete rehabilitation, it is necessary for future research to examine the enduring impacts of cold-water immersion (CWI) on athlete performance and recovery. Additionally, it is important to explore different temperatures and durations of CWI. In addition, research should focus on investigating the biological mechanisms responsible for the effects of CWI, specifically its impact on energy regulation in mitochondria, particularly the expression of PGC-1a.

Conflict of interest

The authors declare no conflict of interest in this study.

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