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Effects of Delayed Cold Water Immersion after High-Intensity Intermittent Exercise on Subsequent Exercise Performance in Basketball Players

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Abstract

The purpose of this research is to compare the effects of passive recovery and delayed cold water immersion one and three hours after high-intensity intermittent exercise (HIIE) on exercise performance and muscle soreness on the subsequent day. Eleven male basketball players participated in the study. They followed the recovery methods after high-intensity intermittent exercise, including 15 minutes cold water (15°C) immersion one hour (CWI1) and three hours (CWI3) after HIIE and passive recovery (CON) in a randomized order on a weekly basis. The protocol for HIIE included progressive speed 20-metre shuttle sprint interrupted with repetitive jumping in order to induce fatigue. Twenty-four hours after HIIE, a 20-metre shuttle sprint and maximal vertical jump test were conducted to evaluate the effect of each recovery method. Maximal vertical jump height after one and three hours did not differ significantly compared to pre-test values. However, the maximal vertical jump height in the control group was significantly lower than their pre-test value. Also, 24 hours after HIIE, perceived muscle soreness in CWI1 and CWI3 groups was significantly lower than that of the control group. The total distance of the shuttle run did not differ depending on the recovery method used. Cold water immersions one and three hours after HIIE affected maximal vertical jump height and athletes' perception of pain. However, there were no significant differences in exercise performance between the cold water immersion at one and three hours after HIIE, which might be due to similar physiological responses during both immersion trials.

Keywords: *cold water immersion, exercise recovery, high-intensity intermittent exercise, shuttle run test*

Introduction

One factor limiting the performance in team sport athletes is insufficient time for recovery after matches, especially after high-intensity, long-duration competitions such as basketball, football, and volleyball tournaments. During competition, high-intensity exertion resulting in micro-injury activates inflammatory processes, thus increasing body temperature and fatigue in athletes. Inadequate recovery between competitions may affect muscular and cardiorespiratory functions, causing fatigue and reducing exercise performance in athletes (Barnett, 2006; Vaile, Halson, Gill, & Dawson, 2008). Adequate recovery from high-intensity exercise is essential to maintain performance throughout training and competitions (Brown et al., 2017). Therefore, techniques that facilitate recovery after competitions are essential for maintaining exercise performance in team athletes (Jackman, Macrae, & Eston, 2009).

At present, cold water immersion (CWI) is a recovery method used mostly by physical therapists, sport science researchers, and coaches to reduce fatigue and facilitate the recovery process (Calleja-González et al., 2016; Versey, Halson, & Dawson, 2013). Several physiological mechanisms to explain the effects of cold water immersion have been proposed. Cold induces vasoconstriction of blood vessels, muscle tissue cooling, and increases in hydrostatic pressure, leading to a reduction in blood

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flow, decreased oedema and inflammation, decreased cell permeability and a reduction in secondary oxidative metabolism (Higgins, Greene, & Baker, 2017; Leeder, Gissane, Someren, Gregson, & Howatson 2012; Wang & Siemens, 2015). Also, cold water immersion generates a series of physiological changes, including reductions in skin and core body temperatures (Peiffer, Abbiss, Nosaka, Peake, & Laursen, 2009; Yanagisawa, Homma, Okuwaki, Shimao, & Takahashi 2007), acute inflammation (Wilcock, Cronin, & Hing, 2006), muscle spasms and sensations of pain (Vaile, Gill, & Blazevich, 2007; Sánchez-Ureña et al., 2017). Several factors related to the effects of cold water immersion on physiological response and exercise recovery are germane, including variations in water temperature, duration, water level, and application techniques. Almeida et al. (2016) studied the effects of immediate cold-water immersion at different temperatures post-exercise. Their results show that cold water immersion for 15 minutes at 14±1 °C resulted in improvements in the autonomic nervous system compared to lower water temperatures (Almeida et al., 2016). The length of the period of cold water immersion after exercise may affect physiological response and subsequent physical performance. Brophy-Williams, Landers, and Wallman (2011) examined the effects of immediate and delayed cold water immersion after exercise and found that cold water immersion immediately and three hours post-exercise significantly improved exercise performance and reduced C-reactive protein levels compared to the control condition. However, there was no difference between the three conditions of immersion (Brophy-Williams et al., 2011).

Previous studies have attempted to determine the duration, water temperature, and level of water immersion on physiological changes in athletes. Most research has focused on the immediate effects of cold water immersion with different protocols. However, immediate cold water immersion is difficult to perform in real situations due to limitations of place and the preparation of cold water in the field or during competitions. In addition, recently, some studies have investigated the effects of cold water immersion on athletes' performance on subsequent days, which is the normal competition schedule in team sports, such as basketball, football, or volleyball. Such sports need both aerobic and anaerobic energy systems to function at a high level.

Therefore, this study aims to determine the effect of delayed cold water immersion one and three hours after high-intensity interval exercise (HIIE) on exercise performance. The exercises used were maximum vertical jump and a 20-metre progressive shuttle sprint in subsequent days in male basketball players.

Methods

Participants

Eleven male basketball players in Walailak University, Thailand, were recruited into the study. The participants were selected based on the parameters in the study by Rowsell, Coutts, Reaburn, and Hill-Haas (2009). The inclusion criteria included 1) must have been regularly exercising at least two hours per day and three days per week for more than one year; 2) body mass index between 18.50–25.00 kg/m^2; 3) must have at least one year of experience in competitions in university games. Individuals with musculoskeletal problems within the six week study period, skin allergies, open wounds, abnormal skin sensations, and cardiopulmonary diseases were excluded. The details of this study were explained to the participants, and informed consent was given by each participant before starting the protocol. The present study was approved by the Ethics Committee of Human Research, Walailak University, Thailand.

Measures and Procedures

The present study used a cross-over design. Participants received three recovery techniques, including passive recovery (control), cold water immersion after one hour (CWI1) and three hours (CWI3) after HIIE. The order of the recovery technique applied was randomized using software with a wash-out period of at least seven days between interventions. On the first day, a twenty-metre shuttle sprint test and maximum vertical jump were performed prior to the study to determine baseline values. During the test, the heart rate at each speed of the 20-metre shuttle sprint was recorded and used to determine the appropriate speed for the high-intensity interval exercise. Seven days after the baseline test, participants received the first recovery techniques after the session of high-intensity interval exercise intended to induce physical fatigue. The protocol of HIIE comprised four rounds of the 20-metre shuttle sprint and repetitive vertical jump at different target heart rates with two minutes rest between rounds. Heart rate, muscle pain, and rating of perceived exertion (RPE) were recorded every two minutes of exercise. Immediately after HIIE, all parameters and blood pressure were repeated. After that, participants received an intervention randomly. Twenty hours after HIIE, the 20-metre shuttle sprint and maximal vertical jump were repeated as in the baseline measurement. All participants were instructed to avoid vigorous exercise, caffeine, and medicine for 24 hours before the test, as well as avoiding meals at least two hours before the test.

Maximal vertical jump

The maximal vertical jump was measured using a Vertec vertical jump® (USA) device, which had cells of 1.5 cm intervals longitudinally. Participants stood with legs at shoulder-width apart, one hand extended over the head to touch the Vertec slate, and the number was recorded. Then participants were asked to perform a maximal jump by doing as many hip and knee flexions as possible. They were assigned to perform the maximum jumps three times with a two-minute rest between each repetition, and the maximum value was recorded.

Twenty-metre progressive shuttle sprint test

The twenty-metre progressive shuttle sprint test consisted of one-minute stages of continuous, incremental speedrunning. The initial speed was 8.5 km/h and increased by 0.5 km/h each minute (Leger et al., 1988). Participants were required to run between two lines 20 metres apart while keeping pace with audio signals emitted from a pre-recorded compact disk. They were instructed to run in a straight line, pivot, then turn on completion and pace themselves in accordance with the audio signals. If the line was reached before the beep sounded, the subject had to wait until the beep sounded again before continuing. If the line was not reached before the beep, the subject was given a warning and had to continue to run to the line, then turn and try to catch up with the pace within two more beeps. The test ended when the individual failed to reach the end lines concurrent with the audio signals on two consecutive occasions. Each participant was encouraged to keep running for as long as possible. During the test, heart rate was continuously monitored using a pulse oximeter and RPE, and the fatigue scale was measured every minute.

High-intensity interval exercise

The protocol for HIIE comprised progressive speed 20-metre shuttle sprints at different percentages of maximum heart rate alternating with repetitive jumping in order to induce fatigue. Heart rate was recorded during the 20-metre progressive shuttle sprint at the end of each stage to calculate the exercise heart rate. Participants were required to perform four sets of sprints and vertical jump sets. The set of HIIE was composed of 1) the 20-metre shuttle sprint at 65–75% HR_{max} for 5 rounds; 2) 2 jumps at 80% maximum jump height; 3) the 20-metre shuttle sprint at 75–85% HR_{max} for 5 rounds; 4) 2 jumps at 100% maximum jump height; 5) the 20-metre shuttle sprint at 85–90% HR_{max} for 5 rounds. Heart rate, muscle pain and RPE were recorded every two minutes of exercise.

Three recovery techniques

After completion of the HIIE session, participants moved to the lab and rested for five minutes. Resting heart rate, blood pressure, SpO_2, thermal sensation scale, and skin temperature were measured. Skin temperature was measured using a digital thermometer (TG-100 Rossmax) and infrared thermometer (AR 360 A+), respectively, at the axilla and the anterior thigh at the mid-line between hip joint and upper border of the patella. After that, participants sat in the long sitting position in a bath tank filled with 15 °C water. The level of the water was to the iliac crest, and the water temperature was monitored and controlled throughout the protocol with a thermostat. Every three minutes, all parameters were measured except thigh skin temperature, which was only repeated at the end of immersion. After immersion, participants were allowed to sit on a chair for five minutes, and all parameters were recorded. For the control intervention, subjects sat in the same room with no activity allowed. Room temperature was controlled at 25 °C, and humidity was recorded. During the test, only the researcher and the participants were in the lab. Participants received each recovery treatment at the same time of day to prevent a diurnal effect.

Statistical analysis

All data were presented as means±SD. One-way ANOVA was applied to determine the differences in the 20-metre progressive shuttle sprint, vertical jump height and muscle pain after 24 hours of the three interventions. The differences in heart rate, blood pressure, respiratory rate, RPE, muscle pain and body temperature were evaluated every three minutes during cold water immersion using a two-way repeated measurement ANOVA. $p<0.05$ was regarded as statistically significant. All analyses were performed using SPSS version 17 (SPSS Inc. USA)

Results

All participants in the study were male basketball players at Walailak University. None had diseases that affected their ability to perform the tests, including musculoskeletal, nervous, cardiovascular, and respiratory disorders. All participants have an average duration of a basketball training period of five days per week for at least six continuous years. The mean and standard deviation for age, weight, height, and body mass index is shown in Table 1.

Table 1 Subject characteristics including age, weight, height and body mass index of all participants (n=11)

Characteristic	Mean±SD
Age (y)	21.00±1.84
Weight (kg)	68.77±7.89
Height (cm)	175.00±6.15
Body mass index (kg/m²)	22.41±1.83

Prior to undergoing the recovery interventions, all participants performed high-intensity exercise for an average duration of about 24.04±1.12 minutes. Physiological responses to HIIE including exercise heart rate (HR), systolic/diastolic blood pressure (BP), respiratory rate (RR), rating of perceived exertion (RPE), percutaneous oxygen saturation (SpO_2), muscle soreness, and body temperature at axilla for each intervention were presented in Table 2. Results show that there was no significant difference between groups for all parameters. This indicates that the same intensity of exercise to induce fatigue prior to undergoing each intervention was achieved.

Table 2 Physiological responses to HIIE before undergoing the recovery intervention in control, cold water immersion 1 and 3 hours after HIIE of all participants (n=11)

Parameters	CON	CWI1	CWI3	p
	Mean±SD	Mean±SD	Mean±SD	
HR (beats per minute)	187.20±7.93	186.45±5.57	184.00±7.06	0.539
SBP/DBP (mmHg)	144.20±21.24/ 69.70±11.74	148.45±15.58/ 75.09±10.20	146.73±24.92/ 73.09±11.55	0.897 0.545
RR (times per minute)	43.00±5.06	43.45±5.43	44.80±4.37	0.705
RPE	16.80±1.62	16.27±2.45	17.00±1.73	0.678
SpO_2 (%)	95.90±2.13	95.91±2.21	96.27±1.27	0.875
Muscle soreness	4.70±3.09	4.36±2.73	3.09±2.88	0.411
Axillary temperature (°C)	36.80±0.71	36.01±1.06	36.57±0.69	0.110

Legend: CON-control; CWI1-cold water immersion 1 h after HIIE; CWI3-cold water immersion 3 h after HIIE; HR-heart rate; SBP-systolic blood pressure; DBP-diastolic blood pressure; RR-respiratory rate; RPE-rate of perceived exertion; SpO_2-oxygen saturation

Twenty-four hours after HIIE, participants performed a 20-metre shuttle sprint and maximal vertical jump test to determine the effectiveness of passive recovery, compared with cold water immersion one and three hours after HIIE on subsequent physical performance. Pre-test values for the maximum vertical jump in all participants were 55.55±6.67 cm. Twenty-four hours after recovery by resting (control), the maximal vertical jump reduced to 50.60±5.50 cm, which is significantly lower than the pre-test value (p<0.05; Table 3). In contrast, there was no significant difference between subsequent maximum vertical jumps in CWI1 and CWI3 groups compared to pre-test values.

Moreover, the results showed a significantly higher maximum jump height in CWI1 and CWI3 than in the control group (p<0.05).

Table 3 Maximum vertical jump height before HIIE (pre-test), and 24 hours after receiving recovery interventions including control, cold water immersion 1 and 3 hours after HIIE in 11 participants

Maximum vertical jump (cm)			
Pre-test Mean±SD	24 hours after intervention		
	CON Mean±SD	CWI1 Mean±SD	CWI3 Mean±SD
55.55±6.67	50.60±5.05*	56.73±6.60†	56.18±5.81†

Legend: * - significantly different compared with pre-test value (p<0.05); † - significantly different compared with control (p<0.05)

Twenty- four hours after each intervention, a maximum 20-metre progressive shuttle sprint test in CON, CWI1, and CWI3 were not significantly different compared with the pre-test values between interventions. The physiological responses during the 20-metre progressive shuttle sprint test before and 24 hours after intervention are shown in Table 4. The results show that maximum heart rate, systolic/diastolic blood pressure, respiratory rate, and rating of perceived exertion scale were not different between groups (Table 4). This indicates that the effort taken to perform the test was of the same level after each intervention.

Table 4. Twenty-metre progressive shuttle sprint test before HIIE, 24 hours after receiving recovery interventions including control, cold water immersion 1 and 3 hours after HIIE in 11 participants (Mean±SD)

Parameters	Pre-test	24 hours after intervention		
		CON	CWI1	CWI3
	Mean±SD	Mean±SD	Mean±SD	Mean±SD
Shuttle sprint completed - Absolute value (m) - Δ change from pre-test (m)	1004.27±297.09	1184.00±257.13 214.00±210.62	1196.36±284.65 229.10±366.20	1238.18±224.05 290.90±280.60
HR (beats per minute)	192.91±7.94	187.90±6.74	186.36±7.53	185.82±6.32
SBP/DBP (mmHg)	150.73±14.23/ 80.73±5.95	163.70±21.45/ 74.70±8.35	166.27±19.88/ 70.82±11.72	151.91±16.22/ 79.00±11.42
RR (times per minute)	44.71±3.68	43.80±4.18	44.90±5.47	43.36±4.74
RPE	16.45±1.04	16.20±1.55	15.82±2.18	17.18±1.08

Muscle pain was evaluated after the HIIE based on the pre-test value and values 24-hours after HIIE. In the control group, 24-hour post-HIIE muscle pain was not significantly different compared with pre-intervention values, whereas groups that underwent cold water immersion one and three hours after HIIE showed significantly lower muscle pain compared to their pre-test value and the control group (p<0.05), as shown in Table 5.

Table 5. Muscle pain scores after HIIE (pre-test) and 24 hours after intervention including control, cold water immersion 1 and 3 hours after HIIE in 11 participants

Muscle soreness			
Pre-test	CON	CWI1	CWI3
Mean±SD	Mean±SD	Mean±SD	Mean±SD
5.12±2.23	2.60±3.27	0.91±1.87*,†	0.73±1.68*,†

Skin temperature changes at the axilla and anterior thigh during cold water immersion in CWI1 and CWI3 were recorded every three minutes and five minutes after the immersion was completed, as well as heart rate, systolic/diastolic blood pressure and a thermal sensation scale as shown in Table 6. Results show that heart rate before, during, and five minutes after recovery after immersion in CWI3 were significantly lower than CWI1 (p<0.05). Systolic and diastolic blood pressure did not show a significant difference except for the systolic blood pressure at three min in the CWI3 condition was significantly higher than their resting condition (p<0.05). The temperature at the anterior thigh was significantly lower than before immersion in both groups (p<0.05).

Table 6. Physiological responses to 15-minute cold water immersion in CWI1 and CWI3 before (0), during 3, 6, 9, 12, and 15 minutes and after immersion for 5 minutes (20) (Mean±SD)

	Minute						
	0	**3**	**6**	**9**	**12**	**15**	**20**
	Mean±SD	**Mean±SD**	**Mean±SD**	**Mean±SD**	**Mean±SD**	**Mean±SD**	**Mean±SD**
HR (beats per minute)							
CWI1	79.73±8.75	75.91±8.46	75.82±6.65	76.00±6.48	76.36±7.90	74.00±7.58	72.36±10.45
CWI3	68.55±7.98‡	69.09±6.92‡	68.91±7.45‡	67.73±4.84‡	69.64±7.68‡	69.36±7.15	63.09±6.17‡
SBP (mmHg)							
CWI1	121.82±8.95	129.27±11.62	122.18±7.03	119.64±7.58	121.27±10.47	122.18±8.00	116.36±10.57
CWI3	121.09±7.83	130.45±10.74#	122.18±6.48	120.18±9.39	122.55±9.80	120.91±8.04	116.82±10.46
DBP (mmHg)							
CWI1	70.00±5.12	75.91±8.63	73.36±3.91	71.55±5.99	71.09±6.46	70.64±7.27	71.09±6.43
CWI3	75.45±9.50	79.82±9.45	75.91±6.50	72.82±4.87	73.27±9.02	77.00±7.63b	71.64±8.29
Thermal sensation scale							
CWI1	-0.59±0.77	-1.27±0.96	-0.59±0.77	-0.45±0.61	-0.45±0.42	-0.45±0.35	0.10±0.70
CWI3	-0.41±0.63	-1.18±1.15	-0.73±0.96	-0.64±0.98	-0.59±0.92	-0.59±1.02	-0.05±0.47
Temperature (℃)							
CWI1	35.56±0.85	35.53±0.92	35.63±1.06	35.57±1.09	34.87±3.50	35.85±1.12	35.77±1.08
CWI3	35.59±0.62	35.45±0.59	35.47±0.69	35.69±0.58	35.88± 0.55	35.83±0.66	35.87±0.51
Anterior thigh							
CWI1	32.16±0.95					17.36±1.02#	22.79±1.04#
CWI3	31.25±1.02					16.99±0.86#	23.01±1.15#

Legend: ‡ - significant difference compared to CWI1 ($p<0.05$); # - significant difference compared to minute 0 ($p< 0.05$)

Discussion

This research aimed to compare the effects of delayed cold water immersions one and three hours after HIIE with passive recovery on exercise performance in male basketball players. Important findings show that the anaerobic performance measured from a maximal vertical jump height one and three hours after delayed cold water immersion can restore strength to pre-test values, whereas the decline in this parameter was demonstrated in the control recovery group. However, there was no significant difference between the two intervals of cold water immersions. In contrast to maximal vertical jump height, a 20-metre shuttle sprint test 24-hours after three recovery interventions showed no significant differences between groups. However, pain sensations were considerably reduced compared with passive recovery (control) in both cold water immersion treatments.

Thus, in this study, it was demonstrated that both cold water immersion conditions were able to restore 24-hour maximum vertical jump capacity, which is a mark of the anaerobic capacity of the muscles involved. This result is consistent with the findings of Ascensao et al. (2011), according to which participants who were immersed in 10 °C water up to the iliac crest for 10 minutes after a match showed a significantly greater maximal isometric voluntary contraction of the quadriceps muscle than control groups. Ascensao et al. (2011) also found that intermediate cooling can reduce perceived soreness and attenuate the biochemical signs of muscle damage demonstrated by the reduction in creatinine kinase (CK), myoglobin (Mb), and C-reactive protein (CRP). Another study done to determine the effect of immediate cold water immersion on anaerobic power is that of Taher, Fsharnezhad, Faghihi, Hazrati, and Bahrami (2017). A significant decrease in the anaerobic performance measured with a 30-second Wingate test after a competition was observed, and CWI were effective in enhancing the anaerobic performance after competition compared with the control group.

The physiological effects of cold water immersion have been studied. The hydrostatic pressure of the water may result in both muscular and vascular compression, which may decrease inflammatory responses as shown by a reduction in C-reactive protein level 24 hours after high-intensity exercise in normal people who undergo a 10-hour delay immersion in cold water (Goodall & Howatson, 2008; Lum, Landers, & Peeling, 2010; Williams, Landers, & Wallmen, 2011). In addition, cold water immersion is proposed to reduce inflammation by evoking vasoconstriction and decreasing peripheral blood flow (Wilcock, 2005). Cold-water immersion may also help to maintain power after exhaustion competition through direct and indirect mechanisms. For instance, cold water immersion inhibits the activity of group III and IV afferents in skeletal muscle and decreases the reduction of lactic acid during muscle activities, resulting in a decrease in the perception of fatigue and pain (Roberts et al., 2015; Yanagisawa, Niitsu, Takahashi, Goto, & Itai, 2003). Another study found that stroke volume and cardiac output increased during cooling, which assisted in decreasing core temperature (Gabrielsen et al., 2002).

However, the exercise performance restoration effects of cold water immersion one and three hours after HIIE were not different in a recent study, which is quite similar to the study of Williams et al. (2011). That previous study aimed at investigating the effects of immediate and three-hour CWI after exercise on subsequent performance. The results demonstrated that shuttle run completed as an intermittent yoyo test was only significantly higher than the control recovery group in CWI0. However, the study did not show a significant difference between CWI0 and CWI3. This could be explained by the similar reduction of CRP level in CWI0 and CWI3 that helped to decrease the inflammatory process to the same degree. In addition, the physiological responses during cold water immersion, including heart rate, systolic/diastolic blood pressure, body temperature and thermal sensation in CWI1 and CWI3, did not differ significantly in all parameters. Therefore, the restoration effects of cold water immersion on exercise performance demonstrate no significant difference between the two immersions.

This study is the first research done to determine the practical effect of delayed cold-water immersion at one and three hours for clinical use instead of applying it immediately, which is practically difficult to do. Our results demonstrate that both delayed cold-water immersion at one and three hours after HIIE resulted in the restoration of the ability to perform a maximal vertical jump and decreased the perception of pain compared to passive recovery, but it did not improve the subsequent 20-metre progressive shuttle sprint performance in basketball players.

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Conflict of interest
The authors declare that there are no conflicts of interest.

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