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Effect of contrast water therapy on blood lactate concentration after high-intensity interval training in elite futsal players

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Abstract

Introduction. In the process of improving an athlete's performance, the recovery methods must be optimized. Recovery is required to maximize training and competition performance; fatigue should be minimized by recovering as fast as possible. This study aimed to assess effects of contrast water therapy on blood lactate concentration after high-intensity interval training (HIIT) in elite futsal players.

Methods. A total of 30 male futsal athletes volunteered to be subjects in this study. The test session consisted of repeated sprints at the distance of 25 m (3 series of two 1-min repetitions at 90% of maximum heart rate). After HIIT, the participants were randomized into 2 groups; 15 received contrast water therapy (CWT), and 15 were given slow jogging recovery (SJR). The recovery for the CWT group consisted of periodic immersions in cold water (18°C) for 1 min and then in hot water (37°C) for 2 min, with accumulating 15 min in the water. The recovery for the SJR group included 8 min of slow jogging (6.8 km · h^{-1}) around a field.

Results. After 30-min recovery, lactate concentration was significantly greater (p = 0.001) in the SJR group (7.67 mmol/l) than in the CWT group (6.82 mmol/l) and remained significantly different 60 min after recovery (p = 0.0001; 6.80 mmol/l and 5.01 mmol/l, respectively).

Conclusions. We demonstrated that CWT after HIIT had an effect on the recovery of elite futsal players by decreasing the lactate concentration and rapid recovery of heart rate.

Key words: recovery, performance, fatigue, muscle function, sprint

Introduction

Futsal is one of the sports involving physical activity that is done to train a person's body [1]. There is only a small difference between futsal and football. Futsal, the 5-side version of soccer (i.e. 1 goalkeeper and 4 outfield players), was introduced in 1930 and continues to grow in popularity around the world. Competitive games comprise of two 20-min periods of high-intensity and intermittent activities requiring substantial physical, tactical, and technical efforts from the players [2–4]. Also, previous studies pointed at the fact that in futsal, more than 75% of all energy is resynthesized by the oxidative phosphorylation pathway during match play and the ratio of activity to rest is about 1:1 [5–7].

Because futsal involves intermittent and high-intensity actions, athletes must avoid harmful factors, one of them being high fatigue [8]. Fatigue can become a significant problem that increases an athlete's risk of injury [9]. Muscle fatigue is caused by the accumulation of lactic acid in muscle fibres during intense exercise [10]. It can be assessed on the basis of the percentage of muscle strength reduction, decreased muscle reaction time, and muscle fatigue recovery time. Fatigue can be classified into that affecting the central nervous system or the peripheral nervous system [11]. Fatigue continues to occur if a person does not have good recovery after intense physical activity, which in turn interferes with metabolism and energy formation [12].

In the process of improving an athlete's performance, the recovery methods must be optimized [13]. Recovery is required to maximize training and competition performance, and fatigue should be minimized by recovering as fast as possible [14]. According to Vaile and Halson [15], recovery refers to the restoration of the body's physiological and psychological processes, allowing athletes to potentially return to their pre-fatigue state and performance level. Water immersion is a recovery technique widely used by athletes [15, 16]. Water immersion for recovery of athletes performance has been divided into 4 techniques depending on water temperature: cold water immersion (CWI; ≤ 20°C), hot water immersion (HWI; ≥ 36°C), contrast water therapy (CWT; alternating CWI and HWI), and thermoneutral water immersion (TWI; from > 20 to < 36°C) [14, 17].

CWT is a recovery technique of water immersion popularly used by athletes to accelerate post-exercise recovery [15, 17]. It is performed by alternating regularly between CWI and HWI [17]. Several studies which examined CWT do not find a performance benefit. Ingram et al. [18] explained that CWI following exhaustive simulated team sports exercise offered greater recovery benefits than CWT or control treatments. Nonetheless, many studies also reported beneficial

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effects of CWT on performance recovery. Versey et al. [19] maintain that CWT for up to 12 min assists recovery of cycling performance. Since this evidence, an increased interest has been noticed in investigations that verify the effect of CWT on performance recovery, with differences protocols [20–22].

Many of the physiological responses to CWT are relatively well documented [13]. However, the optimal protocols to assist CWT of exercise performance remain unclear. Water temperature, timing, immersion duration, immersion depth, and activity level can all vary. Therefore, further research into this recovery procedure is required. On the basis of these problems and interests, this study aimed to assess the effects of CWT on blood lactate concentration after high-intensity interval training (HIIT) in elite futsal players. In the context of previous observations [19], we hypothesized that CWT might reduce the lactate concentration of athletes.

Subjects and methods

Participants

Overall, 30 male futsal athletes from Kosgoro Futsal Club volunteered to be the subjects of this study. All participants were asked to fill in a health questionnaire. They did not have any smoking history. They had a minimum continuous futsal training background of 5 years. Also, all athletes must have participated in systemized training, with at least 3 training sessions per week, each lasting 3 hours. Exclusion criteria involved a cardiovascular or respiratory disease. Alcohol and caffeine were not accepted for about 24 hours prior to the experiments. The study was performed in the period of 18–25 February 2019, which was the official league break and no official games were played.

Study design

The study used a parallel, 2-group, purposive sampling, pretest-posttest design to determine the effect of the independent variable on the dependent variable. The independent variable was CWT, while the dependent one was blood lactate concentration of the athletes. The participants were randomized into 2 groups: 15 were assigned to the experimental (CWT) group, and the other 15, in the control group, were given slow jogging recovery (SJR).

Protocol procedures

In the week preceding the study, anthropometric and cardiorespiratory tests were performed. The participants had not undertaken any intense effort during the previous 24 hours or eaten any food within the 3 hours before the tests were registered. On Monday morning, at 09:00 a.m., anthropometric measurements were taken in a laboratory. Body weight was determined with an Omron Digital Weight Scale HN 289, with participants wearing minimal clothes and being barefoot. Body height was measured with a stadiometer with 0.1-cm readability (Seca 214 Portable Stadiometer, Cardinal Health, Dublin, USA) in accordance with the described standardised procedures. Body mass index was calculated as the ratio of the body mass (kilograms) divided by body height (metres) squared.

After the anthropometric measurements, the cardiorespiratory test were performed outside the laboratory building. After a standardized 6-min warm-up, the cardiorespiratory test began at 10:00 a.m. The selected test was the Yo-Yo intermittent recovery test, level 1 (YYIrT-L1), providing us with each player's maximum heart rate and maximal oxygen consumption. The heart rate was monitored with a test employing a Polar RS400 sports watch (Finland). The protocol and formula of the YYIrT-L1 were based on previous test protocols [23–25]. Anthropometric and cardiorespiratory characteristics of the participants are shown in Table 1.

After the anthropometric and cardiorespiratory tests, the experimental study was carried out at the Bogor Futsal Stadium. Prior to testing, the participants performed a warm-up (6-min jog at 6.8 km · h^{-1}). HIIT was an interval exercise consisting of sprint with a track distance of 25 m. Starting the test, the participants prepared themselves in a standing start position at one end of the 25-m sprint track (i.e. cone A).

Table 1. Anthropometric and cardiorespiratory characteristics of study participants

Variable	CWT group	SJR group
Age (years)		
$\bar{x}$ (*SD*)	19.7 (± 0.6)	19.9 (± 0.6)
Median	20.0	20.0
Range (min–max)	19.0–21.0	19.0–21.0
Weight (kg)		
$\bar{x}$ (*SD*)	70.9 (± 3.9)	69.0 (± 3.8)
Median	70.0	69.0
Range (min–max)	65.0–77.0	63.0–78.0
Height (cm)		
$\bar{x}$ (*SD*)	171.8 (± 3.6)	170.7 (± 3.9)
Median	171.0	169.0
Range (min–max)	165.0–179.0	165.0–178.0
BMI (kg · m^{-2})		
$\bar{x}$ (*SD*)	24.0 (± 0.5)	23.7 (± 0.8)
Median	23.9	23.5
Range (min–max)	23.0–25.4	22.8–25.5
YYIrT-L1 (m)		
$\bar{x}$ (*SD*)	413.3 (± 53.8)	418.7 (± 63.9)
Median	440.0	440.0
Range (min–max)	320.0–480.0	320.0–520.0
VO_2max (ml · kg^{-1} · min^{-1})		
$\bar{x}$ (*SD*)	39.87 (± 0.5)	39.92 (± 0.5)
Median	40.1	40.1
Range (min–max)	39.1–40.4	39.1–40.8
HRmax (bpm)		
$\bar{x}$ (*SD*)	183.7 (± 5.3)	189.5 (± 3.8)
Median	185.0	188.0
Range (min–max)	175.0–191.0	185.0–197.0

CWT – contrast water therapy, SJR – slow jogging recovery, *SD* – standard deviation, BMI – body mass index, YYIrT-L1 – Yo-Yo intermittent recovery test, level 1, VO_2max – maximal oxygen consumption, HRmax – maximum heart rate

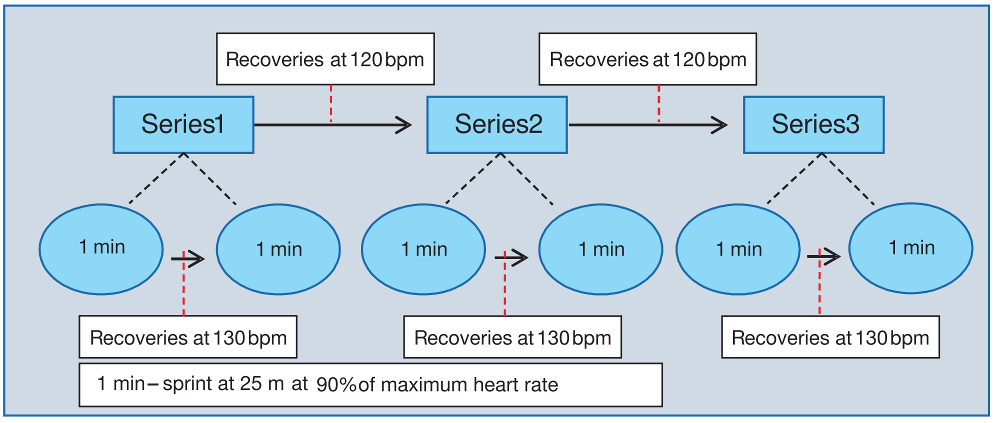


Figure 1. The test period of the high-intensity interval training

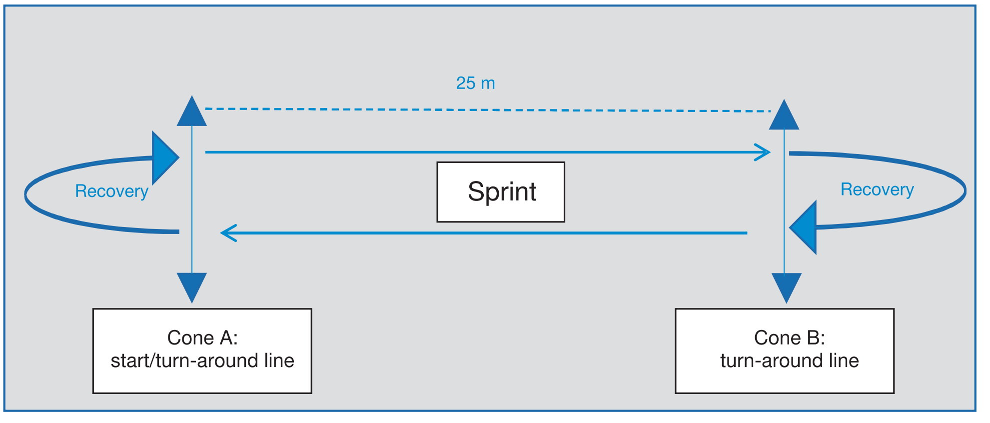
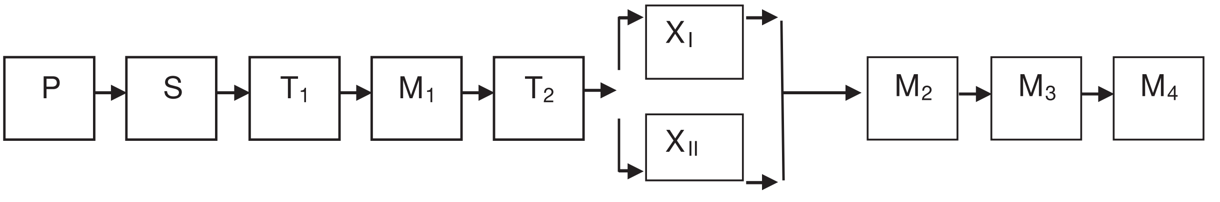


Figure 2. The test configuration of the high-intensity interval training



P – population, S – sample, T_1 – anthropometric and cardiorespiratory test, M_1 – measured lactate in pre-test, T_2 – high-intensity interval training test, X_I – contrast water therapy, X_{II} – slow jogging recovery, M_2 – measured lactate and average heart rate post-test (in the 3rd minute after high-intensity interval training), M_3 – measured lactate and average heart rate post-30-min, M_4 – measured lactate and average heart rate post-60-min

Figure 3. The research design

Then they sprinted to the end of the 25-m track (i.e. cone B), touched the line with a foot, and came back to the starting line. There were 3 series of two 1-min repetitions at 90% heart rate intensity (3 × 2 × 1 min), with recoveries at 130 bpm between repetitions and at 120 bpm between series. During the recovery period, the participants should get ready standing (stand position) to perform another 25-m sprint back to where they had started. Polar heart rate monitors were used (Polar RS400, Finland), registering the data at all times. The test period of the HIIT is displayed in Figure 1. After the end of the last task section, blood lactate was measured in the 3rd minute after HIIT. The test configuration for the HIIT is displayed in Figure 2.

Recovery interventions

Blood lactate was measured in the 3rd minute after HIIT. The participants were divided into the CWT group and the SJR group, to receive the following recovery procedures. Recovery for the CWT group consisted of periodic immersions in cold water (18°C) for 1 min and then in hot water (37°C) for 2 min, accumulating 15 min in the water. The subjects were passive during the water immersion. They started with cold water by lowering themselves into an upright 250-l plastic container and finished with hot water by standing under a shower directed onto the legs below the hips (water temperatures were measured with a Testo AG T 106 thermometer). In turn, recovery for the SJR group included 8 min of slow jogging (6.8 km · h^{-1}) around a field. The jogging speed was controlled via verbal feedback of lap times. The participants were allowed to drink mineral water *ad libitum* during the recovery period and were encouraged to drink enough to maintain hydration.

Blood sample analyses

A 100-μl sample of fingertip capillary blood was obtained to measure lactate pre-test, post-test (in the 3rd minute after HIIT), post-30-min, and post-60-min. The blood samples were analysed with a Lactate Pro analyser (Arkray, Shiga, Japan). The research design is illustrated in Figure 3.

Statistical analysis

The values are presented as mean ± *SD*. The repeated measures ANOVA was used to evaluate the lactate concentration and heart rate pre-test, post-test, post-30-min, and post-60-min. Independent *t*-test served to determine any differences among the CWT and SJR groups. Also, Bonferroni correction was applied for *p*-value. Statistical significance was accepted at the level of $p < 0.05$. Statistical analysis was performed with the use of the SPSS V.21.0 software.

Ethical approval

The research related to human use has complied with all the relevant national regulations and institutional policies, has followed the tenets of the Declaration of Helsinki, and has been approved by the ethics committee of the State University of Jakarta.

Informed consent

Informed consent has been obtained from all individuals included in this study.

Results

Lactate

Tables 2–4 show the lactate measures in the CWT and SJR groups. In both groups, lactate concentration increased from pre-test to post-test after HIIT ($p = 0.0001$). No significant difference in lactate concentration at pre-test was found between groups ($p = 0.516$). Furthermore, no significant difference in the parameter post-test was observed between the CWT and SJR groups ($p = 0.550$). After 30 min of recovery, lactate concentration was significantly greater ($p = 0.001$) in the SJR group (7.67 mmol/l) than in the CWT group (6.82 mmol/l) and remained significantly different at 60 min after recovery ($p = 0.0001$; 6.80 mmol/l and 5.01 mmol/l, respectively). During recovery, the lactate concentration of the CWT and SJR groups decreased from post-30-min to post-60-min ($p = 0.0001$). But significant differences in post-30-min ($p = 0.001$) and in post-60-min ($p = 0.0001$) were observed between the CWT and SJR groups.

Table 2. Changes in lactate measures in the study groups

Measurement time	Lactate concentration (mmol/l)			*p*-value[a]
	CWT group	SJR group	*t*-value	
Pre-test	3.39 (± 0.48)‡#^	3.53 (± 0.67)‡#^	–0.657	0.516
Post-test	9.49 (± 0.85)†#^	9.66 (± 0.64)†#^	–0.605	0.550
Post-30-min	6.82 (± 0.60)†‡^*	7.67 (± 0.69)†‡^*	–3.594	0.001
Post-60-min	5.01 (± 0.80)†‡#*	6.80 (± 0.68)†‡#*	–6.607	0.0001
F-value	4472.4	2740.1		
p-value[b]	0.0001	0.0001		

CWT – contrast water therapy, SJR – slow jogging recovery
The values are presented as mean ± *SD*.
[a] independent *t*-test, [b] repeated measure ANOVA, † values significantly different compared with pre-test ($p < 0.05$), ‡ values significantly different compared with post-test ($p < 0.05$), # values significantly different compared with post-30-min ($p < 0.05$), ^ values significantly different compared with post-60-min ($p < 0.05$), * values significantly different between the CWT and SJR groups ($p < 0.05$)

Table 3. Specific changes in lactate measures in the CWT group

Measurement time (I)	Measurement time (J)	Mean difference (I–J)	Standard error	Sig.[a]	95% confidence interval for difference[a]	
					Lower bound	Upper bound
Pre-test	Post-test	–6.100*	0.283	0.001	–6.968	–5.232
	Post-30-min	–3.427*	0.236	0.001	–4.151	–2.703
	Post-60-min	–1.613*	0.183	0.001	–2.174	–1.053
Post-test	Pre-test	6.100*	0.283	0.001	5.232	6.968
	Post-30-min	2.673*	0.122	0.001	2.298	3.049
	Post-60-min	4.487*	0.337	0.001	3.453	5.521
Post-30-min	Pre-test	3.427*	0.236	0.001	2.703	4.151
	Post-test	–2.673*	0.122	0.001	–3.049	–2.298
	Post-60-min	1.813*	0.296	0.001	0.905	2.722
Post-60-min	Pre-test	1.613*	0.183	0.001	1.053	2.174
	Post-test	–4.487*	0.337	0.001	–5.521	–3.453
	Post-30-min	–1.813*	0.296	0.001	–2.722	–0.905

Based on estimated marginal means.
* mean difference significant at $p < 0.05$, [a] adjustment for multiple comparisons: Bonferroni

Table 4. Specific changes in lactate measures in the SJR group

Measurement time (I)	Measurement time (J)	Mean difference (I–J)	Standard error	Sig.[a]	95% confidence interval for difference[a]	
					Lower bound	Upper bound
Pre-test	Post-test	–6.127*	0.221	0.001	–6.805	–5.449
	Post-30-min	–4.133*	0.232	0.001	–4.846	–3.421
	Post-60-min	–3.267*	0.251	0.001	–4.036	–2.497
Post-test	Pre-test	6.127*	0.221	0.001	5.449	6.805
	Post-30-min	1.993*	0.130	0.001	1.593	2.393
	Post-60-min	2.860*	0.109	0.001	2.525	3.195
Post-30-min	Pre-test	4.133*	0.232	0.001	3.421	4.846
	Post-test	–1.993*	0.130	0.001	–2.393	–1.593
	Post-60-min	0.867*	0.080	0.001	0.620	1.113
Post-60-min	Pre-test	3.267*	0.251	0.001	2.497	4.036
	Post-test	–2.860*	0.109	0.001	–3.195	–2.525
	Post-30-min	–0.867*	0.080	0.001	–1.113	–0.620

Based on estimated marginal means.
* mean difference significant at $p < 0.05$, [a] adjustment for multiple comparisons: Bonferroni

Table 5. Changes in average heart rate in the study groups

Measurement time	Average heart rate (bpm)		*t*-value	*p*-value[a]
	CWT group	SJR group		
HR-HIIT	181.40 (± 5.05)‡#^	184.27 (± 5.44)‡#^	–1.495	0.146
HR-post	176.60 (± 4.81)†#^	179.27 (± 5.12)†#^	–1.471	0.153
HR-30-min	86.93 (± 5.48)†‡^	88.93 (± 5.40)†‡^	–1.006	0.323
HR-60-min	69.93 (± 1.58)†‡#*	71.20 (± 1.61)†‡#*	–2.173	0.038
F-value	26461.7	28832.3		
p-value[b]	0.0001	0.0001		

CWT – contrast water therapy, SJR – slow jogging recovery, HR-HIIT – average heart rate in the total 3 series, HR-post – average heart rate post-test (in the 3rd minute after high-intensity interval training), HR-30-min – average heart rate post-30-min, HR-60-min – average heart rate post-60-min
The values are presented as mean ± *SD*.
[a] independent *t*-test, [b] repeated measure ANOVA, † values significantly different compared with HR-HIIT ($p < 0.05$), ‡ values significantly different compared with HR-post ($p < 0.05$), # values significantly different compared with HR-30-min ($p < 0.05$), ^ values significantly different compared with HR-60-min ($p < 0.05$), * values significantly different between the CWT and SJR groups ($p < 0.05$)

Table 6. Specific changes in average heart rate in the CWT group

Measurement time (I)	Measurement time (J)	Mean difference (I–J)	Standard error	Sig.[a]	95% confidence interval for difference[a]	
					Lower bound	Upper bound
Pre-test	Post-test	4.800*	0.460	0.001	3.389	6.211
	Post-30-min	94.467*	1.732	0.001	89.153	99.781
	Post-60-min	111.467*	1.150	0.001	107.938	114.996
Post-test	Pre-test	–4.800*	0.460	0.001	–6.211	–3.389
	Post-30-min	89.667*	1.912	0.001	83.801	95.533
	Post-60-min	106.667*	1.120	0.001	103.230	110.103
Post-30-min	Pre-test	–94.467*	1.732	0.001	–99.781	–89.153
	Post-test	–89.667*	1.912	0.001	–95.533	–83.801
	Post-60-min	17.000*	1.483	0.001	12.448	21.552
Post-60-min	Pre-test	–111.467*	1.150	0.001	–114.996	–107.938
	Post-test	–106.667*	1.120	0.001	–110.103	–103.230
	Post-30-min	–17.000*	1.483	0.001	–21.552	–12.448

Based on estimated marginal means.
* mean difference significant at $p < 0.05$, [a] adjustment for multiple comparisons: Bonferroni

Table 7. Specific changes in average heart rate in the SJR group

Measurement time (I)	Measurement time (J)	Mean difference (I–J)	Standard error	Sig.[a]	95% confidence interval for difference[a]	
					Lower bound	Upper bound
Pre-test	Post-test	5.000*	0.710	0.001	2.820	7.180
	Post-30-min	95.333*	1.982	0.001	89.250	101.417
	Post-60-min	113.067*	1.378	0.001	108.837	117.296
Post-test	Pre-test	–5.000*	0.710	0.001	–7.180	–2.820
	Post-30-min	90.333*	2.065	0.001	83.997	96.670
	Post-60-min	108.067*	1.225	0.001	104.309	111.825
Post-30-min	Pre-test	–95.333*	1.982	0.001	–101.417	–89.250
	Post-test	–90.333*	2.065	0.001	–96.670	–83.997
	Post-60-min	17.733*	1.329	0.001	13.655	21.812
Post-60-min	Pre-test	–113.067*	1.378	0.001	–117.296	–108.837
	Post-test	–108.067*	1.225	0.001	–111.825	–104.309
	Post-30-min	–17.733*	1.329	0.001	–21.812	–13.655

Based on estimated marginal means.
* mean difference significant at $p < 0.05$, [a] adjustment for multiple comparisons: Bonferroni

Heart rate

Tables 5–7 show the average heart rate in the CWT and SJR groups. In both groups, average heart rate decreased from average heart rate in the total 3 series (HR-HIIT) to average heart rate post-60-min ($p = 0.0001$). There were no significant differences in the average heart rate of HR-HIIT, average heart rate post-test (in the 3rd minute after HIIT), and average heart rate post-30-min between the CWT and SJR groups ($p = 0.146$, $p = 0.153$, $p = 0.323$, respectively). Only in the average heart rate post-60-min, significant differences were observed between the CWT and SJR groups ($p = 0.038$).

Discussion

The aim of the study was to assess the effect of CWT in reducing lactate concentration after HIIT protocol in elite futsal players. With respect to our prior hypothesis, we stated that CWT, with periodic immersions in cold water (18°C) for 1 min and then with hot water (37°C) for 2 min, accumulating 15 min in the water, would produce a significant decrease of lactate concentration in elite futsal players. This represents an important fact because post-exercise recovery is crucial in open sports such as futsal [26].

In our study, we applied HIIT because it comes from a small period of rest, leading to increased fatigue and high lactate concentration [27]. This may be explained by raised lactate levels after simulated HIIT in the CWT and SJR groups. On the other hand, previous studies pointed at the fact that the benefit of HIIT can be a promising tool to improve cardiac autonomic control, recommended especially in athletes or healthy individuals with metabolic syndrome [28].

The presented findings show that CWT is more effective in decreasing lactate concentration than SJR in elite futsal players after HIIT. These results support 3 previous studies in which CWT was observed to enhance recovery of exercise performance [19, 21, 29, 30]. Versey et al. [19] used 3 CWT protocols (CWT for 6 min, 12 min, or 18 min which commenced in hot water of 38°C and alternated between hot and cold water of 14°C every minute), suggesting that CWT for up to 12 min assisted recovery of cycling performance. In addition, these results are in line with the present study finding that CWT with accumulating 12 to 15 min in the water aided recovery of athletes after HIIT.

Pournot et al. [21], employing CWT temperature of 10–42°C and passive recovery, found that CWI and CWT are more effective immersion modalities to promote a faster acute recovery of maximal anaerobic performance after an intermittent exhaustive exercise. A study conducted by Vaile et al. [29] suggested that the benefits of CWT might be greater when athletes had cumulative fatigue from a daily training session. Furthermore, these results explained that CWT appeared to improve recovery from high-intensity cycling when compared with HWI and passive recovery.

The rapid recovery of heart rate in the CWT group after 30 min and 60 min supports some previous research relating to a positive influence of CWT as a recovery strategy [30]. The finding of the current study is that the application of CWT after HIIT may have advantageous effects on heart rate.

The results obtained in the present study may be explained by the observations by Enwemeka et al. [31], who indicate that cryotherapy results in a lower skin, subcutaneous, and muscle temperature, leading to vasoconstriction and a decrease in swelling and inflammation through the slowing metabolism. Conversely, the application of HWI has been shown to increase tissue temperature, metabolite production, and muscle elasticity, to stimulate local blood flow, and to reduce muscle spasm [32]. Also, Zurawlew et al. [33] imply that HWI is commonly used to reduce pain or strain and promote healing in soft tissue injuries.

Furthermore, the findings of this study add to the scientific literature that supports the use of CWT to assist post-exercise recovery and suggests that CWT for up to 15 min can assist recovery after HIIT. Nevertheless, further studies are required to indicate the underlying mechanisms by which this recovery strategy is efficient.

Limitations

The research has some limitations. Firstly, the physical, role-related, and emotional functioning, as well as the patients' lifestyle differences could have an impact on the obtained results. Secondly, the time of alternating from cold (18°C) to hot water (37°C) was approximately 15 seconds, which could also influence the outcomes.

Conclusions

We demonstrated that CWT after HIIT, with periodic immersions in cold water (18°C) for 1 min and then in hot water (37°C) for 2 min (total time: 15 min), had an effect on the recovery of elite futsal players by decreasing the lactate concentration and causing a rapid recovery of heart rate. Thus, CWT should preferably be used by coaches and sports scientists to accelerate post-exercise recovery in athletes, especially in futsal players.

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Disclosure statement

No author has any financial interest or received any financial benefit from this research.

Conflict of interest

The authors state no conflict of interest.

References

1. Kenney WL, Wilmore JH, Costill DL. Physiology of sport and exercise. Champaign: Human Kinetics; 2012.
2. Ismail SI, Adnan R, Sulaiman N. Moderate effort instep kick in futsal. Procedia Eng. 2014;72:186–191; doi: 10.1016/j.proeng.2014.06.031.
3. Ayala F, Sainz de Baranda P, De Ste Croix M, Santonja F. Criterion-related validity of four clinical tests used to measure hamstring flexibility in professional futsal players. Phys Ther Sport. 2011;12(4):175–181; doi: 10.1016/j.ptsp.2011.02.005.
4. Cejudo A, Sainz de Baranda P, Ayala F, Santonja F. Test-retest reliability of seven common clinical tests for assessing lower extremity muscle flexibility in futsal and handball players. Phys Ther Sport. 2015;16(2):107–113; doi: 10.1016/j.ptsp.2014.05.004.
5. Farhani F, Rajabi H, Negaresh R, Ali A, Shalamzari S, Baker JS. Reliability and validity of a novel futsal special performance test designed to measure skills and anaerobic performance. Int J Sports Physiol Perform. 2019; 1–23; doi: 10.1123/ijspp.2018-0850.
6. Castagna C, Barbero Alvarez JC. Physiological demands of an intermittent futsal-oriented high-intensity test. J Strength Cond Res. 2010;24(9):2322–2329; doi: 10.1519/JSC.0b013e3181e347b9.
7. Barbieri R, Barbieri F, Milioni F, Dos-Santos J, Soares M, Zagatto A, et al. Reliability and validity of a new specific field test of aerobic capacity with the ball for futsal players. Int J Sports Med. 2017;38(3):233–240; doi: 10.1055/s-0042-12304.
8. Wilke CF, Fernandes FAP, Martins FVC, Lacerda AM, Nakamura FY, Wanner SP, et al. Faster and slower post-training recovery in futsal: multifactorial classification of recovery profiles. Int J Sports Physiol Perform. 2019;1–22; doi: 10.1123/ijspp.2018-0626.
9. D'Amico A, Paolone V. The effect of foam rolling on recovery between two eight hundred metre runs. J Hum Kinet. 2017;57:97–105; doi: 10.1515/hukin-2017-0051.
10. Ream E, Richardson A. Fatigue: a concept analysis. Int J Nurs Stud. 1996;33(5):519–529; doi: 10.1016/0020-7489(96)00004-1.
11. Thorpe RT, Atkinson G, Drust B, Gregson W. Monitoring fatigue status in elite team-sport athletes: implications for practice. Int J Sports Physiol Perform. 2017;12(Suppl 2):S227–S234; doi: 10.1123/ijspp.2016-0434.
12. Sousa M, Fernandes MJ, Carvalho P, Soares J, Moreira P, Teixeira VH. Nutritional supplements use in high-performance athletes is related with lower nutritional inadequacy from food. J Sport Health Sci. 2016;5(3):368–374; doi: 10.1016/j.jshs.2015.01.006.
13. Versey NG, Halson SL, Dawson BT. Water immersion recovery for athletes: effect on exercise performance and practical recommendations. Sports Med. 2013;43(11): 1101–1130; doi: 10.1007/s40279-013-0063-8.
14. Vaile J. Recovery: research and practice. Mod Ath Coach. 2007;45(3):37–42.
15. Vaile J, Halson S. Recovery review: science vs. practice. Helensvale: Australian Strength and Conditioning Association; 2010.
16. Craig AB Jr, Dvorak M. Thermal regulation during water immersion. J Appl Physiol. 1966;21(5):1577–1585; doi: 10.1152/jappl.1966.21.5.1577.
17. Hing WA, White SG, Bouaaphone A, Lee P. Contrast therapy – a systematic review. Phys Ther Sport. 2008; 9(3):148–161; doi: 10.1016/j.ptsp.2008.06.001.
18. Ingram J, Dawson B, Goodman C, Wallman K, Beilby J. Effect of water immersion methods on post-exercise recovery from simulated team sport exercise. J Sci Med Sport. 2009;12(3):417–421; doi: 10.1016/j.jsams.2007.12.011.
19. Versey N, Halson S, Dawson B. Effect of contrast water therapy duration on recovery of cycling performance: a dose-response study. Eur J Appl Physiol. 2011;111(1): 37–46; doi: 10.1007/s00421-010-1614-4.
20. Higgins TR, Heazlewood IT, Climstein M. A random control trial of contrast baths and ice baths for recovery during competition in U/20 rugby union. J Strength Cond Res. 2011;25(4):1046–1051; doi: 10.1519/JSC.0b013e3181cc269f.
21. Pournot H, Bieuzen F, Duffield R, Lepretre PM, Cozzolino C, Hausswirth C. Short term effects of various water immersions on recovery from exhaustive intermittent exercise. Eur J Appl Physiol. 2011;111(7):1287–1295; doi: 10.1007/s00421-010-1754-6.
22. Argus CK, Broatch JR, Petersen AC, Polman R, Bishop DJ, Halson S. Cold-water immersion and contrast water therapy: no improvement of short-term recovery after resistance training. Int J Sports Physiol Perform. 2017;12(7):886–892; doi: 10.1123/ijspp.2016-0127.
23. Bangsbo J, Iaia FM, Krustrup P. The Yo-Yo intermittent recovery test: a useful tool for evaluation of physical performance in intermittent sports. Sports Med. 2008;38(1): 37–51; doi: 10.2165/00007256-200838010-00004.
24. Bangsbo J, Nørregaard L, Thorsø F. Activity profile of competition football. Can J Sport Sci. 1991;16(2):110–116.
25. Clemente FM, Nikolaidis PT, Linden CMI, Silva B. Effects of small-sided soccer games on internal and external load and lower limb power: a pilot study in collegiate players. Hum Mov. 2017;18(1):50–57; doi: 10.1515/humo-2017-0007.

26. Nakamura FY, Antunes P, Nunes C, Costa JA, Esco MR, Travassos B. Heart rate variability changes from traditional vs. ultra-short-term recordings in relation to preseason training load and performance in futsal players. J Strength Cond Res. 2018; doi: 10.1519/JSC.000000 0000002910.
27. Suárez Rodríguez D, del Valle Soto M. A study of intensity, fatigue and precision in two specific interval trainings in young tennis players: high-intensity interval training versus intermittent interval training. BMJ Open Sport Exerc Med. 2017;3(1):e000250; doi: 10.1136/bmjsem-2017-000250.
28. Conconi F, Ferrari M, Ziglio PG, Droghetti P, Codeca L. Determination of the anaerobic threshold by a noninvasive field test in runners. J Appl Physiol Respir Environ Exerc Physiol. 1982;52(4):869–873; doi: 10.1152/jappl.1982.52.4.869.
29. Vaile J, Halson S, Gill N, Dawson B. Effect of hydrotherapy on recovery from fatigue. Int J Sports Med. 2008; 29(7):539–544; doi: 10.1055/s-2007-989267.
30. Hamlin MJ. The effect of contrast temperature water therapy on repeated sprint performance. J Sci Med Sport. 2007;10(6):398–402;doi:10.1016/j.jsams.2007.01.002.
31. Enwemeka CS, Allen C, Avila P, Bina J, Konrade J, Munns S. Soft tissue thermodynamics before, during and after cold pack therapy. Med Sci Sports Exerc. 2002; 34(1):45–50; doi: 10.1097/00005768-200201000-00008.
32. Cochrane DJ. Alternating hot and cold water immersion for athlete recovery: a review. Phys Ther Sport. 2004; 5(1):26–32; doi: 10.1016/j.ptsp.2003.10.002.
33. Zurawlew MJ, Mee JA, Walsh NP. Post-exercise hot water immersion elicits heat acclimation adaptations in endurance trained and recreationally active individuals. Front Physiol. 2018;9:1824; doi: 10.3389/fphys.2018. 01824.