**Effect of Cold-Water Immersion, Foam Rolling, and Slow Jogging Recovery to Aid Futsal Athlete’s Recovery after One-Off Futsal Match**

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**Abstract**—This study is the examination of the effects of cold-water immersion group (CWI), foam rolling group (FR), and a slow jogging group (SJR) on creatine kinase activity (CK), blood lactate concentration, perceptual measures (PM) and anaerobic performance after exhibition game in futsal players. Twenty-four male futsal athletes were recruited into the study; eight participants were assigned to the CWI group were given cold-water recovery, eight to the FR group were given roller exercises, and another 8 to the SJR group were given slow jogging recovery. <…> The total quality recovery (TQR), and visual analog-scale (VAS) was evaluated in pre- and post-recovery interventions. The CWI group showed significant reduction of the blood lactate concentration compared with the SJR group in immediate post-recovery (3.13 ± 0.46 vs. 3.76 ± 0.26, *p* = 0.026), and 15-min post-recovery interventions (1.91 ± 0.37 vs. 2.36 ± 0.29, *p* = 0.007). No prominent differences were detected in the three groups in reducing the CK activity 24-h post-recovery interventions. Post-hoc comparisons showed that TQR values in 24-h post-recovery interventions of the CWI group were significantly higher compared with RF and SJR groups (all *p* < 0.001). The VAS values were significantly lower in the CWI group than in RF (*p* = 0.002), and SJR (*p* < 0.001) groups in 24-h post-recovery interventions. The CWI group was more efficient in reducing blood lactate concentration compared with the SJR group at immediate post-recovery, and 15-min post-recovery interventions.

**Keywords:** inﬂammation, muscle damage, performance, self-myofascial release, soccer, vasoconstriction

INTRODUCTION

Futsal is a strenuous contact team sport that is characterized by intermittent high intensity exercise activities [1]. Fast movements with integrated tactical, technical, and physical skills are some of the characteristics observed in futsal [2]. Previous literature has observed that during a futsal match, the ratio of activity to rest in futsal is about 1 : 1 with anaerobic processes playing the biggest role in supplying energy during match play. Specifically, the study revealed that futsal is an anaerobic multiple-sprint sport in which high-intensity exercise, this can be seemed from the efforts high-intensity effort (13.7% for a speed of 15 km/h) and medium-intensity effort (8.9% for a speed of 25 km h–1) that shown by the players during match play [3].

Because of futsal characteristics, it is not surprising if some players had an injury caused by the stress body’s physiological systems during the match or a heavy training system designed by a coach [4]. Muscle damage that is caused by strenuous physical exercise [5] and muscle fatigue that’s caused by the accumulation of lactic acid in muscle fibers [6] are harmful factors that can increase the risk of injury [7, 8]. Therefore, coaches, medical staff, and sport researchers used a variety of different post-exercise strategies [9–11], because they believed that post-exercise strategies will accelerate the recovery process by reducing muscle damage or blood lactate and thus improving the athlete’s performance [12].

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Meanwhile, FR is a recovery method that utilizes pressure exerted by body mass on a foam roller, so it can mimic therapeutic massage on the soft tissue [22]. In other words, FR is a recovery method known based on self-myofascial release [23]. Specifically, previous literature suggested that use of FR may assist in recovery from fatigue, enhanced blood lactate removal, improving vascular endothelial function, and enhancing muscular blood ﬂow that can decrease inflammation [24]. Currently, there are only a few studies that have analyzed the benefit effects of FR on recovery [25, 26], and the others reported FR to have no benefit [27]. Because some previous studies show equivocal findings, the mechanisms of FR to assist in recovery from muscle damage and fatigue remain widely debated.

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Therefore, the aim of this study was to assess and compare physiological effects among CWI, FR, and slow jogging recovery (SJR) on creatine kinase activity (CK), blood lactate concentration, perceptual measures (PM) and anaerobic performance after exhibition game in futsal players. We hypothesized that CWI would promote greater recovery-related effects compared to FR or the SJR. Furthermore, this study is expected to add to the scientific literature that suggests the use of recovery modalities that are effective for futsal athletes.

METHODS

**Subjects.** In this study, participants recruited using an advertisement published in social media. After advertisement period was carried out, a total 24 male futsal athletes (aged 18–21 years), were recruited into the study with the following criteria: all participants were futsal athletes from whole University in Bandung city, training history of at least 15 h per week, participants had no previous experience of FR and CWI recovery, participants had previous experience of YYlrT-L1, and had of VO2max results were range 38–40 mL kg–1 min–1. Participants were not including the criteria for this study if they were smokers, had concomitant diseases, a history of any cardiovascular or respiratory disease, had an allergy to cold, used of any anti-inflammatory or antioxidant drugs within 2 months prior to the initial testing or during the experimental period, and had a history of musculoskeletal injury 3 months prior to the study began. Specifically, we recruited players with position fixed defender (*n* = 6), left winger (*n* = 6), right winger (*n* = 6), and pivot (*n* = 6) that were considered for analysis. Moreover, this study also recruited goalkeepers (*n* = 6), but not considered for analysis.

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**Procedure*.***In this study, a week prior to the experiments, all participants were performed anthropometric and cardiorespiratory tests. The anthropometric and cardiorespiratory test were carried out at the in laboratory and outside the laboratory building, respectively. Testing began with anthropometry measurement (Monday morning at 07:00 a.m.). We used Omron Digital Weight Scale HN 289 to measure body weight, with the provisions of the measurement process that is; all participants wore minimal clothes and were barefoot. Seca 214 Portable Stadiometer, Cardinal Health, Ohio, USA was used to measure body height of all participants. Body height measurement procedures were carried out in accordance with established procedures. The body mass index (BMI) was taken from the ratio of the body mass (kilograms) formula divided by body height (meters) squared. After anthropometric measurements, all participants were required to begin a cardiorespiratory test. The Yo-Yo intermittent recovery test, level 1 (YYirT-L1) was used to measure VO2max of each participant. The protocol and formula of the YYirT-L1 were based on previous test protocols [28]. Polar RS400 sports watch (Finland) was used to monitor heart rate (HR) during cardiorespiratory test.

A week after the last day of anthropometric and cardiorespiratory tests, experimental sessions was carried out in Saraga Athletic Stadium. TQR and VAS were administered prior to the sprint test, to ensure all participants were avoided excessive fatigue. After that, 5-mL samples of venous blood were collected from the forearm vein, and a 100-μL sample of fingertip capillary blood was obtained to measure blood lactate concentration of each participant. Participants required completed a 6-min warm-up (static and dynamic movement), followed by 6-min jog at 6.8 km/h. The sprint test began at 07:30 a.m. All participants were instructed to run as fast as possible. After the end of the last sprint test, 5-min rest was given for all participants prior to beginning futsal matches.

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**Physiological analyses (PA).** A 100-μl sample of fingertip capillary blood was obtained to measure lactate pre-sprint test, post-matches, immediate post-recovery, and 15-min after recovery. The blood samples were analyzed with a Lactate Pro analyzer (Arkray, Shiga, Japan). Furthermore, blood samples for CK activity were collected from the medial cubital vein (5 mL). This study used CK-MM as an isoform CK method, which can be useful for determining whether the muscle damage before and 24-h post-recovery interventions. The blood samples were centrifuged at 1700 g for 10 min at 4ºC. Serum plasma was analyzed using Chemistry Auto Analyzer, Cobas Mira S, USA with Kinetic method in accordance with Clinical Chemistry Association I.F.C.C and D.G.K.C for the determination of CK activity. For analyses, we mixed reagent (A) CK liquid consisted of Good’s Buffer (125 mmol/L, Magnesium Acetate 12 mmol/L, EDTA 2 mmol/L, D-glucose 25 mmol/L, *N*-acetyl-L-cysteine 25 mmol/L, NADP 2.5 mmol/L, and HK-hexokinase ≥6500 u/L with a reagent (B) CK liquid, vol=10/20mL (consisted of ADP 15 mmol/L, AMP 25 mmol/L, Di-adenosine 5-phospate 103 mmol/L, G-6-PDH ≥8800 U/L, and Creatine Phosphate 250 mmol/L) with λ = 340 nm and temperature 37ºC.

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**Recovery Interventions**(CWI, FR, and SJR). The CWI group was submerged in a plastic swimming pool (diameter, 300 cm; height, 76 cm), with a water level of approximately 45 cm. The temperature and protocol of CWI recovery were based on literature [31]. All participants were required periodic immersions in cold water (15°C and water was maintained at the mean temperature by the addition of crushed ice). During the time of CWI, participants in the CWI group remained seated while immersing their lower limbs in a water bath at a mean temperature (water temperatures were measured with a Testo AG T 106 thermometer). All participants were in cold water for 15 minutes. The subjects were passive while being in water (this procedure according to previous study literature) [13]. Additionally, during CWI interventions, Additionally, during CWI interventions, all participants were required to wear minimal clothes.

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RESULTS

The anthropometric and cardiorespiratory characteristics of futsal players from all of the groups are shown in Table 1. No signiﬁcant differences was found among three groups regarding anthropometric and cardiorespiratory variables. Furthermore, the examination of the intensity of effort during futsal matches was estimated from the average HR assessments obtained during the whole time that the futsal players played on court, also including breaks at half times (Fig. 3).

**Creatine kinase activity.**As shown in Fig. 4,ANOVA showed significant time effect (F4.04 = 577.096, *p* < 0.001, $η\_{partial}^{2}$ = 0.932), indicating CK activity still an increase in 24-h post-recovery interventions. However, ANOVA revealed no significant for group (F3.19 = 0.091, *p* = 0.913, $η\_{partial}^{2}$ = 0.004), and group × time effect (F3.19 = 0.146, *p* = 0.865, $η\_{partial}^{2}$ = 0.007). No prominent differences were detected in all three groups to reducing CK activity in 24-h post-recovery interventions.

**20-m sprint.**Regarding 20-m sprint test, there was no performance enhancement in all three groups after 24-h recovery interventions (Fig. 4). No significant for group (F3.19 = 0.043, *p* = 0.958, $η\_{partial}^{2}$ = 0.002), time effect (F4.04 = 1.679, *p* =0.202, $η\_{partial}^{2}$ = 0.038), and group × time effect (F3.19 = 0.075, *p* = 0.928, $η\_{partial}^{2}$ = 0.004) was evident.

**Blood lactate concentration.**No significant for group (F3.09 = 3.401, *p* = 0.038, $η\_{partial}^{2}$ = 0.075), and time effect (F2.70 = 1693.776, *p* =0.001, $η\_{partial}^{2}$ = 0.984). However, a significant group × time effect was observed for blood lactate concentration measurements (F2.19 = 0.491, *p* = 0.813, $η\_{partial}^{2}$ = 0.034). Specifically, LSD post-hoc analyses revealed that CWI group significantly reduced the blood lactate concentration compared with SJR group in immediate post-recovery (3.13 ± 0.46 vs. 3.76 ± 0.26, *p* = 0.026) and 15-min post-recovery interventions (1.91 ± 0.37 vs. 2.36 ± 0.29, *p* = 0.007). No significant differences among CWI and FR groups were observed for all lactate measurements. Different results of blood lactate concentration in each group shown in Table 2.

**TQR and VAS.**For TQR (Fig. 4), no significant time effect (F4.04 = 1.241, *p* = 0.272, $η\_{partial}^{2}$ = 0.029) was observed. However, there was significant group (F3.19 = 18.468, *p* < 0.001, $η\_{partial}^{2}$ = 0.468), and group × time effect (F3.19 = 8.539, *p* < 0.001, $η\_{partial}^{2}$ = 0.289). Furthermore, post-hoc comparisons showed that TQR values in 24-h post-recovery interventions of the CWI group were significantly higher compared with RF and SJR groups (all *p* < 0.001). On the other hand, ANOVAs revealed significant group × time effect (F2.19 = 2.557, *p* =0.025, $η\_{partial}^{2}$ = 0.154), group (F3.09 = 5.238, *p* = 0.007, $η\_{partial}^{2}$ = 0.111), and time effect (F2.70 = 172.965, *p* < 0.001, $η\_{partial}^{2}$ = 0.861) were observed for VAS (Table 3). The VAS values decreased between immediate post recovery to 15-min post-recovery interventions in all three groups. However, VAS values were significantly lower in the CWI group than RF (*p* = 0.002), and SJR (*p* < 0.001) groups in 24-h post-recovery interventions.

DISCUSSION

The purpose of the study was to assess and compare physiological effects among CWI, FR and SJR on CK activity, blood lactate concentration, and anaerobic performance after exhibition games in futsal players. The main findings of this study are: (1) There were no prominent differences were detected in all three groups to reducing CK activity in 24-h post-recovery interventions; (2) compared to SJR, CWI significantly decreased lactate concentration in immediate post-recovery, and 15-min post-recovery interventions; (3) the results of perceptual measures (TQR and VAS) of CWI are generally better than FR and SJR groups; (4) CWI, FR, and SJR recovery did not enhance 20-m sprint performance. Generally, these data are in line and contrast with those of previous studies in which CWI and FR were used as a recovery tool after exercise.

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We realize that there are still some limitations in this study. Firstly, we did not pay attention to the body fat and muscle mass of the participants, which may have been the factors that could differentiate the results. Secondly, the lack of several physiological measurement parameters, such as c-reactive protein (CRP), lactate dehydrogenase (LDH), muscle temperature, skin temperature, and core temperature. These physiological parameters are needed to explain the unanswered phenomena in this study. Thirdly, we are encouraged by future studies to be concerned with several factors such as, circadian rhythm, emotional functioning, and other psychological aspects that are likely to be influential in the results of this study.

CONCLUSIONS

To our knowledge this study is the first to directly compare CWI, FR, and SJR on performance, perceptual and physiological variables after a one-off futsal match. We demonstrated that CWI group is more efficient in reducing blood lactate concentration compared with SJR group at immediate post-recovery, and 15-min post-recovery interventions. There were no prominent differences detected in all three groups to reduce CK activity in 24-h post-recovery interventions. Furthermore, CWI, FR, and SJR recovery after one-off futsal matches did not have an enhanced 20-m sprint performance.

COMPLIANCE WITH ETHICAL STANDARDS

Before the initiation of the study, all participants received an explanation of the procedure and the risks that would later be faced in their participation, and they provided informed consent to participate in this study. The study was approved by the ethics committee of the POLTEKKES Bandung, and all procedures were in accordance with the Declaration of Helsinki.

CONFLICT OF INTEREST

The authors state no conflict of interest with respect to the research, authorship, and/or publication of this article.

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AUTHOR CONTRIBUTIONS

C­­onceptualization: Kuswahyudi; Methodology: Agung Dwi Juniarsyah; Formal analysis and investigation: Junaidi; Writing: original draft preparation: Bagus Winata; Writing: review and editing: Bagus Winata; Funding acquisition: Junaidi; Resources: Sri Indah Ihsani Supervision: Kuswahyudi.

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TABLES

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**Table 2.** Effects of CWI, FR, and SJR recovery interventions on blood lactate concentration in the three groups

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| --- | --- | --- |
| Measurement time | Lactate concentration (mmol/L) | *p*-value\* |
| CWI group$$\overbar{X}(SD)$$ | FR group$$\overbar{X}(SD)$$ | SJR group$$\overbar{X}(SD)$$ |
| Pre-sprint test | 1.18 (± 0.41) | 1.20 (± 0.33) | 1.16 (± 0.33) | 0.978 |
| Post-matches | 11.23 (± 1.02) | 11.40 (± 0.86) | 11.60 (± 0.63) | 0.685 |
| Immediately after recovery | 3.13 (± 0.46) | 3.40 (± 0.76) | 3.76 (± 0.26) | 0.079 |
| 15 min after recovery | 1.91 (± 0.37) | 2.13 (± 0.24) | 2.36 (± 0.29) | 0.025\*\* |

*SD* is the standard deviation. \*One-way ANOVA. \*\*Statistically significant differences between CWI, FR and SJR (*p* < 0.05).

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FIGURE CAPTIONS

**Fig. 1.** Schematic of the test protocol. A&C test is the anthropometry and cardiorespiratory tests, PM1 is the TQR and VAS measurements in pre-sprint test, PA1 is the CK activity and blood lactate measurements in pre-sprint test, S1 is the sprint test before match, M is the futsal matches, PA2 is the blood lactate measurements in immediately after match, R randomly recovery interventions, PA3 is the blood lactate measurements in immediate post-recovery interventions, and 15-min post-recovery interventions, PM2 is the VAS measurements in immediate post-recovery interventions, and 15-min post-recovery interventions, PM3 is the TQR and VAS in 24-h post-recovery interventions, PA4 is the CK activity measurement in 24 h post-recovery interventions, S2 = sprint test in 24 h post-recovery interventions.

**Fig. 2.** Schematic of matches design based on recovery interventions. All participants were assigned randomly to three groups recovery interventions that divided 2 team in each group. Players with position: fixed defender, left winger, right winger, and pivot were considered for analysis and only goalkeepers were excluded.

**Fig. 3.** Average HR during matches. Min-0 (1) = average HR in minute-0 before matches, Min-5 (1) = average HR in minute-5 (first half), Min-10 (1) = average HR in minute-10 (first half), Min-15 (1) = average HR in minute-15 (first half), Min-20 (1) = average HR in minute-20 (first half), Rest-5 = average HR in rest minute-5, Rest-10 = average HR in rest minute-10, Min-5 (2) = average HR in minute-5 (second half), Min-10 (2) = average HR in minute-10 (second half), Min-15 (2) = average HR in minute-15 (second half), Min-20 (2) = average HR in minute-20 (second half).

**Fig. 4.** Effects of CWI, FR, and SJR recovery interventions on creatine kinase, 20-m sprint, and TQR.

FIGURES

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Fig. 3.