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Effect of Cold Water and Contrast Immersion on Physiological and Psychological Responses of Elite Athletes after High-Intensity Exercises

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Abstract

Background. Circuit training (CT) increases the interrelation of bio-motor components but neuromuscular performance contrarily produces a high concentration of lactate, cortisol, muscle inflammation, which disrupts metabolism, thus reducing performance and generating psychological stress. While Contrast Water Therapy (CWT) increases nerve sensitivity and reduces the risk of metabolic disorders, Cold Water Immersion (CWI) reduces local tissue temperature, muscle pain and avoids musculoskeletal injuries. **The purpose of the research** is to examine the effect of Contrast Water Therapy and Cold-Water Immersion on lactate, cortisol, flexibility, muscle pain, depression, anxiety, and stress levels post sub-maximal intensity of circuit training. **Material and methods.** Thirty elite athletes were engaged in a cross-sectional study with pre-and post-test after a 3 series x 3 sets x12 repetitions in a workout session of 85%-90%RM. The prerequisite test employed Shapiro-Wilk, while Bivariate analysis utilized Independent Sample T-test and Paired Sample T-test. **Results.** CWT maintained body temperature significantly ($t=36\pm0.27$, $p=0.019$). CWI reduced lactate levels ($t=2.32\pm0.27$, $p=0.001$), cortisol ($t=12.72\pm2.27$, $p=0.001$), muscle pain ($t=5.32\pm1.07$, $p=0.003$), depression ($t=8.16\pm1.63$, $p=0.012$), anxiety ($t=6.56\pm1.34$, $p=0.002$), and stress ($t=13.02\pm1.27$, $p=0.001$). Meanwhile, SS increased flexibility ($t=17.98\pm2.76$, $p=0.001$). There was no significant difference in the regeneration process at 1st, 5th, 10th, and 15th minutes post-manipulation of all three methods. **Conclusion**. CWI 5°C for 15 minutes accelerates the lactate and cortisol regeneration as well as reducing muscle inflammation, depression, anxiety, and stress, while CWT raises the body's temperature and SS increases flexibility.

Keywords: Cold Water Immersion, Lactate, Cortisol, Soreness, Anxiety, Depression

Introduction

The interrelation coupling of strength, speed, power, coordination, and flexibility are known as crucial bio motor components (Bompa & Haff, 2019) to reduce the prevalence of musculoskeletal injuries as well as stimulating neuromuscular system by involving joints, ligaments, and tendons to cope the internal and external load and enhance performance. Circuit training (CT) focuses on improving the performance of intermuscular coordination that works on the fast-twitch muscle group through stimulating the load received by the neuromuscular system in order to increase the speed of muscle contraction, the number of muscle fibers working when contracting, and muscle strength when contracting (Haff & Nimphius, 2012). Determining type of intensity, volume, and time of rest is crucial to achieve the optimum speed strength of muscle contraction; therefore, the intensity must be done in a submaximal level with a small amount of volume and sufficient time to rest (Kusuma;, 2021). In contrast, weight training focuses on the slow-twitch muscle group, increasing the sub-maximal muscle size and mass through muscle hypertrophy (Listiandi et al., 2019). The muscle hypertrophy begins with damage of actin and myosin filaments in the myofibril tissue, causes an increased H+ concentration and high lactate production and at the same time decreases pH levels; as a result, the enzyme glycolysis process is slowed down, ATP supply is reduced, and acute musculoskeletal fatigue occurs (Kusuma; et al., 2019). Consequently, micro-damage conditions in myosin actin filaments cause muscle abnormalities and disorders, reduce muscle contraction function and ability, and reduce glycogen reserves, resulting in lactate buildup which leads to Delayed Turnover Muscle Soreness (DOMS), and risk of musculoskeletal injury (Schoenfeld, 2010).

Circuit training known as multifunctional physical training (Kusuma et al., 2021) involves strength, speed, endurance, and intra- and inter muscle coordination in a rapid and repetitive manner to activate the eccentric-concentric contractions through stretch-shortening movements, such as lifting, jumping, throwing, hitting, or kicking (Bettcher et al., 2013). Accordingly, CT produces a high level of lactic acid along with the inability of the heart and lungs to supply oxygen through the process of breathing during activity (Martínez-Lagunas et al., 2014) and reduces endurance and performance (Kusuma; et al., 2018). The increasing lactate in muscles and blood creates an acidic pH environment and inhibits the formation of creatine-phosphate and enzyme action, which results in increased urea levels, decelerated fat oxidation, interfered performance of several enzymes that work on neutral pH, and less favorable impact on cell activity in producing energy to support body activity thus reduces the ability to coordinate movements and become physiological stressor that causes muscle inflammation and excessive physical fatigue (Bogdanis, 2012). Although homeostatic will maintain the enzyme performance to normal state by degrading and neutralizing lactic, excessive physiological stressor leads to inability to degrade lactate and triggers acute symptoms, such muscle disorders, decreased function of muscle contraction, muscle discomfort, soreness, stiffness, and potential musculoskeletal injuries (Widanita et al., 2019)

The accumulation of physical symptoms, accompanied by repetitive improper recovery, leads to metabolic disorders, decreased muscle function and life quality, and impaired performance quality, as well as inducing psychosomatic problems, anxiety, depression, stress, loss of appetite, difficulty sleeping, and trauma (Davis IV et al., 2007). For elite athletes, an immense imbalance between physical and psychological stressors may result in state anxiety, such a fear of unsuccessful training, losing a match, feeling unconfident, personal emotion (Ivarson et al, 2021). Further, these stressful conditions can gradually produce trait anxiety connected with persistent emotions and spread to various aspects of the athletes' life, such as feeling confine and fear for their post-athletic future due to the effects of excessive exercise, which ultimately leads to depression and psychosomatic disorder (Kandola & Stubbs, 2020) as the real consequences of ongoing disruption of physical condition, mental health, and life quality (Komarudin & Ani Hastuti, 2021). Moreover, psychosomatic disorders also respond to the production of depressant hormones of cortisol and epinephrine that functions to withstand the pressure by increasing blood sugar and preventing insulin from being converted into glycogen (Rumbold et al., 2012). It results in increased heart rate and blood pressure, decreased immune system, impaired organ function, increased muscle tension, and the risk of developing degenerative diseases (Parwata, 2015). To reverse this condition, it takes a regeneration process accompanied by proper nutrition stimulate growth hormone, IGF-1, myofibril protein synthesis, and actin mRNA protein synthesis, which help increase the number of new myosin actin filaments in myofibril tissue, and increase mitochondrial enzymes, phosphagen metabolism, glycogen, and triglyceride reserves so the number of muscle fibers, mass, and the ability to contract muscles will increase after adapting to physical training (Fink et al., 2018).

Cold-Water Immersion (CWI) replaces the role of nitrogen which is commonly used as anesthetic and analgesic to treat pain and reduce symptoms of inflamed muscles (Peake et al., 2017) and has physiological effects, including vasoconstriction of arterioles and decreased metabolic rate of cells which result in decreased demand for cell oxygen, reduced swelling, reduced pain, reduced muscle spasm, and the risk of cell death (Leeder et al., 2012). The stimulation of cold water helps the capillary permeability function to decrease and improve cognitive function, produce a lower prefrontal temperature of the cortex in the brain, decreases the tension on the nerves of the brain, decreases the physiological responses, thus stimulate the body to relax (Kellmann et al., 2018). Studies suggest that conducting cold therapy with temperatures of 10°C for 10 minutes will reduce lactate, muscle spasms and soreness as well as improve regeneration cycle, muscle contractions, and stress (Tipton et al., 2017). Similarly, 15 minutes of Contrast Water (CW) is reported to benefit body temperature, flexibility, and relaxation (Ascensão et al., 2011). However, improper manipulation of CWI and CW has been reported to cause skin irritation, hypothermia, decreased muscle flexibility, disrupts body metabolism, and causes damage to skin tissue due to exposure to cold temperatures (frostbite) (Tipton et al., 2017). This study has conducted CWI-5°C and CW manipulations for 15 minutes after sub-maximal circuit training to measure its impact on the profile of lactate, cortisol, soreness, flexibility, and psychosomatic profile (Elias et al., 2012).

Material and Method

Participants

This experimental study used a cross-sectional approach with a pre-test and post-test control group design, involving 30 male athletes (aged 18.23±1.17, BMI 21.12±1.56, RHR 63.4±8.2bpm, Lactate 2.62±0.41Mmol/L) who were prepared for national competition as a part of monitoring for training progression and selected through inclusion and exclusion criteria. Before enrolling in the experiments and received approvals, the samples were assessed by a medical doctor and physical trainer to observe their anthropometrical, health and physiological status, including an absence of cardiovascular risks, then signed a written informed consent compliant with Indonesian law and the university policies. The study design was approved by the Institutional Review Board of Human Ethics Committee of Gadjah Mada University, while the clinical data were assembled in a secured institutional database according to GDPR (General Data Protection Regulation)

Materials

The initial phase began with providing the participants with informed consent, International Physical Activity Questionnaire (IPAQ), and the profile of nutritional intake to measure 48-hours food recall at Indoor Sports Hall, followed by taking their anthropometrical measurements, such as age, height, weight, and body mass index (BMI) using a digital microtome stature with an accuracy of 0.1 mm. The basal levels of lactate were tested in the earlobe by Lactate Scout+ h/p cosmos, resting pulse rate was taken under the palpation method in a sitting position by the Polar-H10 Chest Heart Rate Monitor, body temperature was measured with Omron MC-246 digital thermometer, and salivary cortisol test was undertaken by "passive drooling" on 8-9 AM. The index of muscle pain perception was measured using electro-goniometer and Rating of Perceived Exertion (RPE), the flexibility of lower back muscle and hamstrings were measured using sit and reach. Meanwhile, stress, anxiety, and depression levels were measured using the Depression Anxiety and Stress Scales Questionnaire (DASS-42).

Methods

Samples were categorized into experimental CWI, CW, and control groups using ordinal pairing techniques based on the T-score of the lactate, cortisol, perceptions of muscle pain, flexibility, and psychosomatic disorders profile at the pre-test. Subsequently, all groups performed 3set x 6reps x 85% -95%RM followed with 3-minutes for rest periods between series and 8-minutes for rest sets against 12-stations of circuit training such as *squats, push-ups, sit-ups, power cleans, lunges, triceps dips, back-ups, overhead ball throws, high knees, planks, back-ups, and jumping jacks* repetitively. Upon completing the circuit training, all groups were given recovery methods following the implementation protocol. CWI group in cold temperatures (5°C) for 15 minutes started by immersing their lower body from the *Spina Iliaca Anterior Superior* (SIAS) to the soles of the feet. CWT group was manipulated using contrast water temperatures (cold 15°C, warm 38°C) for 15 minutes, whereas the control group was manipulated with conventional cooling down method, i.e., 15-minute static stretching. The immersion was carried out in a water drum of 1.4 m diameter filled with water and ice cubes periodically until it reached a temperature of 5°C. Initially, the sample put down his legs to adapt to the cold temperature, then slowly put his body inside the 5°C-water-filled drum and took a sitting, stretched-legged position, and the immersion time begins (Cochrane, 2004). At the final stage, the samples left the water drum and cleaned their body with a towel, then followed a set of procedure to evaluate their flexibility, perceptions of muscle soreness, and psychosomatic profile, which took a full 25 minutes altogether to complete. Simultaneously, their body lactate and recovery pulse rate were retested every 5 minutes.

Analysis

The data description employed the Statistical Product and Service Solution (SPSS) program for Windows, while the prerequisite test was performed using the Shapiro Wilk method for homogeneity of variances. A paired t-test (t-test) and an independent sample T-test were used to determine different influence between groups in pre- and post-treatment. Duncan post hoc ANOVA was applied to identify which variable has the greatest impact on the treatment groups. The data were delivered as mean ± of standard deviation (SD), with 95% confidence interval and statistical significance was accepted as $p < .05$.

Results

The profile of anthropometrical, health, nutritional, physiological as well as psychological of respondents are presented as follows.

Table 1. Characteristics of Age, BMI, Nutritional, Pulse, and Lactate

Variable	n	Experiment	Control
		Mean±SD	Mean±SD
Age (years)	30	18.23±1.17	18.31±1.02

BMI (kg/m2)	30	21.12±1.56	21.78±1.25
Carbohydrates (gr/day)	30	282.18±6.43	317.23±6.84
Protein (gr/day)	30	63.37±6.32	69.23±6.84
Fat (gr/day)	30	22.72±4.59	23.97±4.84
Resting Heart Rate (pulse/minute)	30	63.4±8.2	68.1±6.4
Lactate (mmol/l)	30	2.62±0.41	2.75±0.37
Cortisol	30	7.21±0.31	8.63±1.56

The participants were in a healthy and fit state as productive age group (18.27±1.09 yr.) with a normal level of BMI (21.45±1.13kg/m2), not in fatigue (lactate 2.68±0.37mmol/l, pulse 65.75±7.35bpm) and had a balance nutritional intake profile in the last 48-hours as reported in the normal values for carbohydrates (299.7±6.6g/day), protein (66.3±5.5g/day), fat (23.34±4.7g/day). The simultaneous qualitative measurement to obtain characteristics of muscle soreness, flexibility, and psychosomatic profile which included depression, anxiety, and stress levels potentially experienced by the participants during the exercises (Table 2).

Table 2. Characteristics of Soreness, Flexibility, Stress, Depression, and Anxiety

Variable (n=30)	n	%	Mean±SD
High pain (score >05)	18	60	
Low pain (score ≤05)	12	40	6.12±2.27
High flexibility (score >13)	16	53.4	
Low flexibility (score ≤13)	14	46.6	16.47±5.14
High depression (score >17)	22	66.7	
Low depression (score ≤17)	08	33.3	18.45±1.19
High anxiety (score >12)	24	66.7	
Low anxiety (score ≤12)	06	33.3	13.12±1.48
High stress (score >22)	20	66.9	
Low stress (score ≤22)	10	33.1	24.54±3.21

Table 2 shows that before the treatment, an accumulated exercise has made more than half (60%) of the participants in a painful state, 16 (53.46%) participants in a high level of flexibility, 22 (66%) in psychosomatic/depression state (18.45±1.19), 24 (67%) showed anxiousness (13.12±1.48), and 20 (66%) in stressful state (24.54±3.21).

Statistical Analysis.

The Paired Sample T-test was conducted to identify the difference of variable's value before and after manipulation in the groups as well as examine the differences values between the two research groups (Table 3).

Table 3. Paired Sample T-test

Variable	Groups	Mean±SD	Signif.	Variable	Groups	Mean±SD	Signif.
	CWT (Pre)	3.07±0.11			CWT (Pre)	17.31±3.71	

Lactate	CWT (Post)	2.54±0.42	0.001	Flexibility	CWT Post)	15.31±3.32	0.029
	CWI (Pre)	2.77±0.23			CWI (Pre)	17.88±4.01	
	CWI (Post)	2.32±0.27	0.001		CWI (Post)	14.46±3.31	0.031
	SS (Pre)	2.93±0.10			SS (Pre)	17.27±2.23	
	SS (Post)	2.62±0.31	0.012		SS (Post)	17.98±2.76	0.027
Cortisol	CWT (Pre)	17.41±5.07		Depression	CWT (Pre)	10.23±1.07	
	CWT (Post)	16.63±4.68	0.001		CWT Post)	9.17±0.72	0.017
	CWI (Pre)	18.39±5.53			CWI (Pre)	10.96±1.63	
	CWI (Post)	15.31±4.32	0.001		CWI (Post)	8.37±0.23	0.009
	SS (Pre)	18.32±5.31			SS (Pre)	10.72±0.84	
	SS (Post)	17.44±4.57	0.015		SS (Post)	9.51±0.78	0.002
Body Temperature	CWT (Pre)	37.91±0.17		Anxiety	CWT (Pre)	9.15±1.27	
	CWT (Post)	37.13±0.32	0.001		CWT Post)	7.92±0.55	0.031
	CWI (Pre)	37.39±5.53			CWI (Pre)	9.31±1.05	
	CWI (Post)	34.51±4.32	0.001		CWI (Post)	7.17±0.23	0.019
	SS (Pre)	36.12±5.31			SS (Pre)	9.04±1.12	
	SS (Post)	37.83±4.57	0.005		SS (Post)	8.07±0.46	0.021
Soreness Status	CWT (Pre)	7.53±0.51		Stress	CWT (Pre)	15.18±1.37	
	CWT (Post)	6.33±1.25	0.001		CWT Post)	14.21±1.05	0.017
	CWI (Pre)	7.37±0.23			CWI (Pre)	15.68±1.14	
	CWI (Post)	5.32±1.07	0.001		CWI (Post)	13.02±1.27	0.001
	SS (Pre)	7.51±0.87			SS (Pre)	15.73±1.35	
	SS (Post)	7.26±0.33	0.002		SS (Post)	15.62±2.48	0.028

**Significance* ($p < 0.05$)

The results showed the differences in means and standard deviation of research variables before and after treatment. In CWI, different means of lactate was r=2.54±0.25 (p=0.001), while in SS group was r=2.77±0.21 (p=0.004). It reflects an impact of CWI 5°C and SS in reducing lactate levels. In muscle soreness variable, the experimental group showed a difference with the mean value of r=6.34±0.65 (p=0.001) while the control group's mean value was r=7.39±0.61 (p=0.095). Therefore, CWI 5°C reduced the muscle pain level but SS did not reduce muscle soreness (p> 0.05). On the flexibility, the experimental group showed a mean value of r=16.02±3.66 (p=0.004) (p<0.05), while the control group was r=16.17±2.49) (p=0.157), thus reflecting a significant impact of CWI 5°C as opposed to SS in terms of flexibility (p<0.05). In the stress level variable, the mean value of CWI 5°C was r=13.85±1.21 (p = 0.001) compared to r=15.17±1.91 (p = 0.028) of the control group. Therefore, both CWI 5°C and SS significantly affected stress levels, but CWI 5°C had a greater impact. The independent test results on CWI, CWT, and SS are described in Table 4.

Table 4. Independent Sample T-Test Results

Variables	Group	Mean±SD	Signf.	Remarks	Variables	Group	Mean±SD	Signf.	Remarks

Lactate	CWI	4.62±1.27	0.000	Signif	Flexibility	CWI	14.46±2.31	0.017	Signif.
	CWT	7.71±1.61	0.000	Signif		CWT	15.68±3.31	0.024	Signif.
	SS	8.09±1.31	0.000	Signif.		SS	17.91±3.76	0.033	Signif.
Cortisol	CWI	6.92±0.23	0.001	Signif	Depression	CWI	7.21±2.01	0.004	Signif.
	CWT	8.27±1.72	0.003	Signif		CWT	9.58±2.37	0.011	Signif.
	SS	11.13±2.46	0.001	Signif.		SS	10.75±2.81	0.023	Signif.
Body Temperature	CWI	36.21±1.23	0.002	Signif.	Anxiety	CWI	4.43±3.01	0.000	Signif.
	CWT	37.72±0.27	0.011	Signif.		CWT	6.19±2.88	0.001	Signif.
	SS	38.89±1.46	0.007	Signif.		SS	7.27±2.23	0.026	Signif.
Pain	CWI	5.32±1.04	0.003	Signif	Stress	CWI	11.02±2.27	0.005	Signif.
	CWT	6.32±1.77	0.018	Signif		CWT	12.02±3.52	0.014	Signif.
	SS	7.26±0.33	0.026	Signif.		SS	13.62±3.48	0.021	Signif.

Table 4 shows the differences in the significant values of lactate, cortisol, muscle pain, flexibility, depression, anxiety, and stress to the CWT, CWI 5°C, and SS groups. Lactate (p=0.000), cortisol (p=0.002), muscle pain (p=0.015), flexibility (p=0.024), depression (p=0.012), anxiety (p=0.009), and stress (p=0.013) indicated a significance value of p>0.05, hence significance between pre-test and post-test. Also, a smaller mean difference in lactate value was indicated in CWI (4.62 mg/dL) than CWT (7.71 Mmol/L) and SS (8.09 mmol/kg Bb). As the sig. (2-tailed) value between the two groups was p=0.000 (p<0.05), there was a significant difference between the study groups, where the CWI lowered lactate level compared to CWT and control.

Regarding the experience of stress level, a lower lactate mean value in CWI (6.77) was indicative of fewer stress hormones than CWT (8.77) and SS group (11,126). The sig. (2-tailed) value on this variable showed a mean p=0.002 (p<0.05), hence, a significant difference between the treatment and the effects experienced by the two groups after training, namely CWI 5°C could lower stress hormone better than the CWT and SS groups. The mean body temperature in SS, CWI, and CWT was 38.89, 36.21, and 37.72, respectively, indicating better maintenance of pre- and post-body temperature in CWT. In the flexibility variable, the SS had the highest mean (17.91), hence the highest flexibility, followed by CWI (15.68) and CWT (15.68). Referring to the sig. (2-tailed) value of p=0024 (p<0.05), there was a significant difference between CWT and CWI manipulation on the muscle flexibility level.

For depression variable, the CWI had the lowest mean (2.37) as opposed to moderate level in CWT (9.58) and high level in SS (10.75). The sig. (2-tailed) of p=0012 (p<0.05) showed a significant difference between the CWI, CWT, and SS, where CWI had the lowest or no-stress status compared to the CWT (higher stress level) and SS (the highest level). For anxiety status, the CWI had the lowest score (4.43) compared to CWT (6.19) and SS (7.27). It shows that CWI could reduce anxiety levels better than other manipulations with a sig. (2-tailed) significance of p=0009 (p<0.05).

These results indicated significant differences among the manipulations in order to decrease anxiety levels. For the stress category, it appears that CWI had the lowest score (11.02), compared to CWT (12.02,) and SS (13.62). Therefore, CWI could significantly reduce stress levels, indicated by a significance value of sig. (2-tailed) p=0003 (p<0.05). Furthermore, there was a significant difference between the interventions given to reduce stress levels in athletes. In the recovery process, the profile of lactate levels in the CWI, CWT, and SS on the 1st, 3rd, 5th, 10th, 15th, and 20th minutes are presented in Fig.1.

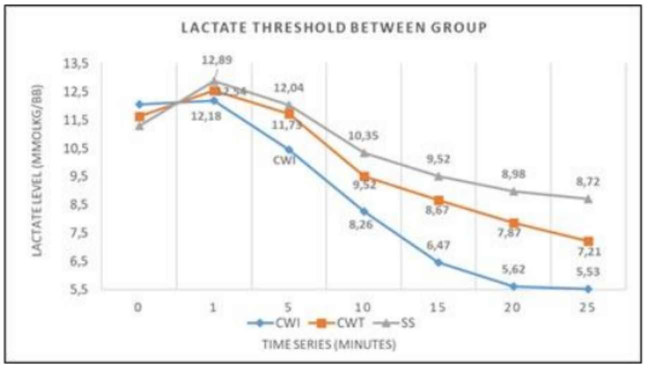

Fig. 1. Lactate Profile between the Groups

In three groups, the first minute after giving the manipulation, the body still produced lactate in an upward trend as a result of the body's metabolic adaptation process to the given physical stressors (Shen & Wen, 2019). Lactate production in the CWI group continued to decline gradually, with an average rate of 2 Mmol/L from the 5th, 10th, to 20th minutes of cold-water manipulation and became steady at the threshold at the 25th minute. It implies that lactate was already at a steady level with a level of 5.5 Mmol/L so that the lactate deposits generated when doing sub-maximal intensity exercise had been broken down optimally at the 20th minute.

In CWT, a decrease in lactate levels also occurred from the 5th to 20th minutes, with an average decrease of 1.7 Mmol/L and continued until 25th minutes with a level of 8.65 Mmol/L. It indicated that the body was still not steady, and it took a long time to break down lactate until it recovered from its original position. Meanwhile, in the SS, a decrease in lactate was observed since the 5th minute, with an average decrease of 1.2 Mmol/L up to 9.09 Mmol/L at the 20th minute, then remained steady. In this case, the body was in its original state of recovery with lactate levels of 9.23 Mmol/L. The different influence was also indicated by the pulse profile (Young & Benton, 2018) between the groups presented in the figure below.

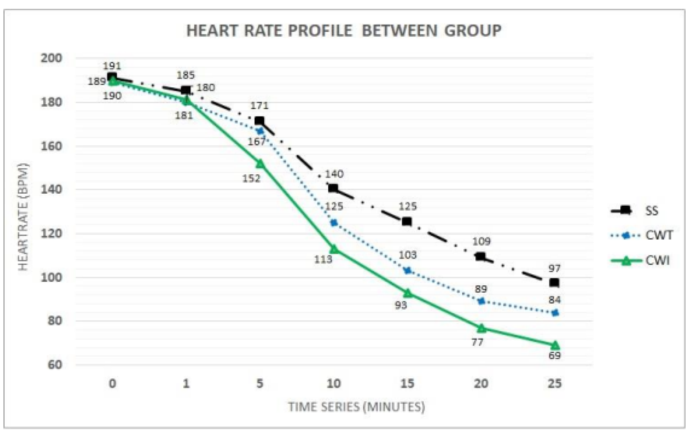

Fig. 2. Profile of Decrease in Pulse Rate between Groups

Figure 2 shows that three groups had a positive effect on the recovery process after circuit training; however, CWI appears to lower the pulse more optimally with an average decrease of 29 beats per minute (BPM) and a total of 69 BPM at the 25th minute, compared to the CWT group ($\pm$21 BPM, 84BPM) and SS group ($\pm$16 BPM, 97 BPM).

Discussion

Strength is an essential aspect of the bio-motor components since it affects the development of speed, power, agility, and others interrelation aspects. For this reason, circuit training is used to increase strength through the process of muscle hypertrophy, improving the coordination performance of the neuromuscular system and the ability to recruit more muscles during muscle contraction (Anggraeni et al., 2019). However, circuit training provides a sizeable physical stressor, causes muscle inflammation, decreases muscle endurance, increases lactate levels, disrupts body metabolism, and causes physiological as well as a psychological stressor that potentially leads to overtraining thus reducing performance. Cold-Water Immersion (CWI) is a common recovery method used currently in the regeneration phase besides Contrast Water Treatment (CWT) and the conventional Static Stretching (SS) recovery method.

Our findings found a significant effect between Cold-Water Immersion at 5°C (CWI 5°C), Contrast Water Treatment (CWT), and Static Stretching (SS) on levels of lactate, cortisol, body temperature, muscle pain status, flexibility, and psychosomatic profiles after sub-maximum intensity weight training. The CWI5°C method accelerated the process of reducing lactate levels and restoring the pulse faster than CWT and SS. A previous study supported this result that the stimulation of cold water given after physical exercise on the type of structural fatigue can help facilitate the transportation of intracellular and intravascular fluids in the body, increase cardiac output without expending energy, increase blood flow and nutrients throughout the body as well as the flow of body waste, and accelerates the breakdown of lactate levels, thus speeding up the recovery process (Bleakley et al., 2012). The CWI 5°C method has been shown to better reduce pain perception (DOMS) in the lower back muscles and hamstrings after the sub-maximal intensity of circuit training than the CWT and SS methods. This finding confirmed a previous study that the manipulation of Cold-Water Immersion helps decrease the performance of capillary permeability in the body, which results in lowering the prefrontal temperature of the cortex in the brain, reducing tension on the nerves of the brain, decreasing physiological responses, and relaxing the body. Additionally, it lowers the cortisol hormone levels to reduce spasms and pain in the muscles and accelerate the recovery cycle (Buchheit et al., 2009).

Furthermore, the athletes' psychosomatic problems were improved after CWI manipulation, as evidenced from their decreased levels of depression, anxiety, and stress compared to the CWT and SS methods. Cold sensation was reported to reduce nerve conduction velocity, alter sensory conduction, and increase the production of glutathione and antioxidants. Subsequently, the cold sensation that was exposed to skin receptors enables the central nerve to receive a lot of electrical impulses sent by the peripheral nerves which then stimulate a hypo-algetic effect, produce an antidepressant effect and ultimately, reduce the nerves tension of the brain, stress, depression, and anxiety (Herrera et al., 2010). Another effect of cold water is shock therapy which triggers beta-endorphin and noradrenaline in the brain like an electric shock therapy. A large number of electrical impulses travel from the nerve nodes of the skin to brain, jolt the system, reduce the production of the hormone cortisol, and result in beneficial effect of reducing depression, anxiety, and stress (Kusuma; et al., 2020)

Contrast Water Treatment (CWT) recovery method with a change of contrast temperature (cold 15°C, warm 38°C) for 15 minutes gave a positive effect on body temperature stability compared to CWI and SS. It was evidenced by the absence of a significant decrease in body temperature after circuit training and immersion. Investigations on heat therapy reported its ability to increase blood flow, stretch tissues, increase body metabolism, and dilate blood vessels, which eventually increases the supply of oxygen and nutrients to the tissues in order to better maintain body temperature (Ghavami et al., 2019). Additionally, three stages of heat therapy (delivery/conduction, convection, and exchange/change) maintain body temperature better through the supply of protein, nutrients, and O2 to the surrounding area of injury, increasing the work of metabolism in the local area by 10-15%, reduces the pH level, increases capillary permeability, and releases histamine and bradykinin that results in vasodilation and increases the elasticity of collagen tissue by increasing the flow of viscosity matrix and collagen fibers (Tan et al., 2010). On the other hand, the Static Stretching (SS) method in post-circuit training significantly affected the level of muscle flexibility compared to the CWI 5°C and CWT methods. Some literature explained that SS helps reduce macrophages in damaged muscles, restore blood flow to muscles, reduce prostaglandin E2 synthesis, and stimulate endorphin hormones so that the transmission of pain impulses in the spinal cord becomes obstructed and blood circulation is improved, and hence, maintaining muscle flexibility (Ahmed et al., 2015). Additionally, several studies have shown a significant relationship between SS and muscle flexibility in which post-exercise stretching dilates the blood vessels better, maintains muscle elasticity, and expedites the vascularization process, and therefore, accelerating the metabolic waste degradation, reducing inflammation and pain, and increasing muscle flexibility (Arofah, 2009).

However, the contraindications effect of cold therapy reported a slowing blood flow that contains nutrients and oxygen transported through blood vessels across body organs (Diong & Kamper, 2014), resulting in delays of nutrient fulfillment and oxygen demand in the brain and potential damage in the peripheral body in some cases where excessive time of manipulation (>25 minutes) was performed. In case of extreme temperature (e.g., under 0°C), the body will respond differently, such as inflamed blood vessels (vasculitis), decreased protein content in the blood (cryoglobulinemia), and the formation of antibodies degrading red blood cells (Crowe et al., 2007) but will not experience any differences in the strength of muscle contraction and elasticity. However, Baar (2014) in the applied exercises physiology study explains that a proper management of ultra-low temperatures (cryotherapy) for several minutes followed by personal physiological adjustment and medical control is one of the trending methods after physical exercise on types of structural fatigue because it can reduce migraine symptoms, treat yearly injuries (through numb pain), pinched nerves, neuromas, chronic and acute injuries, as well as improving mood disorder by releasing adrenaline, noradrenaline, and endorphins. However, negative effect are repetitively reported due to lack of scientific evidence for both advantages and disadvantages.

While CWI method has been shown to have a positive effect on reducing the levels of lactate, cortisol, muscle soreness, depression, anxiety, and stress post-sub-maximal intensity of circuit training, CWT was reported to better maintain post-workout body temperature better, and SS maintains the level of post-workout muscle flexibility. In addition, performing CWI, CWT, and SS alternately according to the types and levels of fatigue being experienced could accelerate the regeneration process faster, reduce the risk of injury due to overtraining, and maintain better performance (Peck et al., 2014). Structural fatigue characterized by high intensity and low volume has a different metabolic effect from hormonal fatigue caused by training with a low-intensity pattern and high volume and long duration, such as long-distance, marathon, or triathlon. Similarly, another type of fatigue caused by forms of training with sub-maximal volume patterns with sub-maximum intensity (e.g., power endurance training on circuit training, tennis, or martial arts with long-duration of maximal muscle contraction) requires proper recovery methods that involves various enzymes for body regeneration. It can be concluded that selecting the appropriate recovery method should involve adjustment of physiological symptoms that appear, as well as the types of fatigue, accompanied by medical investigation and control of the physiological response (Kusuma; et al., 2018)

Conclusion

Cold-Water Immersion using 5°C of water (CWI 5°C) for 15 minutes significantly reduced the levels of lactate, cortisol hormone, muscle aches, depression, anxiety, and stress. Meanwhile, Contrast Water Treatment (CWT) affected body temperature stability after Circuit Training (CT), and Static Stretching (SS) had a significant effect on increasing the flexibility of the lower back muscles and hamstrings. Post-training regeneration process is not only influenced by the accuracy in selecting a recovery method according to the type of fatigue but also strongly influenced by the technical implementation of the recovery. Providing a short duration of CWI, CWT, and SS produce non-optimal effects. Likewise, excessive manipulation results in a counter-productive effect and negative response to the body. Also, nutritional pattern, age, genetics, and physiological profile are external factors that affect the speed of body recovery .

Additionally, we did not find significant differences in lactate, cortisol, muscle pain, flexibility, and psychosomatic factors on macronutrient element of carbohydrates, protein and fat appear. We assumed a lack of laboratory measurement related to macronutrient elements to the regeneration post-sub-maximum intensity of physical exercise was behind this drawback. Therefore, studies that reported no effect on body metabolism and the ability to repair body cells need further systematic investigation (Potgieter, 2013). Some limitations include the diverse background and characteristics of the athletes, such as athletics, soccer, basketball, and badminton which may affect general physical condition, working system, and muscle metabolism, as well as the ability to recover (Hartmann et al., 2015). The measurement of cortisol, soreness, body temperature, flexibility, and psychosomatic in this study were not carried out using time interval (repetitive) compared to lactate and resting heart rate that measured employing with the repetitive method of 5^{th}, 10^{th}, 15^{th}, 20^{th}, and 25^{th} minutes (Georgieva et al., 2017). Conclusively, measurements of such variables involving time intervals are expected to provide comprehensive results related to the effect of CWI, CWT, and SS on post-exercise recovery process with submaximal loads.

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