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Effects of Recovery Techniques in Reducing Fatigue Levels of Badminton Athletes in Sumenep District

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Abstract

This study provides new insights into the differences of lactate clearance between the active recovery and the passive recovery using CWI techniques. The method used in this research was the true experimental research with a randomized control group pre-test-posttest design. The samples were randomly selected and were divided into three groups. Group 1 was the treatment group using an active recovery in cold water at <15 oC for 7.5 minutes. Group 2 was the treatment group using a passive recovery in cold water at <15oC for 7.5 minutes. Group 3 was the control group using a passive recovery. The results of this study showed that both recovery methods, the CWI with active recovery and the CWI with passive recovery, positively affected the elimination of lactate in the athlete body. However, the results showed that the CWI with active recovery tended to have a better effect on reducing lactate levels than passive recovery methods. Based on the research results, there were significant influences of both types of recovery, the active recovery and the passive recovery, and a substantial influence of the cold-water immersion in an active recovery on the lactate clearance. The active recovery reduced blood lactic acid levels more efficiently than the passive recovery. Several factors, such as the water temperature, recovery time, and intensity of previous physical activity, might have influenced the results of this study.

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INTRODUCTION

Badminton is a popular game among teenagers, both for men and women. Badminton is a sport often played by two pairs of badminton players or one against one, playing against the other (Ramirez-Campillo et al., 2019). Many people think badminton is similar to tennis as the way to play it is almost the same, but the game rules are clearly different (Girard et al., 2020). The aim of the badminton game is simple, namely to score as many points as possible on the opponent court. To obtain good skills in each sport, we must consider the required physical condition (Moreno-Perez et al., 2020). Badminton requires an optimal condition to make the players more robust and enthusiastic. Badminton games not only require a strategy and playing techniques but also need a good physical condition of the badminton players and athletes (Schneider et al., 2020). When undergoing a training program, a badminton athlete body can adapt over a long time and has a high level of fatigue resistance. In this context, it has a threshold value. For this reason, sometimes, the endurance can decrease or even no longer be able to be maintained. There are two types of fatigue levels, namely the muscle fatigue and general fatigue. In essence, fatigue generally occurs due to the athlete psychology, while muscle fatigue is caused by the inability of the muscles to contract and metabolize the materials needed to recover muscles from fatigue. Solid contractions cause the muscle fatigue lasts for a long duration, resulting in the compression of muscle fibers and blood vessels so that the exchange of nutrients and the performance of the circulatory system are disrupted (Shubao & Dong, 2023).

Badminton is a sport that requires complex movements, thus the players must be physically and technically ready to perform at their best. Badminton players must have an excellent technique and physical condition to achieve higher achievements (Yang et al., 2023). Badminton is a swift sport. The shuttlecock is hit every ± 5 seconds, meaning the player has a short time, around 2-3 seconds, to quickly start, move, and find the correct position to hit the ball and return it to the opponent. At the same time, the player has about one second to return to his original work and prepare to make the next rally shot (Zubaida et al., 2023). The high intensity of movement can cause badminton players to experience fatigue easily (Rusdiawan et al., 2020). This impact will hurt the players if it is not handled on time, when they finish the training or during the competition, which will affect the development of the athlete performance. The body exposure to a repetitive exercise or high-intensity activity triggers various negative reactions in the form of micro- and macro-physiological stresses, with negative responses lasting from minutes to months (Lin et al., 2023).

Various recovery methods can be used to prevent fatigue in athletes by returning them to their original performance after the training, such as balanced periodizations (Bird, 2019), active recovery, stretching, rehydration, nutritional fulfillments (Tong et al., 2023), massage, physiotherapy (Sánchez-Pay et al., 2023), compression garments (Haetami & Triansyah, 2021), local thermal applications, and water immersions. All methods have their respective advantages with different usage times. Various studies have stated the advantages and disadvantages of each technique. The water immersion method is a method with an exposure to the external environment that is free and safe from the contradictions of the recovery method (Bahri et al., 2022). The water immersion method is a recovery method where the part or all of the body is immersed in the water at a specific temperature. Hydrostatic pressure is the basic working principle of immersions (Loch et al., 2023). A number of water immersion methods have been proven to reduce lactic acid levels in the body. In general, among the varied water immersion methods, researchers can find that the cold water immersion method is often used (Jannah et al., 2021). The previous research was limited to the water immersion method only, hence the researchers wanted to apply the water immersion after a high-intensity exercise in this study. The mode usually applied to cold water immersions is the passive immersion mode, where the body does not move when the temperature is below 150C. Of course, this contradicts previous research showing that the active recovery treatment is superior to the passive recovery treatment (Molaeikhaletabadi et al., 2022).

One possible explanation, for the novelty of this study, is that the active recovery using CWI improves the circulation and oxygen flow to the affected muscles (Hacker et al., 2021). The cold water immersion therapy is a recovery method that replaces the role of nitrogen, which is usually used as an anesthetic and analgesia to treat pains and reduce inflammation symptoms in muscles (Van Cutsem et al., 2019). The cold water immersion therapy provides physiological effects, including the vasoconstriction of arterioles, decreased cell oxygen demand, and reduced cell metabolic levels, swelling process, pains, muscle spasms, and the risk of cell death (Ramirez-Campillo et al., 2019). The stimulation of cold water immersions helps the performance function of capillary permeability decrease, improves cognitive functions, and lowers the temperature of the prefrontal cortex in the brain, thereby reducing the tension in the brain nerves and the physiological response so that the body is relaxed (Buga & Gencer, 2022). The similar research explains that the cold therapy, with a water temperature of 10°C for 10 minutes, can reduce muscle spasms and pains and increase the recovery cycle, but it does not affect the strength of muscle contractions (Zhang et al., 2023). In other words, the CWI application needs to be given immediately after a weight training to reduce the lactate pain and stress. However, the cold water immersion with too cold temperatures for a long time results in skin irritations, hypothermia, decreased muscle flexibility, disrupted body metabolism, and a damage to the skin tissue due to the exposure to frostbites. In a research, the 5°C CWI procedure for 15 minutes was administered for the recovery process related to the lactate accumulation profile, muscle pains, and flexibility to avoid the effects of irritation, hypothermia, and forstbite triggering muscle, body metabolism, and psychological disorders (Wang et al., 2020).

METHODS

This research is quantitative research using a pure experimental research type (actual experimental design). The research design used in this research was a randomized control group pretest-posttest design. In this design, the samples were divided into three groups chosen randomly.

Participant

The population of this study were badminton athletes from the PBSI (Indonesian Badminton Association) of Sumenep Regency. The determination of the sample size in this study was based on age criteria, namely 15-18 years. Each group consisted of 9 people so that the samples required for this study were 27 badminton athletes.

The samples were divided into three groups chosen randomly. Group 1 was the treatment group given an active recovery in cold water <150C for 7.5 minutes. Group 2 was the treatment group receiving a passive recovery in cold water <150C for 7.5 minutes. Meanwhile, Group 3 was the control group receiving a passive recovery. The design of this research can be seen in the following picture:

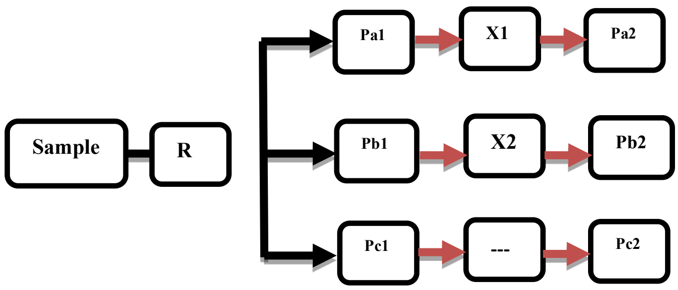

Figure 1. Randomized Control Group Pretest-Posttest Design

Information:

Sample	: Badminton athletes aged 15-18 years
R	: Random sample placement
Pa1, Pb1, Pc1	: Pre-test blood sampling, 10 minutes after carrying out a maximum intensity physical activity
X1	: Active recovery treatment in cold water<15^{0}C
X2	: Passive recovery treatment in cold water<15^{0}C
---	: Passive recovery
Pa2	: Post-test blood sampling for lactic acid levels during the active recovery, 15 minutes after the maximum intensity physical activity
Pb2, Pc2	: Post-test blood sampling for lactic acid levels during the passive recovery, 15 minutes after the maximum intensity physical activity

Instrument and Procedure

The collected data included the athlete characteristics, anthropometry, nutritional intake, physical activity, stress levels, and menstrual cycles. The anthropometric data involved the body weight and height. Body weight was measured using a stepping scale, while body height was measured using a microtome with an accuracy of 0.1 cm. The athlete nutritional status was assessed using a z-score. Body mass index was based on age (BMI/U) and categorized into thin, normal, overweight, and obese. Food intake data were obtained using a 3x24-hour food record (2 training days and one holiday). Physical activity levels were obtained using the International Physical Activity Questionnaire (IPAQ). The total score calculated for physical activity level was then categorized into light (<600 MET-minutes/week), moderate (600-2999 MET-minutes/week), and heavy (>2999 MET-minutes/week) physical activity levels. Stress levels were obtained using the Hamilton Anxiety Rating Scale (HARS) questionnaire. The total stress level score was then categorized into mild (<18), moderate (18–24), and severe (>24) stress levels. The menstrual cycle was categorized into two categories, including standard (between 25 to 35 days) and abnormal (<25 days or >35 days).

RESULT

The followings are the results of research based on the maximum load using the drilling training method given to the Experimental Group I, Experimental Group II, and Control Group. These data explain the data description, normality test distribution, paired t-test, and independent t-test. This research was carried out on badminton athletes from the PBSI Sumenep District. The samples were 27 people divided into three groups. Each group consisted of nine participants. The results of this research described the mean and standard deviation obtained from the test results carried out in each group. The test results were calculated and recorded based on the group and the type of treatment carried out. The treatment results of the three groups, namely the active recovery, passive recovery, and control groups, were analyzed. The analysis of the data employed SPSS version 25.0. The descriptions of blood lactate test results after being given a maximum intensity exercise are presented in Table 1, Table 2, and Table 3.

Based on the measurement results in Table 1, data for Group I receiving the cold water immersion active recovery, the mean for the pre-test (before drilling) was 2.81 mmol. After the drilling treatment, there was an increase shown by the post-test mean (after training) of 7.62 mmol. After soaking, a decrease in lactic acid was apparent, from 7.62 mmol to 5.29 mmol. There was a decrease in lactic acid of 2.33 mmol. A reduction also accurred 10 minutes after carrying out the cold water immersion active recovery. The 4th post-test experienced a decline of lactic acid of 3.9 mmol.

Based on the measurement results in Table 2, for Group II receiving the cold water immersion passive recovery, the mean of the sample lactic acid before drilling was 2.82 mmol. After drilling, the blood lactic acid increased to 7.60 mmol. After soaking for 7.5 minutes, the blood lactic acid decresed to 6.42 mmol, showing a lactic acid decrease of 1.18 mmol. The reduction also occurred 10 minutes after carrying out the cold water immersion passive recovery, presenting a decrease in lactic acid to 4.41 mmol.

Table 1. Pre-Test and Post-Test Active Recovery Data

No	Pre-Test	Post-Test	Recovery (7.5 Min.)	Recovery (10 Min.)
1	2,5	7,6	5,2	3,4
2	2,1	7,8	5,1	3,6
3	3,6	7,4	5	4,1
4	3,3	7,9	5,3	4,2
5	2,8	7,4	5,4	3,8
6	3,2	7,5	5,6	3,6
7	2,2	7,8	5,2	3,5
8	3,4	7,7	5,1	4,4
9	2,2	7,5	5,7	4,5
Total	25,3	68,6	47,6	35,1
($\bar{X}$)	2,81	7,62	5,29	3,9
SD	0,55	0,17	0,22	0,39
Min	2,1	7,4	5	3,4
Max	3,6	7,9	5,7	4,5

Table 2. Pre-Test and Post-Test Passive Recovery Data

No	Pre-Test	Post-Test	Recovery (7.5 Min.)	Recovery (10 Min.)
1	2,1	7,4	6,4	4,1
2	2	7,5	6,6	4,2
3	2,8	7,8	6,8	4,4
4	3,2	7,7	6,2	4,6
5	2,2	7,5	6,6	4,4
6	3,4	7,8	6,3	4,1
7	3,6	7,4	6,2	4,5
8	3,3	7,9	6,3	4,6
9	2,8	7,4	6,4	4,8
Total	25,4	68,4	57,8	39,7
($\bar{X}$)	2,82	7,60	6,42	4,41
SD	0,57	0,19	0,19	0,23
Min	2	7,4	6,2	4,1
Max	3,6	7,9	6,8	4,8

Based on the measurement results in Table 3, for Group III receiving no treatments, the mean of the sample lactic acid before drilling was 3.03 mmol. After drilling, the blood lactic acid increased to 7.51 mmol. After no treatments, the sample lactic acid was rechecked after 7.5 minutes. The blood lactic acid decreased to 7.08 mmol, showing a decrease in lactic acid of 0.43 mmol. The reduction also occurred 10 minutes after no activity, showing a decline in lactic acid to 6.18 mmol.

Table 3. Pre-Test and Post-Test Passive Recovery Data

No	Pre-Test	Post-Test	Recovery (7.5 Min.)	Recovery (10 Min.)
1	2,3	7,8	7,1	6,1
2	3,4	7,6	7,2	5,8
3	2,5	7,2	6,9	5,8
4	3,7	7,5	7,2	6,2
5	2,9	7,4	7	6,3
6	3,8	7,3	6,8	5,7
7	2,1	7,4	7,1	6,8
8	3,6	7,5	7,1	6,4
9	3	7,9	7,3	6,5
Total	27,3	67,6	63,7	55,6
(X̄)	3,03	7,51	7,08	6,18
SD	0,60	0,21	0,15	0,35
Min	2,1	7,2	6,8	5,7
Max	3,8	7,9	7,3	6,8

The statistical prerequisite tests carried out include normality tests using the Shapiro-Wilk test with a significance level (α) of 0.05. The results of the normality test showed that all research groups obtained a value > 0.05. The data were normally distributed. While in the homogeneity test results, it was found that the values of all groups had the same variance value (homogeneous).

provements in the lactate removal compared to the control group. The use of CWI after an intensive training helps reduce lactate accumulations in the athlete body more effectively compared to not using the CWI (Erlina et al., 2019). However, there were differences between the active and passive recovery groups regarding the effectiveness of the lactate removal. The active recovery group with CWI showed a more significant increase in the lactate removal than the passive recovery group. This suggests that the athlete active participation in the recovery process has added benefits of removing lactate from their bodies (Hardiansyah et al., 2023).

Strength is an essential aspect of the body motor component because it can affect the development of other motor aspects such as speed, power, agility, and other motor aspects (Hardiansyah & Wahdian, 2023). The weight training method can increase the strength through the muscle hypertrophy process as well as improving the coordination performance of the neuromuscular system. However, weight training also provides a sizeable physical stressor reducing the muscle endurance, increasing lactate levels, disrupting the body metabolism, and causing muscle inflammations, high fatigue, and overtraining, thereby decreasing performance. Cold water immersion is a recovery method often used in the recovery phase to replace the conventional static stretching recovery method (Pradas et al., 2020).

Table 4. Hypothesis Testing

Information	Active Recovery (n=9) (SD)	Passive Recovery (n=9) (SD)	Control (n=9) (SD)
Pre-Test	2.81 (0.55)	2.82 (0.57)	3.03 (0.60)
Post-Test	7.62 (0.17)[a]	7.60(0.19)[a]	7.51(0.21)[c]
Recovery 7.5 Minutes	5.29 (0.22)[b *]	6.42 (0.19)[b*]	7.08(0.15)
Recovery 10 Minutes	3.9 (0.39) [*]	4.41 (0.23)[*]	6.18(0.35)

a. Significantly different (p<0.05) to the 7.5-minute recovery
b. Significantly different (p<0.05) to the 10-minute recovery
c. Not significantly (9>0.05) different to the 7.5-minute recovery (p value =0.107)
d. *) Significantly different (p<0.05) to the control group

DISCUSSION

The research data related to the effect of the cold water immersion (CWI) on the active and passive recovery and lactate clearance of PBSI badminton athletes in the Sumenep district showed exciting findings. This research was conducted to evaluate the effectiveness of CWI in accelerating the lactate removal in the body of badminton athletes after an intensive training. The study involved three groups, namely the active recovery group with CWI, the passive recovery group with CWI, and the control group without CWI interventions. The results showed that both active and passive recovery groups with CWI experienced significant im-

A study found a significant effect of the cold water immersion at a temperature of 5°C (CWI) and the static stretching on lactate levels, muscle pain status, flexibility, and stress levels after a sub-maximal intensity weight training. The CWI at 5°C method can help speed up the process of reducing lactate levels and recovering heart rate compared to the static stretching. The cold water stimulation given after physical exercises with structural fatigue can help facilitate the intracellular and intra-vascular fluid transportation process, increase cardiac outputs without expending energy, increase the flow of blood and nutrients throughout the body, and reduce the waste disposal flow. The body accelerates the breakdown of lactate levels, thereby speeding up the recovery process (Buga & Gencer, 2022). The CWI 5°C method has also been proven to reduce the perception of pain in the lower back muscles and hamstrings after weight trainings compared to the static stretching method. This result is confirmed by other research explaining that the cold water immersion manipulation helps the capillary permeability performance in the body to decrease, thus lowering the prefrontal cortex temperature in the brain, the tension in the brain nerves, and physiological responses. The body becomes relaxed, reducing hormone levels. Cortisol can reduce muscle spasms and muscle pains (delayed onset of muscle soreness) and speed up the recovery cycle (Kons et al., 2023).

The study also found that the CWI 5°C group showed a significant reduction in stress levels after a weight training. This is explained in other research that the cold sensation in the cold water immersion can reduce the sensory nerve conduction velocity (nerve conduction velocity), change the sensory conduction, and increase the glutathione and antioxidant production. The cold sensation received by receptors on the skin makes the central nervous system receive more electrical impulses sent by peripheral nerves, stimulates a hypoalgesic effect, and produces an antidepressant effect so that they can reduce the tension in the brain nerves as well as reducing stress (Rusdiawan et al., 2020). Another study explained that the cold therapy with a water temperature of 10°C for 10 minutes could reduce muscle spasms and pains and increase the recovery cycle but did not affect the strength of muscle contractions (Bin Shamshuddin et al., 2020). In other cases, administering the CWI 5°C method provides contraindications, including slowing blood flows in the blood vessels between body organs due to the cold temperature given, reducing the rate of blood flow containing nutrients and oxygen, resulting in delays in fulfilling the nutritional and oxygen needs of the brain which might lead to the occurrence of peripheral body damage (Machado et al., 2016). The adverse effects of the cold water immersion were also reported in similar studies, showing the inflammation of the blood vessels (vasculitis), decreased protein content in the blood (cryoglobulinemia), and the formation of antibodies damaging red blood cells as the body response to the effects of the cold applied (Wang et al., 2020).

This study aimed to investigate the effect of two recovery methods after administering intensive trainings on the PBSI Sumenep Regency badminton athletes, namely the cold water immersion (CWI) with an active recovery method and a passive recovery method, on the process of eliminating lactate in the body (Biswas & Ghosh, 2022). Active recovery methods involve a light exercise or aerobic activity in cold water (Van Cutsem et al., 2019), while passive recovery methods involve immersing the athlete body in cold water without additional physical activities. Lactate, a byproduct of anaerobic metabolism during an intense exercise, can result in fatigue and reduced performance if not removed effectively (Hasan et al., 2022). The results of this study show that both recovery methods (Silva et al., 2019), both CWI with an active recovery and CWI with a passive recovery, have a positive impact on the lactate removal in the athlete body (Sánchez -Pay et al., 2023). However, the results showed that CWI with an active recovery tended to have a better effect on reducing lactate levels than the passive recovery methods.

In the group using CWI with an active recovery method, there was a more significant reduction in blood lactate levels after the recovery period (Jannah et al., 2021). A light aerobic activity in cold water is believed to help speed up the blood circulation, thus lactate is more efficiently carried to the organs that eliminate it. On the other hand, the group undergoing CWI with a passive recovery also experienced a decrease in lactate levels, although it was not as fast as in the active recovery group (Deng et al., 2022). This research empirically supports that active and passive recovery methods using the cold water immersion are effective (Loch et al., 2023) in assisting the lactate removal process in badminton athletes after intensive trainings (Deng et al., 2023). For coaches and athletes, these results can be a guidance in choosing a recovery method that suits the recovery goals after an intense training.

CONCLUSION

Based on the research results, the study concludes that there is a significant effect of both recovery types, the active and passive methods. There is a substantial effect of the cold water immersion with an active recovery on the lactate clearance. The active recovery could reduce blood lactic acid levels more efficiently than the passive recovery. The cold water immersion using a water temperature of 5 degrees (CWI 5°C) for 15 minutes has a significant effect on reducing lactate levels, muscle pains, and stress levels, while the static stretching has a substantial effect on increasing the lower back muscle flexibility and hamstrings. Besides being influenced by external stimulus factors, the regeneration process is also determined by internal factors such as nutritions, age, genetics, and physical conditions (kusuma et al., 2020). This research had involved protein as a nutritional element, but there was no significant difference in the lactate, muscle pains, flexibility, and stress. This might be because macronutrient elements, including carbohydrates, proteins, and fats, have not been fully involved as research variables, thus affecting the metabolism and the ability to repair body cells. Another limitation is related to the background of athletes. The athletes were from several sports with different unique physical condition characteristics, such as badminton. This is believed to affect the structure, working system, and metabolism of muscles, thereby affecting the recovery ability. The following limitation is that the lactate, muscle soreness, flexibility, and stress measurements have not been carried out using rest periods (repetitive), measured immediately after the exercise, 5 minutes, 15 minutes, and 30 minutes. It will make it possible to get more accurate results regarding the influence of CWI on the recovery process after a submaximal load training.

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CONFLICT OF INTEREST

The authors declared no conflict of interest.

REFERENCES

Barnett, A. (2006). Using recovery modalities between training sessions in elite athletes: does it help?. Sports medicine, 36, 781-796.

Bastos, F. N., Vanderlei, L. C. M., Nakamura, F. Y., Bertollo, M., Godoy, M. F., Hoshi, R. A., ... & Pastre, C. M. (2012). Effects of cold water immersion and active recovery on post-exercise heart rate variability. International journal of sports medicine, 873-879.

Bieuzen, F., Bleakley, C. M., & Costello, J. T. (2013). Contrast water therapy and exercise induced muscle damage: a systematic review and meta-analysis. PloS one, 8(4), e62356.

Bompa, T. O., & Buzzichelli, C. A. (2019). Peridization: Theory and Methodology of Training (JW Gibson).

Bosquet, L., Montpetit, J., Arvisais, D., & Mujika, I. (2007). Effects of tapering on performance: a meta-analysis. Medicine & Science in Sports & Exercise, 39(8), 1358-1365.

Coffey, V. G., & Hawley, J. A. (2007). The molecular bases of training adaptation. Sports medicine, 37, 737-763.

Oliveira, C. M. C. D., Vidal, C. L. D. C., Cristino, E. F., Pinheiro Jr, F. M. L., & Kubrusly, M. (2015). Metabolic acidosis and its association with nutritional status in hemodialysis. Brazilian Journal of Nephrology, 37, 458-466.

Foucquier, A., Robert, S., Suard, F., Stéphan, L., & Jay, A. (2013). State of the art in building modelling and energy performances prediction: A review. Renewable and Sustainable Energy Reviews, 23, 272-288.

Peiffer, J. J., Abbiss, C. R., Watson, G., Nosaka, K., & Laursen, P. B. (2010). Effect of a 5-min cold-water immersion recovery on exercise performance in the heat. British journal of sports medicine, 44(6), 461-465.

Hinzpeter, J., Zamorano, Á., Cuzmar, D., Lopez, M., & Burboa, J. (2014). Effect of active versus passive recovery on performance during intrameet swimming competition. Sports health, 6(2), 119-121.

Parwata, I. M. Y. (2015). Kelelahan dan recovery dalam olahraga. Jurnal pendidikan kesehatan rekreasi, 1(1), 2-13.

Ilbeigi, S., Moazani, H., Saghbejoo, M., & Yousefi, M. (2021). The effect of recovery methods after a session of exhaustive activity on some performance indicators and muscle damage in teenage soccer players. Journal of Sport and Exercise Physiology, 14(2), 127-136.

Kusuma, M. N. H., Syafei, M., Saryono, S., & Qohhar, W. (2020). Pengaruh cold water immersion terhadap laktat, nyeri otot, fleksibilitas dan tingkat stres pasca latihan intensitas sub maksimal. Jurnal Keolahragaan, 8(1), 77-87.

Kuswahyudi, Juniarsyah, A. D., Winata, B., Junaidi, & Ihsani, S. I. (2021). Effect of Cold-Water Immersion, Foam Rolling, and Slow Jogging Recovery to Aid Futsal Athlete's Recovery after One-Off Futsal Match. Human Physiology, 47, 467-477.

Lambert, D. M., & Muccioli, G. G. (2007). Endocannabinoids and related N-acylethanolamines in the control of appetite and energy metabolism: emergence of new molecular players. Current Opinion in Clinical Nutrition & Metabolic Care, 10(6), 735-744.

Lim, J., Park, H., Lee, S., & Park, J. (2022). Comparison of 4 Different Cooldown Strategies on Lower-Leg Temperature, Blood Lactate Concentration, and Fatigue Perception After Intense Running. Journal of Sport Rehabilitation, 31(8), 1052-1060.

Milon, A. G. (2014). Study Regarding The Complexity Of Physical Training In Badminton. GYMNASIUM, 15(1).

Mitchell, C. R., Harris, M. B., Cordaro, A. R., & Starnes, J. W. (2002). Effect of body temperature during exercise on skeletal muscle cytochrome c oxidase content. Journal of Applied Physiology, 93 (2), 526-530.

Mokayef, M., Moghadasi, M., & Nuri, R. (2014). Effect of cold water immersion on blood lactate levels of table tennis players. Int. J. Curr. Res. Aca. Rev, 2(9), 115-123.

Noakes, T. D. (2011). Time to move beyond a brainless exercise physiology: the evidence for complex regulation of human exercise performance. Applied physiology, nutrition, and metabolism, 36(1), 23-35.

Parouty, J., Al Haddad, H., Quod, M., Leprêtre, P. M., Ahmaidi, S., & Buchheit, M. (2010). Effect of cold water immersion on 100-m sprint performance in well-trained swimmers. European journal of applied physiology, 109, 483-490.

Patellongi, I. (2004). Fisiologi Olahraga. Universitas Hasanuddin.

De Pauw, K., Roelands, B., Vanparijs, J., & Meeusen, R. (2014). Effect of recovery interventions on cycling performance and pacing strategy in the heat. International journal of sports physiology and performance, 9(2), 240-248.

Pelana, R., Maulana, A., Winata, B., Widiastuti, W., Sukur, A., Kuswahyudi, K., ... & Hermawan, R. (2019). Effect of contrast water therapy on blood lactate concentration after high-intensity interval training in elite futsal players. Physiotherapy Quarterly, 27(3), 12-19.

Tipton, M. J., Collier, N., Massey, H., Corbett, J., & Harper, M. (2017). Cold water immersion: kill or cure?. Experimental physiology, 102(11), 1335-1355.

Vaile, J., Halson, S., Gill, N., & Dawson, B. (2008). Effect of hydrotherapy on the signs and symptoms of delayed onset muscle soreness. European journal of applied physiology, 102, 447-455.

Valle, X., Til, L., Drobnic, F., Turmo, A., Montoro, J. B., Valero, O., & Artells, R. (2013). Compression garments to prevent delayed onset muscle soreness in soccer players. Muscles, ligaments and tendons journal, 3(4), 295.

Vanderlei, F. M., De Albuquerque, M. C., De Almeida, A. C., Machado, A. F., Netto Jr, J., & Pastre, C. M. (2017). Post-exercise recovery of biological, clinical and metabolic variables after different temperatures and durations of cold water immersion: a randomized clinical trial. The Journal of sports medicine and physical fitness, 57(10), 1267-1275.