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Original Article

Effect of cold water immersion during half time on body recovery in soccer player

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Abstract
The purpose of this research was to study the effect of cold water immersion during halftime on physical rehabilitation in soccer players. The participants were 16 male soccer players (18–25 years old). All participants were categorized into two groups, i.e., the control group (CG; n = 8) and the cold water immersion group (CWI; n = 8). Both groups competed in a soccer match for 90 min; the match was divided into 45 min in the first half and 45 min in the second half, with a 15-min halftime. Interleukin-6, creatine kinase, and lactic acid were evaluated before the match, after the first half, after the half-time, immediately after the match and 24 h after the match. One way repeated ANOVA was used to identify differences between the groups. The obtained results showed that blood biochemical variables [i.e., lactic acid levels of CWI during half time (8.08 ± 2.16) compared to those after half time (5.51 ± 0.52)] had a statistically significant decrease. In addition, muscle pain perception of CG (3.00 ± 0.76) and CWI (0.88 ± 0.83) was different with statistical significance at the 0.05 level. The perception of muscle pain of CG at the first half (5.00 ± 1.20) and after the first half rest (0.88 ± 0.83) was significantly decreased. However, there were no changes in IL-6, creatine kinase, and lactic acid between the groups. Therefore, it was concluded that cold water immersion during halftime in soccer slowed down muscle fatigue and decreased lactic acid level in soccer players. This protocol can be used as an alternative recovery method for soccer players.
Keywords: Muscle fatigue, Blood lactate, Creatine kinase, Interleukin-6, Muscle pain

Introduction

Soccer is the most popular sport in the world (Bangsbo, 1994). It is considered as the intermittent sport. Normally, the duration of the game is 90 minutes, 45 minutes for two rounds, 15 minutes for the half time break. During the match play, the athlete's capability can be measured by the covered distance. However, match play is an interval alternation between the highest speed and power (sprinting) which need to change mostly (Buchheit, 2012). The soccer physical abilities have been dependent on complex system in cardiovascular and muscular systems which have boosted up both anaerobic and aerobic energy system during the game competition (Bangsbo, 2001, Mohr et al, 2010). For instance, the combination of high speed and running race is vital during the football game due to the concern of the game condition (Gregson et al, 2010).

In term of environment such as humidity and temperature, the soccer match at 43°C has been shown that running distance of player and speed have been reduced for 7% and 26%, respectively despite no alternation in heart rate and blood lactate, when compared to match play at the 21°C (Mohr et al, 2013). Moreover, low oxygen concentration such as anoxia also plays some role on soccer's ability. Anoxia reduced about 3% of total distance including running, and walking. The speed also reduced for 15%, including cardiac system, blood vessels and muscle when compare to sea level environment data (Billaut & Aughey, 2013, Buchheit et al, 2015, Garvican et al, 2013, Nassis, 2013). These kinds of situation, the athletics' performance in the latter round get lower. The form of energy used in the game is for the highest movement performance in the form of anaerobic energy. In the meantime, the result occurred from this sort of energy, caused a wasted product which called lactic acid. This waste was resulted from an incomplete oxidation and it will inhibit oxygen consumption after heavy activity.

Cold water immersion or bathing in ice water, a swimming pool or cryotherapy (cold therapy) is a process of recovery by staying in cold water (≤15° C / 59 ° F) during exercise or immediately after exercise for physical recovery (Bleakley et al, 2012). It may be little effect on the recovery but cold water immersion proves that it is an effective strategy for recovery (Bieuzen et al, 2013.) Cold water immersion can be applied for physical fitness recovery and relieve delayed onset muscular soreness (DOMS). Cold water immersion is a popular strategy for physical fitness recovery among sport scientists (Bleakley et al, 2012, Hohenauer et al, 2015).

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However, although there have been many studies on the area of rehabilitation and cold water immersion for soccer athletes It's just a simulation, not a real soccer match. However, it was found that in the research study, the cold water during the actual soccer match. There are still very few studies. Especially with regard to education patterns in hot-weather soccer matches and the first half-time where athletes immerse in cold water, there have not been many studies reported. This may be due to the time at half-time that is only 15 minutes, may be too little. However, if the first 15 minutes of the half-time break was useful, the coaches had to adjust the game of soccer and the athletes had time to recuperate by immersing in cold water to listen to the coach's explanation and change the game style strategy at the same time. It is something that should be done in the sports room as it will benefit the athletes to recover and understand the football strategy in the second half more easily.

Therefore, aim of our study was to evaluate the benefit of the cold water immersion during half break on physical body in soccer players. The simulation match game model is set as real as the competition in order to find out the result to apply to recover the physical body in athletes during the halftime of the competition which will affect the physical fitness in order to be ready to compete effectively.

Methods

Participants

Twenty male university soccer team athletes were participant in this study. They were chosen by purposive sampling, which then divided into 2 groups; control and cold water immersion group. Each position of player is divided equally by matching method that depend on the efficiency of oxygen consumption and were then randomized to cold water immersion and control group. All participants met the inclusion criteria as following: participants being healthy, there is no chronic disease and history of inflammatory drug used before the experiment. Written informed consents were obtained from all participants after they had been informed about the details, purpose and procedures of the study. The study was approved by the Center for Ethics in Human Research, Khon Kaen University.

Experimental design

Before collecting the data, the researcher summited the document asking for permission to use the location and materials, prepare place for experiment, training timetable for data collection, clarifying the training processes for the participant before signed a consent form.

A week prior to the test, all participants were tested for body composition and maximum aerobic capacity. The participants were divided into 2 groups, (n = 10 per group), equally each position by using the maximum oxygen consumption. The obtained values were calculated to find out the average maximum oxygen consumption test and dividing them equally according to the player's position after dividing samples into 2 groups.

Before the competition, both groups were collected blood samples and evaluated muscle pain level by visual analogue scale. After that warmed up for 30 minutes and then played the first half of the football match for 45 minutes. During the match, both groups were allowed to drink water freely. After the first half of the game, both groups rested, their second blood samples were collected, and muscle damage was measured within 5 minutes. The CWI group sat on the chair in cold water tank for 10 minutes with waist depth, temperature of water was 10 degrees Celsius, which was controlled by research assistants. The CG group sat and rest for 10 minutes and drinking cold water at a temperature of 10 degrees Celsius after 10-minute rest.

Before the second half, muscle pain was measured again. The players then competed in the second half for 45 minutes. After the end of the second half, both groups rested and their blood samples were collected, muscle pain was measured, and allowed to rest for 30 minutes. After finishing the match, the participants rest for 24 hours. Next day, the last blood samples were collected and then maximum aerobic capacity was measured.

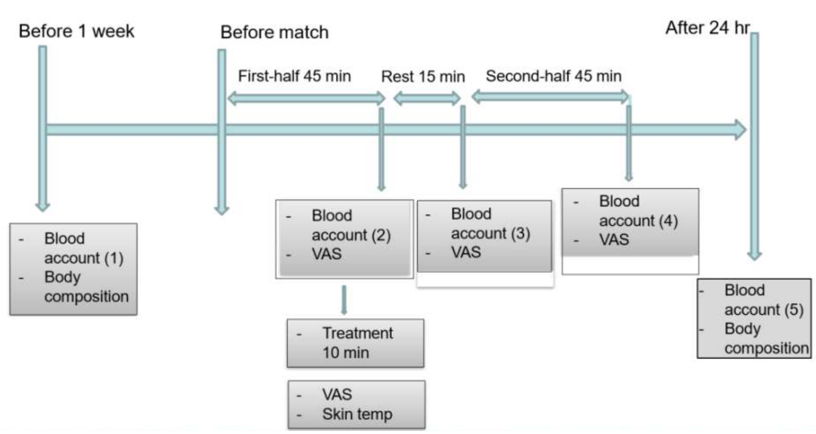

Figure 1. Outline testing schedule.

Measurement

Body Composition Measurement

Body weight (kg) and fat percentage were measured using a digital scale (Tanita, BWB0800, Allied) whereas height (cm) was measured by using the altimeter (Stadiometer, Harpenden, HAR 98.602, Holtain). For measuring the samples' height, the samples stood against on the ground, against the wall, looked forward, and then research assistant adjusted the height scale onto the top of the sample's head.

To measure weight and fat percentage, before measurement, digital scale, Omron HBF-306C muscle mass monitor was set to zero to measure muscle mass. The sample grabbed the handle of the monitor, waited for the processing completed and saved the data.

Blood Sampling and Analyses

10 ml of blood sample was collected for measurement of IL-6, lactate and creatine kinase (CK), that was performed 5 times. The blood obtained from antecubital vein then placed in a vacuum tube containing approximately 4 ml of anticoagulant (EDTA) mixture. Lactate plus test strips are single use devices that measure lactate in blood. To perform a test, insert a test strip into the meter and touch the strip to the blood sample.

The result is available in 13 seconds. Approximately 500 µl of blood as collected for analysis of white blood cells and neutrophils. Another part of blood was taken into a centrifuge (NK 400R, Germany) using speed of 3000 rpm, at 4 degrees Celsius for 10 minutes. The centrifuge blood was separated from the machine and stored in a storage tube for 500 microliters.

Plasma was stored in a vacuum tube without containing anticoagulants. The blood was set aside for 1 hour until the blood was agglutinated, then blood was taken into a centrifuge (NK 400R, Germany) at a speed of 3000 rpm at 4 °C for 10 minutes. 500 microliters serum was separated and stored in a refrigerator at -20 °C for analysis. Serum levels of IL-6 was measured by electrochemiluminescence immunoassay method (automatic analyzer Cobas e 411), creatine kinase (CK) was measured by UV-test method (automatic analyzer Cobas c 311).

Muscle pain test

Visual analogue scale (VAS) was implemented for muscle pain test using 10-centimeter straight tape with one end representing the value 0, meaning no pain whereas another end written number 10 referring to most painful. Measurement was performed by mark the position on this tape to show the severity of pain and then the value was recorded in centimeter for identifying pain ranged from 0 - 10.

Statistical analysis

Statistical analysis was performed using SPSS 19 (SPSS Inc.; Chicago, IL, USA). Data were expressed as mean(X) ± standard deviation (SD). The average of IL-6, Creatine kinase, and Lactic acid were compared before and after the experiment was analyzed using one way repeated ANOVA whereas Kruskal Wallis was used for Non – normal distribution. The mean of IL-6, creatine kinase, lactic acid, and muscle pain was compared between experiment and control groups using independent paired sample - t test.

Table 1. Athletes' characteristics in the 2 training groups.

Body composition parameters	**Control Group (CG = 8)**	**Cold Water Immersion Group (CWI = 8)**
Age (years)	21.33±0.50	21.60 ± 1.26
Weight (kg.)	65.95±9.90	69.75 ± 12.42
Height (cm.)	172.88±6.62	173.50±4.75
BMI (kg./ m.^{2})	24.10±0.71	24.15 ± 0.58
Fat (percent)	13.30±6.29	14.25±3.87
Muscular mass (kg)	53.54±5.68	56.51±8.26

Results

From table 1, body composition including age, body weight, height, body mass index, fat percentage, and muscle mass of control group, and cold water immersion group before testing. There was no significant difference between both groups.

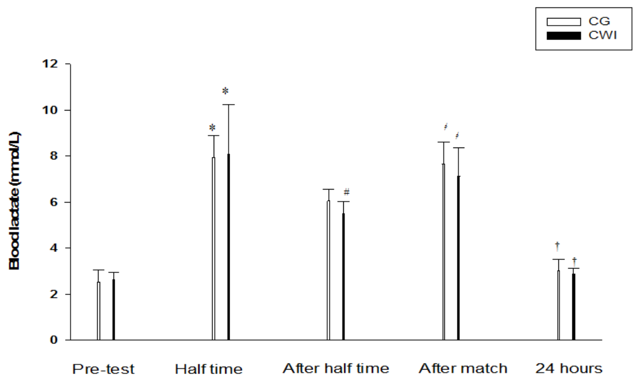

Figure 2. Blood lactate, at different time point of control group and cold water immersion group. Values are present as mean ± SD.
* $p < .05$ (pretest vs half time in the same group).
$^{\#}p < .05$ (half vs after half in CWI).
$^{ǂ}p < .05$ (after half time vs after match in the same group).
$^{\dagger}p < .05$ (after match vs 24 hours in the same group).

As showed in Fig. 2, when compared blood lactates of CG between pre-test and half time. It was found that blood lactate was increased significantly (p = .01). Moreover, it was found in the same pattern in CWI as well. CG, when compared blood lactate of during half time and after half time, there was no significant difference. For CWI, blood lactate in the half time (8.08 ± 2.16 mmol/L) and after half time (5.51 ± 0.52 mmol/L), there was decreased significantly (p = .01).

When compare blood lactate of CG between after half time (6.05 ± 0.52 mmol/L) and after match (7.66 ± 0.96 mmol/L), it was found that after match, lactate concentration was increased significantly when compare to after half time (p = .01).

After the first half (5.51 ± 0.52 mmol/L), lactate concentration was lower than after the match (7.13 ± 1.24 mmol/L). On the other hand, for CG, when compared lactate between after the match (7.66 ± 0.96 mmol/L) and 24 hours after the match (3.01 ± 0.50 mmol/L), there was decreased (p = .01). Moreover, when compared blood lactate between after the match (7.13 ± 1.24 mmol/L) and 24 hours after the match (2.88 ± 0.25 mmol/L), there decrease was a statistically significantly (p = .01). However, when compared blood lactates between control and CWI group, there was no significant difference.

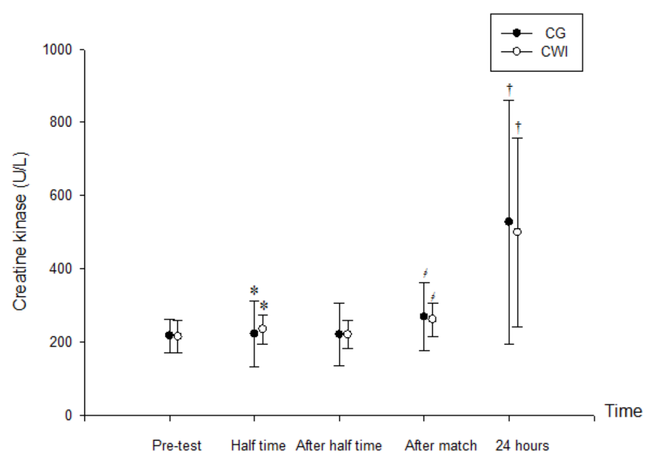

Figure 3. Creatine kinase, at different time point of control group and cold water immersion group. Values are present as mean ± SD. * $p < .05$ .05 (pretest vs half time in the same group). $^{ǂ}p < .05$ .05 (after half time vs after match in the same group). $^{\dagger}p < .05$ .05 (after match vs 24 hours in the same group).

As showed in Fig. 3, when compare creatine kinase activity in CG between pre-test and half time. It was found that there were increased significantly. Moreover, it was found in the same pattern in CWI as well. The CG and CWI, when compared creatine kinase of during half time and after half time, there was no significant difference. When compare creatine kinase of the CG between after half time and after the match, it was found that creatine kinase at after half time (221.33 ± 86.18 U/L) and after the match (269.13 ± 92.89 U/L), there increase was a statistically significant difference (p = .01). After the first half, (220.88 ± 37.97 U/L) and after the match (262.50 ± 45.56 U/L), creatine kinase activity was increased (p = .01).

On the other hand, for the CG, when compared creatine kinase (269.13 ± 92.89 U/L) and 24 hours after the match (528.38 ± 332.44 U/L), there increase was a statistically significant difference (p = .05). According to the figure 3, when compared creatine kinase after the match (262.50 ± 45.56 U/L) and 24 hours after the match (500.18 ± 257.18 U/L), within the CWI, there increase was a statistically significant difference (p = .01). However, when compared creatine kinase between CG and CWI group, there was no significant.

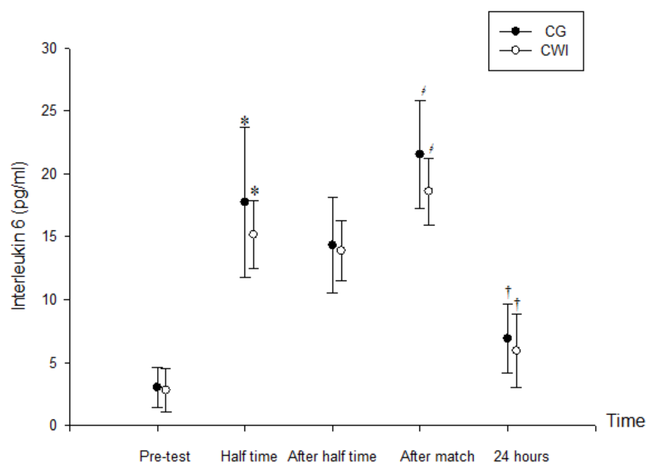

Figure 4. Interleukin 6, at different time point of control group and cold water immersion group. Values are present as mean ± SD. * p < .05 .05 (pretest vs half time in the same group). ‡p < .05 .05 (after half time vs after match in the same group). †p < .05 .05 (after match vs 24 hours in the same group).

Interleukin 6 of CG between pre-test (3.03±1.62 pg/ml) and half time (17.74±5.94 pg/ml). It was found that interleukin 6 increase were significantly difference (p = .05). Moreover, it was found in the same pattern in CWI as well. The CG, when compared interleukin 6 of during half time (17.74±5.94 pg/ml). and after half time (14.31±3.78 pg/ml), there was no significant difference. For the CWI, there was no significant difference too. When compare interleukin 6 of the CG after half time and after the match, it was found that interleukin 6, after the rest during the half time (14.31 ± 3.78 pg/ml) and after the match (21.54 ± 4.30 pg/ml) there increase was a statistically significant difference (p = .01). After the first half (5.51 ± 0.52 mmol/L), interleukin 6 after the first half (13.87 ± 2.41 pg/ml), and after the match (18.59 ± 2.64 pg/ml), there increase was a statistically significant difference (p = .01). On the other hand, for CG, when compare interleukin 6 after the match (21.54 ± 4.30 pg/ml) and after the first half (6.90 ± 2.73 pg/ml), there was decreased (p = .01). Interleukin 6 level between after match (18.59 ± 2.64 pg/ml) and 24 hours after match (5.93 ± 2.89 pg/ml) within CWI group, there was decreased. However, when compared interleukin 6 between control and CWI group, there was not difference as shown in figure 4.

Table 2. Muscle pain at different time point of control group and cold water immersion group. Values are present as mean ± SD.* p < .05 when comparing between half time and after half time in the same group. ᵗ p < 0.05 when comparing the difference between experimental groups

	Half time	After half time	After match
Control group (CG = 8)			
muscle pain	5.25±0.89	3.00±0.76	6.88±1.36
Cold water immersion groups (CWI = 8)			
muscle pain	5.00±1.20	0.88±0.83* ᵗ	6.38±1.30

The perception of muscle pain of the CG at the first half and after the first half had no significant difference. However, when compared the perception of muscle pain of the CWI at the first half (5.00 ± 1.20) and after the first half rest (0.88 ± 0.83), there decrease was a statistically significant difference (p = .01). as shown in table 2. When compared the perception of muscle pain between the CG and the CWI. It was found that muscle pain perception of the CG (3.00 ± 0.76) and CWI (0.88 ±
0.83) were less than CG with statistical significance difference (p = .01).

Discussion

According to the results this research, it was found that the concentration of blood lactate after cold water immersion during halftime of soccer match was lower when compare to control group. In addition, the level of muscle pain perception after cold water immersion was lower than before starting the match. When considering the result between group, it was found that blood lactate concentration after cold water immersion during halftime in soccer match were different from before immersion. Our result was consistent with study of Crowe in 2007 reported that when exercising heavily and resting by soaking in cold water at a temperature between 13-14 °C for 15 minutes, blood lactate was decreased with a statistical significance when compared with the control group. It can be seen that immersion in cold water at a temperature at 10 °C for 10 minutes, provides a positive effect on the physiological response. Cold water immersion activates the contraction of blood vessels as a result of vasoconstriction and lower blood flow (Gregson et al, 2011). In other words, lower amount of blood lactate in the blood, then the physical fatigue was also reduced and football players are ready to play in the second half faster. This indicates that resting during halftime while soaking the legs in cold water at a temperature at 10 °C for 10 minutes, that help the athletes' body return to normal faster. Moreover, it enhances pH balance faster which result in accumulating sufficient energy in the body including glucose and glycogen that returned to be accumulated in the blood and muscles appropriately.

Soaking in cold water is similar to an active recovery mechanism which is able to spread the heat of the water better than in the air. Heat conduction rate of water to air is about 24:1, which means that when soaking legs in cold water, the body recovers faster than just sitting and the body also are compensated with energy to return the same professionally. Another mechanism that decreases the concentration of lactate in the blood, it might be due to coldness that causes peripheral vasoconstriction, resulting in reduction of blood flow to main working muscles.This causes a body temperature decrease as well as resists inflammation. Consequently, it helps to increase muscle recovery effectively. It has been reported that when body temperature increases 2 °C, if there is no process to reduce body heat, the perception of fatigue will begin faster. An ability of athletes to continue playing will decrease (Golzalez et al, 1999). In addition, after the match, the soccer players soak in cold water at 10 ° C for 10 minutes which resulted in slowing down of muscle fatigue. Cold water also decreases rate of peripheral blood flow, because of the contraction of the blood vessels under skin (Ascensao, 2011). This increases the cardiac preload rate of blood flow return into the heart. In other words, it increases the central blood volume that results in increasing in the amount of stroke volume and cardiac output. (Wilcock et al, 2006) Consequently, there is adequate blood supply to the muscles for exogenous and intracellular exchange, and potentially eliminates waste produced in muscular systems, such as lactic acid. (Vaile J., 2008) Then, it may provide a positive effect on the level of physical ability capacity later.

In addition, cold water immersion affects perception of muscle pain. According to the results of the experiment, it was found that the perception of muscle pain of the cold water immersion group during the first half (5.00 ± 1.20) and after the half-time (0.88 ± 0.83) was significantly difference at the 0.05 level. Moreover, it was also found that the muscle pain perception of control group (3.00 ± 0.76) and cold water immersion group (0.88 ± 0.83) were statistically significant. The explanation might be that reduced pain perception is due to analgesic effect of cold water that decreases speed of nerve impulses and stimuli (Algafly & George, 2007). The spinal cord contains a neurological gate that either blocks pain signals or allows them to continue on to the brain. It could reduce the communication between sensory nerves which respond specifically to stimuli that may damage a tissue through sympathetic nervous system (Wilcock et al, 2006; Eston & Peters, 1999; Coffey el al, 2004). Another pain reduction theory suggests that the effectiveness of cold water, to reduce backache after exercise and fatigue is a psychological perception (e.g., the placebo effect) indicating that an individual feels awake during and/or after immersion in cold water, resulting in reducing pain sensitivity (Bieuzen et al, 2013, Leeder et al, 2012). This theory was supported by recent and extensive reviews as being reported that cold water immersion reduced pain perception after exercise and reduce the perception of fatigue in athletes (Hohenauer et al, 2015). Current finding suggest that these physiological factors are not important. Specific inflammatory factors and stress of muscle cell after exercise; cold water immersion improves perception of fatigue and muscle soreness. Then, it helps to increase muscle function and performance after exercise. Cold water also reduces clinical symptoms of inflammation such as swollen limbs and edema after exercise (Yanagisawa, et al. 2010).

According to the results of the present study, there were no differences in inflammatory variables including creatine kinase and interleukin-6 between both groups. Inflammation occurs four times during a soccer game before returning to normal in 24 hours. The application of cold water immersion had little effect on reducing the concentration of inflammatory indicators after the match. However, cold water immersion immediately had little effect on eliminating these inflammatory indicators compared with the traditional method (providing carbohydrates with stretching during the match). Creatine kinase is a commonly used as blood biomarker that indirectly indicates muscle damage after exercise with high intensity (Greenham G. et al, 2018). Serum CK measures indicate what is relevant with the amount of CK released, enzyme activity level of released CK and the removal rate from the serum (Thompson HS. Et al, 2006). The instability during the increases in CK after exercise show that the appearance of CK probably not be totally the indicator of muscle cell damage (Magal M. et al, 2010) and it could be affected by sex, ethnicity and age (Baird MF. et al, 2012). Increasing of creatine kinase concentration is consistent with the results of the study of Bailey (2007) that CK intensity may slightly drop 10 hours after concentric exercise and never reach the baseline within 24 hours. Consistent with this research, it was found that CK of both groups after 24 hours of competition were increased when compared to after match. The response pattern is an indicator stating that both concentric and eccentric exercises cause minor damage to membrane tissues after the match. The transition period of fatty acid binding protein (FABP) and myoglobin after the match, transition period of FABP and myoglobin after the match were parallel, normally decrease 6 hours after the match. The rapid disintegration of FABP and myoglobin compared to the consistent increase of CK indicates that an inflammatory indicator is appropriate for measuring changes in muscle tissue permeability. In consecutive games is reasonable to assume that injury occurred from the mechanism of free radical leakage during exercise may amplify cell membrane leakage and allow protein to flow into the circulation system after exercise. Although this research did not measure free radical concentration, restricted radicals and metabolic reducing the integrity of membranes.

At the initial stage, plasma IL-6 level was increased as responding to exercise which is the result of muscle damage that occurs during strenuous exercise. However, later studies proved that myocytes are responsible for production and releasing IL-6 in order to response to muscle contraction. Therefore, muscle injury is not necessary for increased IL-6 levels after exercise (Pedersen BK, 2009). The severity of delayed onset muscle soreness (DOMS) occurs when exercise with unfamiliar resistance and will continue until reaching the highest concentration, especially when there is an abnormal contraction. Doing the same exercise activity repeatedly will reduce the occurrence of DOMS and this is called the repeated exercise result. Only few times of this activity can provide adequate protection against DOMS (Hody, et al, 2019). Therefore, in the current study, intensity of exercise is remained at the lowest level and focused on enhancing familiarization to avoid muscle damages.

Recent evidence suggests that Tumor necrosis factor-alpha (TNF-α) is a driver in metabolic syndrome, which stimulates IL-6 production. IL-6 of muscles plays a greater role in metabolism than inflammation (Pal M., Febbraio M. A., Whitham M., 2014). IL-6 functions inside the skeletal muscle (autocrine or paracrine action) and is released into circulation to function in peripheral organs. IL-6 helps to eliminate glucose and lipoprotein from circulatory system and increases insulin sensitivity. The circulating levels of anti-inflammatory cytokine receptors, IL-1 receptor antagonist (IL-1ra), and IL-10 will follow the increase of IL-6, which is effective as anti-inflammatory IL-6 (Paola, et al, 2018).

Conclusions

Cold water immersion during halftime in soccer player might be a choice of tool to activate body rehabilitation that has been proven appropriated by many specialists in sports and exercise science. In other words, 10 minutes of immersion in cold water at 10 degrees Celsius reduce rate of fatigue. It also reduces the level lactic acid in the blood effectively including cold water immersion can also help reduce the level of muscle soreness as well. Therefore, a cold water immersion during halftime in soccer is an option for sports coaches who want to recovery their athletes between matches. Therefore, it should be promoted and applied to the rehabilitation of athletes.

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Conflicts of interest The authors declare that they have no conflict of interest.

References

Algafly AA, George KP (2007). The effect of cryotherapy on nerve conduction velocity, pain threshold and pain tolerance. Br J Sports Med 41: 365–369; discussion 369.

Ascensao, A. (2011). Effects of cold water immersion on the recovery of physicalPerformance and muscle damage following a one-off soccer match. Journal of Sports Sciences, February 1st 2011; 29(3): 217–225

Bailey, D. M., Erith, S. J., Griffin, P. J., Dowson, A., Brewer, D. S.Gant, N. 2007. Influence of cold-water immersion on indices of muscle damage following prolonged intermittent shuttle running. *Journal of Sports Sciences*, 25: 1163–1170.

Baird MF, Graham SM, Baker JS, Bickerstaf GF. Creatine kinase and exercise-related muscle damage implications for muscle performance and recovery. J Nutr Metab. 2012;2012:1–13.

Bangsbo, J. (1994). The physiology of soccer with special reference to intense intermittentexercise. Acta physiologica Scandinavica. Supplementum, 619, 1-155.

Bangsbo, Jean ; & Krustrup, Peter. (2001). Physiological Demand Top Class Soccer Refereeing in Relation to Physical Capacity. Effect of Intense Intermittent Exercise Training. Journal of Sports Science. 19:881-891.

Bieuzen, F., Bleakley, C.M., and Costello, J.T. (2013). Contrast Water Therapy and Exercise Induced Muscle Damage: A Systematic Review and Meta-Analysis. PLoS One, 8(4): e62356.

Billaut, F. & Aughey, R. J. (2013). Update in the understanding of altitude-induced Limitations to performance in team-sport athletes. British Journal of Sports Medicine, 47, (Suppl1), i22-i25.

Bleakley, C., McDonough, S., Gardner, E., Baxter, G.D., Hopkins, J.T., & Davison, G.W. (2012). Cold-water immersion (cryotherapy) for preventing and treating muscle soreness after exercise. Cochrane Database Syst Rev. 15(2). CD008262.
Buchheit, M. (2012). Repeated-sprint performance in team sport players: associations withmeasures of aerobic fitness, metabolic control and locomotor function. InternationalJournal of Sports Medicine, 33, (3), 230-239.
Buchheit, M., Hammond, K., Bourdon, P. C., Simpson, B. M., Garvican-Lewis, L. A., Schmidt,W. F., Gore, C. J. & Aughey, R. J. (2015). Relative Match Intensities at High Altitudein Highly-Trained Young Soccer Players (ISA3600). Journal of Sports Science &Medicine, 14, (1), 98-102.
Coffey V, Leveritt M, Gill N (2004) Effect of recovery modality on 4-hour repeated treadmill running performance and changes in physiological variables J Sci Med Sport 7: 1–10.
Eston R, Peters D (1999) Effects of cold water immersion on the symptoms of exercise-induced muscle damage. J Sports Sci 17: 231–238.
Garvican, L. A., Hammond, K., Varley, M. C., Gore, C. J., Billaut, F. & Aughey, R. J. (2013).Lower Running Performance and Exacerbated Fatigue in Soccer Played at 1600 m.International Journal of Sports Physiology and Performance, 9, (3), 397-404.
Greenham G, Buckley JD, Garrett J, Eston R, Norton K. Biomarkers of physiological responses to periods of intensifed, non-resistance-based exercise training in well-trained male athletes: a systematic review and meta-analysis. Sports Med. 2018;48(11):2517–48.
Gregson, W., Drust, B., Atkinson, G. & Di Salvo, V. (2010). Match-to-match variability ofhigh speed activities in premier league soccer. International Journal of SportsMedicine, 31, (4), 237-242.
Gregson, W., Black, M.A., Jones, H., Milson, J., and Morton J. (2011). Influence of cold water immersion on limb and cutaneous blood flow at rest. American Journal of Sports Medicine, 39: 1316–1323.
Gonzalez-Alonso, J., Teller, C., Andersen, S. L., Jensen, F. B., Hyldig, T. & Nielsen, B. (1999). Influence of body temperature on the development of fatigue during prolonged exercise in the heat. Journal of Applied Physiology (1985), 86, (3), 1032-9.
Hody S, Croisier J-L, Bury T, Rogister B and Leprince P. (2019). Eccentric Muscle Contractions: Risks and Benefits. Front. Physiol. 10:536. doi: 10.3389/fphys.2019.00536.
Hohenauer E, Taeymans J, Baeyens J-P, Clarys P, Clijsen R (2015). The Effect of Post-Exercise Cryotherapy on Recovery Characteristics: A Systematic Review and Meta-Analysis. PLoS ONE 10(9): e0139028. doi:10.1371/journal.pone.
Leeder J, Gissane C, van Someren K, Gregson W, Howatson G (2012) Cold water immersion and recovery from strenuous exercise: a meta-analysis. Br J Sports Med 46: 233–240.
Magal M, Dumke CL, Urbiztondo ZG, Cavill MJ, Triplett NT, Quindry JC, et al. Relationship between serum creatine kinase activity following exercise-induced muscle damage and muscle fbre composition. J Sports Sci. 2010;28(3):257–66.
Martin Pal, Mark A Febbraio and Martin Whitham. (2014). From cytokine to myokine: the emerging role of interleukin-6 in metabolic regulation. Immunology and Cell Biology (2014) 92, 331–339.
Mohr, M., Mujika, I., Santisteban, J., Randers, M. B., Bischoff, R., Solano, R., Hewitt,A.,Zubillaga, A., Peltola, E. & Krustrup, P. (2010). Examination of fatigue developmentin elite soccer in a hot environment: a multi-experimental approach. ScandinavianJournal of Medicine & Science in Sports, 20, (3), 125-132.
Mohr, M. & Krustrup, P. (2013). Heat Stress Impairs Repeated Jump Ability After Competitive Elite Soccer Games. Journal of Strength and Conditioning Research, 27, (3), 683-689.
Nassis, G. P. (2013). Effect of altitude on football performance: Analysis of the 2010 FIFAWorld Cup data. Journal of Strength & Conditioning Research, 27, (3), 703-707.
Paola Italiani , Ilaria Puxeddu , Sabrina Napoletano , Emanuele Scala , Daniela Melillo , Simone Manocchio , Antonella Angiolillo , Paola Migliorini , Diana Boraschi , Emilia Vitale and Alfonso Di Costanzo. (2018). Circulating levels of IL-1 family cytokines and receptors in Alzheimer's disease. Italiani et al. Journal of Neuroinflammation. 15:342.
Pedersen, BK. (2009). Muscle as an endocrine organ: IL-6 and other myokines. J Appl Physiol 107: 1006–1014, 2009.
Thompson HS, Scordilis SP, De Souza MJ. Serum creatine kinase activity varies with ovulatory status in regularly exercising, premenopausal women. Horm Res Paediatr. 2006;65(3):151–8.
Vaile, J., Halson, S., Gill, N. and Dawson, B. (2008). Effect of cold water immersion onrepeat cycling performance and thermoregulation in the heat. Journal of SportsScience. March; 26(5) : 431-440
Wilcock, I. (2006). The effect of water immersion, active recovery and passive recovery on repeated bouts of explosive exercise and blood plasma. Master of Health Science:Auckland University of Technology.
Wilcock, I.M., Cronin, J.B., and Hing, W.A., (2006). Physiological response to water immersion: A method of recovery? Sports Medicine, 36(9), pp.747-765.
Yanagisawa, O., Takahashi, H., Fukubayashi., T., (2010). Effects of different cooling treatments on water diffusion, microcirculation, and water content within exercised muscles: evaluation by magnetic resonance T2-weighted and diffusion-weighted imaging. J Sports Sci. 2010 Sep;28 (11):1157-63.