The Effects of Cold Water Immersion on Anaerobic Power, Dynamic Balance and Muscle Activation After a karate kumite fighting in Female Karateka

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ABSTRACT: Many athletes are using specific techniques to minimize fatigue and accelerate recovery processes. Cold water immersion (CWI) is one of the most popular interventions used by athletes to potentially return to their pre-fatigue performance level. The purpose of this study was to investigate the effects of CWI on anaerobic performance, balance and muscle activation of female karateka after a simulated match. 15 young female karateka (age: 18.7±1.7 years, body mass: 55.5±6.3 kg, height: 165±5.1 cm) with at least three years’ experience in karate kumite fighting were included in the study. After three round 3-minute competition, participants were grouped into a CWI group (20 min at 12±1°C) and a control group (CTL). Anaerobic power (30 s Wingate test), and dynamic balance (Star-Excursion test) were measured before the competition and 24 h after intervention. Surface electromyography (EMG) was sampled from quadriceps femoris muscles. Peak normalized muscle activation levels and force were identified during maximal isometric test. A significant decrease in the anaerobic performance after the competition was observed for both groups (p<0.05). CWI were effective in enhancing the anaerobic performance after competition compared with the CTL. Dynamic balance decreased for two groups, although CWI resulted in the smallest reduction in balance. There was a significant difference in peak and mean RMS values of the EMG in Rectus Femoris but not Vastus muscles after the CWI intervention when compared to CTL (p<0.05). CWI improve recovery related to dynamic balance and anaerobic performance of karate kumite fighter. It can be concluded that CWI appears to promote muscle activation and reduce fatigue that is related to better performance in 24 hours post intervention.

KEY WORDS cold water immersion, anaerobic power, dynamic balance, karate kumite fighting

INTRODUCTION

Karate is a competitive martial art that fighter use almost all muscles during competition and it is classified as a high-intensity event [1, 2]. In Karate kumite, two competitors face each other under strict rule (3 min distance for male, and 2 min for female athletes), who need to high fitness levels[3]. Success-related fitness components usually include strength, aerobic fitness, speed, agility, power, balance, coordination and reaction time [4]. Anaerobic alactic metabolism is the predominant energy system used for Karate kumite. Fighting consists of numerous repetitions of kick and punch and has an activity pattern comparable to high intensity interval training [1, 4]. The recovery period between matches is typically 15-30 min allow athlete to return to their pre-fatigue performance level [5]. Recovery between matches is a key determinant of successful performance of kumite and allowing karate fighter to compete optimally. Inadequate recovery between matches induce high level of fatigue experienced by some of kumite fighters.
Karate competitor are progressively using particular modality to improve recovery and choosing suitable recovery type is a major concern for many athletes and coaches. Cold water immersion (CWI) is a form of cryotherapy that is widely used by many athletes for maintaining subsequent performance and reducing muscle soreness [6]. The principle of CWI is to immerse a body segments, or full body in water at temperatures below 15°C for a duration of 10 to 20 minutes [7]. The possible benefits of CWI are related to physiological response to reduce temperature and increase Hydrostatic pressure. Hydrostatic pressure increase blood circulation that result in eliminating of metabolic waste products and delivering oxygen, nutrients and hormones to fatigued muscle. Cold is associated with vasoconstriction and a relative decrease in local metabolism, blood flow and nerve conduction velocity, thereby reduces muscle fibers’ O usage, fluid accumulation (edema) and post-exercise inflammation and hypoxic damage [8].

There is little study about the effectiveness of this modality on recovery of performance in sport-specific settings like as Karate kumite fighting. Much of the research in this area show incompatible results since some investigations report positive results while others report no considerable effects. The beneficial effects of CWI have been reported for many forms of exercise such as cycling, running, climbing, and jumping and are not limited to particular time after exercise or competition [9]. Based on the literature, immersion in 10–15 C water is the Optimal temperature for recovery after exercise[9]. Nevertheless, there is inadequate data to assert CWI following Karate kumite competition. To date, no study has been investigated the effect of CWI on anaerobic power and balance of kumite fighter and the neuromuscular mechanism responsible for improvement in recovery following a competition.

Therefore, the purpose of this study was to investigate the impact of CWI on dynamic balance and anaerobic power, as well as neuromuscular changes in karate kumite fighter after a competition.

**METHODS**

**Participants**

Sixteen female karate kumite fighter (age: 18.7±1.7 years, body mass: 55.5±6.3 kg, height:165±5.1 cm) volunteered to participate in the present study. These well-trained athletes (10 h per week) belonged to Mazandaran province team from the National Iranian Karate League. Athletes trained four days per week and all had participated in the competition 3 weeks before the study. subjects were verbally informed of the reasons and objectives for the study, and provided written informed consent document. The study was approved by the Shomal University Ethics Committee.

**Procedures**

All athletes were familiar with all testing procedures and they performed three round 3-minute kumite fighting competition against the matched weight competitor. Verbal encouragement was provided by the researchers during competition. Competition was followed by one of the two recovery modalities, an inactive recovery (CTL) or a cold water immersion (CWI) intervention. Athletes were asked to refrain from exercise for 48 h before the study and to keep away from any ergogenic aids or drugs, during the experimental period. Measurement process were conducted before the competition (Pre-test) and 24 h after the recovery modality (Post-test).

**CWI Protocol**
During the recovery, the control group rested passively in a comfortable position. The CWI group, in a standing position, were immersed up to the waste in a cold-water plunge pool set at 12 ± 1 C for 20 min. The immersion duration was controlled by a stopwatch and the temperature was controlled by putting ice and stirring the water, and constantly evaluated by a thermometer with ±0.2°C accuracy.

Anaerobic Power

Wingate test (WT) was done on a friction-loaded cycle ergometer (Monark model 864, Sweden). The seat height was adjusted for each subject. The WT consists of a 30 s maximal sprint cycling bout against a resistance determined by the body mass (0.087 kg·kg⁻¹ body mass). Subjects were verbally encouraged during the test. The highest power output (Peak Power) and the mean power (Mean Power) were recorded at the end of the test. The Fatigue Index was equal to the difference between the highest (P peak) and lowest power (P low) divided by the highest power.

Dynamic Balance

The Star Excursion Balance Test was performed with the participants standing in the middle of a grid laid on the floor formed by 8 lines extending out at 45° from the center of the grid. The subjects were requested to reach and light touch along each of the 8 lines (anterolateral, anterior, anteromedial, medial, posteromedial, posterior, posterolateral, and lateral), and return leg back to the center, while maintaining a single-leg stance. A tape measure was used to quantify the distance (cm) from the center point to the point that each subject reached. Participants performed three trials in each of the eight directions and the averages of them was calculated. These data were then normalized to leg length.

Electromyography

For recording of electromyography, the DataLINK (Biometrics Ltd, United Kingdom) was used. EMG signals were amplified and sampled at 1000 Hz. The DataLINK record both a low-pass filter at 450 Hz and a high-pass, third-order filter at 18 dB per octave. The EMG signals of the rectus femoris (RF), vastus lateralis (VL), and vastus Medialis (VM) were measured during the experimental procedure. The skin was shaved and cleaned with 70% alcohol to reduce skin impedance and the electrodes were fixed over the muscle bellies of the dominant limb following the standards of the international protocol [10]. A reference electrode was positioned in the tuberosity of the tibia with adhesive. With verbal encouragement by examiner, participants performed maximal voluntary contraction (MVC) of isometric one leg extension for 5 s with 100° knee joint angles. The raw EMG signals were checked visually for artifacts. The root mean square filter was applied with a DataLINK software. For the analysis, the peak RMS was considered because higher levels of RMS showed greater muscle activity. For normalization, the peak RMS of pre-test signal was considered as reference data.

Statistical analysis

All data are presented as Mean±SD. An Analysis of covariance (ANCOVA) was used to adjust for pre-test differences in two groups. Data were analysed using IBM SPSS statistics (version 23, SPSS Inc., Chicago, IL). Differences were accepted as significant at P<0.05.

RESULTS

All subjects completed the procedure without any side effects from the CWI. Mean ± Standard
Deviation (SD) for all SEBT directions in pre and post intervention are presented in Table 1.

| Dependent variable | Group | Pre-test Mean | SD  | Post-test Mean | SD  |
|--------------------|-------|---------------|-----|----------------|-----|
| Ant                | CTL   | 66.32         | 3.92| 63.45          | 4.58|
|                    | CWI   | 65.29         | 3.75| 64.27          | 3.77|
| Ant-Lat            | CTL   | 66.62         | 4.04| 62.66          | 3.50|
|                    | CWI   | 64.90         | 3.04| 62.38          | 2.47|
| Lat                | CTL   | 74.44         | 5.27| 72.85          | 5.58|
|                    | CWI   | 67.12         | 3.03| 66.21          | 4.60|
| Pos-Lat            | CTL   | 78.07         | 4.91| 76.54          | 5.39|
|                    | CWI   | 73.09         | 6.32| 72.77          | 6.06|
| Pos                | CTL   | 77.80         | 8.51| 75.54          | 8.97|
|                    | CWI   | 71.19         | 8.60| 70.40          | 8.62|
| Pos-Med            | CTL   | 84.96         | 7.31| 83.59          | 7.32|
|                    | CWI   | 77.13         | 5.15| 76.37          | 4.95|
| Med                | CTL   | 79.97         | 5.78| 78.12          | 6.50|
|                    | CWI   | 76.33         | 2.19| 75.09          | 1.86|
| Ant-Med            | CTL   | 70.97         | 6.31| 69.49          | 6.17|
|                    | CWI   | 68.79         | 7.59| 67.82          | 7.43|

For the Anterior and posterior direction, a better recovery was observed, favoring the CWI intervention (F = 8.721, p < 0.05, F = 6.594, p < 0.05 respectively). No significant differences were observed between groups in other directions of SEBT (p > 0.05).

For Mean Power (Figure 2) and Fatigue Index (FI) (Figure 3), there was a better recovery for the CWI group compared to CTL (F = 5.670, p < 0.05, F = 4.903, p < 0.05 respectively). For Peak Power (Figure 1) there was no difference in recovery between groups (p > 0.05).

There is a significant difference between two group in normalized RMS value (normalized to peak RMS of pre-test signal) of Rectus Femoris (F = 4.920, p < 0.05). Beneficial effect in muscle activation were associated with CWI in Rectus Femoris (Figure 4), but not in Vastus Lateralis and Vastus Medialis (Figure 5 & figure 6).
DISCUSSION

The results of this study showed that CWI may play a role in improving recovery between consecutive combats and preventing fatigue in subsequent bouts of fighting. Because of rapid acceleration and deceleration of body segments, karate kumite fighter need to muscle explosive power. Therefore, karateka require higher levels of anaerobic power in upper and lower limb. Previous study reported that anaerobic power was higher in international karate athletes than national level karateka[4]. The results of the current study showed that Mean Power and Fatigue Index (FI) measured through the Wingate test was positively affected by CWI after 24 h after the recovery modality. There was no difference in Peak Power between CWI and CTL groups. Schniepp et al. and Crowe et al. reported that maximum and average power was negatively affected by CWI (compared to the passive rest) when performance tests were one hour apart. The results of these previous studies showed that athletes need to consider the timing of events when deciding whether or not to employ CWI recovery[11, 12]. Previous study suggested that CWI caused peripheral vasoconstriction and a decrease in blood flow to the active muscles. Hypothetically, reduction in muscle blood flow can be cause an anti-inflammatory effect and help to muscle recovery[12]. Furthermore, it is shown that
reduction of core muscle temperature led to decrease muscle strength and power\cite{12}. When the kumite fighter must compete again after a short time of CWI, this reduction in muscle blood flow and temperature cause adverse effect on karate performance. However, when performance tests or competition were done after 24 h of using CWI, subsequent anaerobic power and capacity may be improved. In line with these findings, Lane et al. reported that CWI enhance recovery for intermittent cycling when 24 hours elapsed between tests\cite{13}. In this study, CWI may have helped to maintain power after exhausting competition through direct and indirect mechanisms. Cold exposure inhibits the activity of group III and IV afferents in skeletal muscle and decreases the accumulation of lactic acid (LA) during muscle activities \cite{14}. LA stimulates group III and IV afferents in skeletal muscle, resulting in perceptions of fatigue and pain \cite{15}. By inhibiting the activity of group III and IV afferents and reducing lactic acid accumulation in muscle after competition, CWI may have reduced the perceptions of fatigue. In turn, this could have allowed the participants to produce and maintain greater power during Wingate test following CWI.

In the present study, the effect of CWI on the muscle activation during maximal voluntary contraction of knee extension was assessed using the EMG technique. Muscle activation of rectus femoris (the mean RMS of EMG normalized by the peak RMS of pre-test signal) was improved after cold water immersion compared to the control group, whereas no difference was observed in the Vastus Lateralis and Vastus Medialis muscles. In detail, the effect of CWI on the muscle activation was more clearly observed in the RF compared to the VM and VL. Probably, the greater percentage of the fast twitch fiber in VM and VL rather than in the RF\cite{16} and might explain this observation. Also this finding can be explained by difference in cooling the superficial (RF) and deep muscles (VL and VM). Because the ST fibers have greater cold sensitivity and lower power output in cold, less cold sensitive and more powerful FT fibers are recruited \cite{17}. Based on previous researches, the increase of the RMS level might indicate the more muscle activity and muscle fiber recruitment. Macedo et al, reported that a decrease was observed in basketball player for the peak RMS up to 30 min of reheating after cold water immersion. They suggested that a decrease in temperature, induced by cryotherapy, could cause changes within the CNS, leading to a decrease in muscle activity\cite{18}. Regarding the RMS of EMG, there has been more variable observation in references which reported increased or decreased amplitudes in cold environment \cite{16}. This disagreement could be explained by different protocols including exercise type, cooling procedure, and selected muscle groups.

As the karateka try to acquire complex motor tasks, postural control and balance ability may be improved. high-level karateka have the ability to keep their body stable while applying a huge amount of force \cite{19}. The kumite is more demanding than kata in terms of dynamic balance, as it requires technical and physical abilities to be expressed at their best during unpredictable situations, according to the fighting conditions \cite{20}. In this study, competition fatigue negatively affected dynamic balance. These findings are consistent with findings from several studies of subjects who displayed impaired dynamic balance in a
fatigued state. Fatigue alters joint stability by increasing joint laxity and by causing sensorimotor and biomechanical deficits, such as reduced muscle strength and activity and altered proprioception and kinematics [21]. It was assumed that these factors attenuated by cold exposure and fatigue-induced changes in dynamic balance was decreased. In the present study, there were a significant positive effects of CWI on anterior and posterior direction of SEBT test. Probably, both anterior and posterior are the most used and impaired direction of dynamic balance in kumite fighting and CWI had the most positive impact on them. These results are not consistent with Kernozek et al. and Macedo et al. who showed significant increase in the balance oscillations along the anterior-posterior direction (X-axis), submitted to CWI at 4°C for 20 min. they suggested that athletes should not return to competition after 30 min being submitted to cryotherapy[18, 22]. In our study, athletes were examined again after 24 h of CWI. It means that, after one day, not immediately, cold water immersion appears to be useful for recovery of karate kumite fighting.

CONCLUSION

In summary, the findings of the present study indicate that cold water immersion after a Karate kumite competition had a beneficial effect on anaerobic performance and dynamic balance in 24 hours post intervention. It can be concluded that CWI may be slightly better than passive recovery in the attenuating fatigue and recovering performance in female kumite fighter.

REFERENCES

1. Doria, C., et al., Energetics of karate (kata and kumite techniques) in top-level athletes. Eur J Appl Physiol, 2009. 107(5): p. 603-10.
2. Beneke, R., et al., Energetics of karate kumite. Eur J Appl Physiol, 2004. 92(4-5): p. 518-23.
3. Mori, S., Y. Ohtani, and K. Imanaka, Reaction times and anticipatory skills of karate athletes. Hum Mov Sci, 2002. 21(2): p. 213-30.
4. Chaabene, H., et al., Physical and physiological profile of elite karate athletes. Sports medicine, 2012. 42(10): p. 829-843.
5. Tabben, M., et al., Physiological and Perceived Exertion Responses during International Karate Kumite Competition. Asian Journal of Sports Medicine, 2013. 4(4): p. 263-271.
6. Sánchez–Ureña, B., et al., The use of continuous vs. intermittent cold water immersion as a recovery method in basketball players after training: a randomized controlled trial. The Physician and Sportsmedicine, 2017. 45(2): p. 134-139.
7. Almeida, A.C., et al., The effects of cold water immersion with different dosages (duration and temperature variations) on heart rate variability post-exercise recovery: A randomized controlled trial. Journal of Science and Medicine in Sport, 2016. 19(8): p. 676-681.
8. White, G.E., S.G. Rhind, and G.D. Wells, The effect of various cold-water immersion protocols on exercise-induced inflammatory response and functional recovery from high-intensity sprint exercise. European Journal of Applied Physiology, 2014. 114(11): p. 2353-2367.
9. Versey, N.G., S.L. Halson, and B.T. Dawson, Water Immersion Recovery for Athletes: Effect on Exercise Performance and Practical Recommendations. Sports Medicine, 2013. 43(11): p. 1101-1130.
10. Stegeman, D. and H. Hermens, Standards for surface electromyography: The European project Surface EMG for non-invasive assessment of muscles (SENIAM). Enschede: Roessingh Research and Development, 2007: p. 108-12.
11. Schniepp, J., et al., The Effects of Cold-Water Immersion on Power Output and Heart Rate in Elite Cyclists. The Journal of Strength & Conditioning Research, 2002. 16(4): p. 561-566.
12. Crowe, M., D. O’Connor, and D. Rudd, Cold water recovery reduces anaerobic performance. International journal of sports medicine, 2007. 28(12): p. 994-998.
13. Lane, K.N. and H.A. wenger, effect of selected recovery conditions on performance of repeated bouts of intermittent cycling separated by 24 hours. The Journal of Strength & Conditioning Research, 2004. 18(4): p. 855-860.
14. Roberts, L.A., et al., Effects of cold water immersion and active recovery on hemodynamics and recovery of muscle strength following resistance exercise. American Journal of Physiology-Regulatory, Integrative and Comparative Physiology, 2015. 309(4): p. R389-R398.

15. Yanagisawa, O., et al., Evaluations of cooling exercised muscle with MR imaging and 31P MR spectroscopy. Med Sci Sports Exerc, 2003. 35(9): p. 1517-23.

16. Wakabayashi, H., T. Wijayanto, and Y. Tochihara, Neuromuscular function during knee extension exercise after cold water immersion. Journal of Physiological Anthropology, 2017. 36: p. 28.

17. Wakabayashi, H., et al., Effect of repeated forearm muscle cooling on the adaptation of skeletal muscle metabolism in humans. Int J Biometeorol, 2017. 61(7): p. 1261-1267.

18. Macedo Cde, S., et al., Cold-water immersion alters muscle recruitment and balance of basketball players during vertical jump landing. J Sports Sci, 2016. 34(4): p. 348-57.

19. Cesari, P. and M. Bertucco, Coupling between punch efficacy and body stability for elite karate. J Sci Med Sport, 2008. 11(3): p. 353-6.

20. Filingeri, D., et al., Is karate effective in improving postural control? ArchBudo, 2012. 8: p. 203-308.

21. Steib, S., et al., Fatigue-induced alterations of static and dynamic postural control in athletes with a history of ankle sprain. J Athl Train, 2013. 48(2): p. 203-8.

22. Kernozek, T.W., et al., The effect of immersion cryotherapy on medial-lateral postural sway variability in individuals with a lateral ankle sprain. Physiother Res Int, 2008. 13(2): p. 107-18.