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RESEARCH ARTICLE

The Effect of Two Different Recovery Methods on Muscle Damage after High-Intensity Exercise

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Abstract
The study aims to determine which of the two recovery methods would be more appropriate after high-intensity exercise. Eight professional volleyball players participate in this research. Firstly, the muscle damage exercise protocol was applied to the athletes participating in the research, and then the Cold Water Immersion (CWI) protocol was applied as a recovery method. Aspartate Aminotransferase (AST), Lactate Dehydrogenase (LDH) and Creatine Kinase (CK) blood samples were taken from the athletes in resting conditions and 2 hours and 24 hours after CWI. Ten days later, the muscle damage exercise protocol was reapplied to the same group of athletes, the Massage protocol was used as a recovery method, and blood samples were taken again in a similar way. To compare the AST, LDH and CK changes of the athletes participating in the research, the two-way analysis of variance test was used in repeated measurements. Mann-Whitney U test was used for the dissimilarities between CWI and massage groups. According to the results of the research; It was determined that there were significant differences at the $p<0.05$ level for the AST and LDH variable between the measurement values of massage and CWI ($p<0.05$). No significant difference was found between massage and CWI for CK value. The use of recovery methods after exercise is relatively significant for athletes. Following the consequences of the research, was observed that the muscle damage of the athletes who received massage treatment was lower than those who were applied CWI.

Keywords
Cold Water Immersion, Massage, Muscle Injury, Recovery

INTRODUCTION

The main purpose of the exercises is to increase performance. Implementation of intense exercise programs can cause muscle damage. After exercise, minor muscle damage occurs at the cellular level in striated muscles. The term exercise-induced muscle damage, which is expressed as temporary damage at the cellular level in skeletal muscles after exercise, is also called micro-trauma, micro-injury or muscle damage (Çakir and Şenel, 2017). Exercise-induced muscle damage, which results in muscle pain, edema, swelling, increased intramuscular proteins, and decreased joint range of motion, is seen especially after unusual high-intensity exercises (Clarkson and Hubal, 2002). Although this situation disturbs the athletes, it is known that it negatively affects athletic performance (Burt and Twist, 2011).

With the right recovery method, ıt is possible to reduce or eliminate the muscle damage that occurs (Şenel and Akyüz, 2010; Murray and Cardinale, 2015). Due to some exercises challenging the organism, some breakdown may occur at the muscle fibre level (Çakir and Şenel, 2017). These pieces of training cause fatigue in the athlete and also cause psychological and physiological stress. The resulting fatigue leads to a decrease in the performance of the athlete (Bigland – Ritchie et al., 1986; Budgett, 1998; Ament and Verkerke, 2009). Depending on the

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scope and intensity of exercise, muscle damage, mental fatigue, decrease in desire and motivation, and increase in perceived difficulty are among the causes of fatigue (Stupnicki et al., 2010; Nedelec et al., 2012; Thorpe et al., 2017). The athlete's rest and recovery after the exercises are at least as essential as the exercise. Exercises done without too much difficulty do not have much effect after a particular level. For this reason, since compelling training is mandatory for the outcome, professional athletes also do compelling training at least once a day. This training cause fatigue in the athlete and also cause psychological and physiological stress (Ament and Verkerke, 2009; Krustrup et al., 2005). Therefore, trainers and technical staff should ensure that the athletes rest and recover after high-intensity exercises to minimize the effect of fatigue on performance, and different recovery methods should be developed and applied for each athlete. Thus, with appropriate recovery methods, the athlete can better prepare for training or competition and keep his/her performance at a high level (Bompa, 2009; Andersson et al., 2008). After high-intensity exercises, different recovery methods have been evolved with the developing technology.

Methods of reducing or preventing the effects of exercise-induced muscle damage symptoms have recently been widely explored. Muscle damage is determined by various methods, either directly or indirectly. Magnetic resonance imaging (MRI) method and evaluation of muscle biopsy findings are used as direct methods for defining muscle damage (McHugh et al., 1999). Monitoring of muscle enzyme serum levels increases such as muscle pain, edema, decrease in muscle strength, creatine kinase (CK), troponin (THS), lactate dehydrogenase (LDH), aspartate aminotransferase (AST) is used as an indirect method. Due to the difficulties in applying direct methods, indirect methods are commonly preferred in research. Markers of muscle damage, muscle soreness, muscle dysfunction, and appearance can vary significantly depending on the type, intensity, and duration of exercise performed (Jakeman et al., 2010).

When the relevant literature is examined, the importance of the effect of massage and CWI, which are applied for recovery, on muscle damage in athletes arouses interest in sports scientists. Athletes cannot find enough rest and recovery opportunities due to intense competition schedules and travels. This situation creates fatigue in athletes. The solution to this is only possible with an effective recovery strategy. To prevent efficiency and performance losses in recovery techniques, the knowledge of the athlete and his trainer facilitates the way to success.

MATERIALS AND METHODS

In this part of the research, the population and the research sample, the design of the study, the warm-up protocol, the Cold Water Immersion (CWI) protocol, the Massage protocol, the data collection process and the analysis are explained.

Population and Sample of the Research

The research consists of 8 male professional volleyball players between the ages of 20-30.

This study followed ethical standards and received approval from the Van Yüzüncüyıl University Non-Interventional Clinical Research Ethics Committeewith reference number (Date: 16.04.2021, Number: E-14010876, Meeting number: 2021/05-16). Participant provided informed consent, with the volunteer form covering research details, risks, benefits, confidentiality, and participant rights. The research strictly adhered to the ethical principles of the Declaration of Helsinki, prioritizing participant's rights and well-being in design, procedures, and confidentiality measures.

Design of the Study

The study is planned into two parts. CWI protocol was applied to the athletes participating in the study, respectively, and the massage protocol was applied ten days after the end of this protocol. Here, it is aimed to investigate the effects of two different recovery exercises on the same athletes on muscle damage.

For CWI; Just before the muscle damage protocol, AST, LDH and CK blood samples were taken from all the athletes participating in the study under resting conditions. Immediately after the muscle damage protocol, the group of athletes were immersed in water at 13.5 ^{o}C for 10 minutes, keeping the neck and shoulders out. AST, LDH and CK blood samples were taken from the study group 2 and 24 hours after the cold water application. As for the massage protocol; Just before the muscle damage protocol, AST, LDH and CK blood samples were taken from all athletes

participating in the study under resting conditions. Afterwards, the athletes in the study group were placed on a massage stretcher, respectively, and a 10-minute classical sports massage including effleurage, petrissage, friction, tapotement and vibration applications for the lower extremities was performed. AST, LDH and CK blood samples were taken from the study group 2 and 24 hours after the massage application.

Muscle Damage Exercise Protocol

The muscle damage exercise protocol consisted of a depth jump from a height of 60 cm. jumps; performed with 5 sets, 20 repetitions and 10 seconds intervals. A rest period of 2 minutes was given between the sets. The athletes who performed the jumps from a height of 60 cm were asked to jump as high as possible from 90 degrees of flexion as soon as they touched the ground. This protocol has been successfully applied in previous studies (Goodall and Howatson, 2008; Kirby et al., 2012; Çakır and Şenel, 2017).

Coldwater Immersion Protocol

The study group is immersed in water at an average of 13.5 °C for 10 minutes, leaving the neck and shoulders out. To keep the temperature of the water constant at 13.5 °C, the temperature of the water is monitored with a thermometer. If the water temperature rises, ice particles are added to the water (Takeda et al., 2014).

Massage Protocol

10-minute classical sports massage including effleurage, petrissage, friction, tapotement and vibration applications for the lower extremities was applied to the study group.

Data Collection Process

On the day before the tests for body composition, the height and body weights of the participants were measured with the Seca measurement scale. The height of the participants with bare feet and their weight with only shorts were measured. Bioelectrical Impedance was used to determine the body fat percentage of the participants. Body temperature was measured with a non-contact thermometer (F.Bosch Fb-Scan).

Biochemical Analysis

5 ml of venous blood samples were taken from the antecubital veins before and after the cold water and massage therapy to evaluate the results of the subjects regarding the biochemical variables. Afterwards, CK, LDH and AST levels of each athlete were determined.

Statistical Analysis

Data analysis was done in SPSS 18 package program. To compare the changes in CK, LDH and AST of the athletes participating in the study, the two-way analysis of variance test was used in repeated measurements. THE Mann-Whitney U test was used to differentiate between Cold Water Immersion and massage groups. The significance level of $p<0.05$ was determined in all of the statistical procedures.

RESULTS

Table 1. Descriptive data of the study group

	Group	n	Minimum	Maximum	X̄	Ss
Age(years)	Experiment	8	20.00	29.00	24.00	75.43
Height(cm)	Experiment	8	180.00	201.00	193.25	125.04
Body Weight(kg)	Experiment	8	74.00	106.00	87.87	600.93
Body Mass Index(kg/height^2)	Experiment	8	20.87	26.24	23.46	25.65

X̄: Average, ss: Sum of Suares

Age values of the study group were calculated as 24 years, height as 193.25 cm, bodyweight as 87.87 kg, body mass index as 23.46 kg/m^2.

Table 2. Comparison of the AST level differences of the massage and cold water ımmersion study group

Group	n	Pre test X̄±Ss.	Intermediate Test X̄±Ss.	Post test X̄±Ss.	Measurement*Group F	p
CWI	8	25.37±7.48	25.50±5.63	21.87±5.59	3,826	0.032*
Massage	8	24.75±5.47	25.12±6.10	21.75±3.91		
Between Groups						
z		-1,125	-3,428	-2.182		
p		0.021*	0.658	0.045*		

*p<0.05; Abbreviations: CWI: Cold Water Immersion, AST: Aspartate Aminotransferase

It was determined that there were significant differences at the p<0.05 level for the AST variable between the measurement values of massage and CWI (p<0.05). Among the study groups of CWI and massage for the AST variable; a significant difference was found for the pre-test and post-test values (p<0.05). No significant difference was found for the intermediate test values (p>0.05).

Table 3. Comparison of the AST level differences of the massage and cold water ımmersion control group

Group	n	Pre test X̄±Ss.	Intermediate Test X̄±Ss.	Post test X̄±Ss.	Measurement*Group F	p
CWI	8	25,27±4,83	27,11±8,64	22,61±6,21	2,262	0,038*
Massage	8	22,25±6,27	23,65±7,21	23,21±4,65		
Between Groups						
z		-1,624	-2,456	1,262		
p		0,042*	0,234	0,034*		

*p<0.05 ; Abbreviations: CWI: Cold Water Immersion, AST: Aspartate Aminotransferase

When the AST levels of the massage and cold water protocols were compared between the groups, it was observed that the massage application after CWI improved significantly according to the pre-test averages (p<0.05), while a statistically significant difference was obtained in the post-test averages compared to the CWI of the massage application (p <0.05).

Table 4. Comparison of the differences in LDH levels of the massage and cold water ımmersion of study group

Group	n	Pre test X̄±Ss.	Intermediate Test X̄±Ss.	Post test X̄±Ss.	Measurement*Group F	p
CWI	8	179.37±13.80	178.25±42.59	164.25±22.92	1,121	0.036*
Massage	8	180.37±18.46	190.12±16.98	169.80±22.94		
Between Groups						
z		2,126	1,815	3,126		
p		0.620	0.038*	0.022*		

*p<0.05; Abbreviations: CWI: Cold Water Immersion, LDH: Lactate Dehydrogenase

It was determined that there were significant differences at the p<0.05 level for the LDH variable between the measurement values of massage and CWI (p<0.05). Among the study groups of CWI and massage for the LDH variable; A significant difference was found for the mid-test

and post-test values (p<0.05). No significant difference was found for the pre-test values (p>0.05).

Table 5. Comparison of the differences in LDH levels of the massage and cold water ımmersion of control group

Group	n	Pre test X̄±Ss.	Intermediate Test X̄±Ss.	Post test X̄±Ss.	Measurement*Group F	p
CWI	8	187,25±15,91	210,21±13,44	170,42±17,61	1,422	0,044*
Massage	8	148,22±12,61	192,11±35,25	176,85±20,52		
Between Groups						
z		-2,364	-1,462	2,356		
p		0,840	0,046*	0,030*		

*p<0.05; Abbreviations: CWI: Cold Water Immersion, LDH: Lactate Dehydrogenase

In the comparison of the athletes participating in the study between the groups, it was determined that the intermediate test average was statistically significant compared to the average of the massage application after CWI, while a statistically significant difference was obtained in the posttest averages compared to the CWI of the massage application (p<0.05).

Table 6. Comparison of the differences in CK levels of the massage and cold water ımmersion of study group

Group	n	Pre test X̄±Ss.	Intermediate Test X̄±Ss.	Post test X̄±Ss.	Measurement*Group F	p
CWI	8	190.97±76.64	245.80±76.96	325.40±81.67	2,232	0.065
Massage	8	185.93±68.65	222.85±82.72	280.97±95.40		
Between Groups						
z		1,862	2,326	2,168		
p		0.009*	0.019*	0.076		

*p<0.05; Abbreviations: CWI: Cold Water Immersion, CK: Creatine Kinase

It was determined that there were no significant differences at the p<0.05 level for the CK variable between the measurement values of massage and CWI (p>0.05). Among the study groups of CWI and massage for the CK variable; A significant difference was found for the pre-test and mid-test values (p<0.05). No significant difference was found for the post-test values (p>0.05).

Table 7. Comparison of the differences in CK levels of the massage and cold water ımmersion of control group

Group	n	Pre test X̄±Ss.	Intermediate Test X̄±Ss.	Post test X̄±Ss.	Measurement*Group F	p
CWI	8	191,52±67,60	257.58±91,21	407,19±60,80	1,486	0,058
Massage	8	194,60±70,28	260,35±90,21	401,41±74,21		
Between Groups						
z		1,325	1,986	-1,865		
p		0,049*	0,055*	0,068		

*p<0.05; Abbreviations: CWI: Cold Water Immersion, CK: Creatine Kinase

While no statistically significant difference was observed in the comparison of the pre-, intermediate and post-test of the athletes participating in the study ($p>0.05$), the mean of the pre-test ($p=0.049$) and the intermediate test ($p=0.055$) compared to the CWI of the massage application protocol in the comparison between the groups was statistically significant. It was determined that there was a significant difference in terms of ($p<0.05$).

DISCUSSION

Muscle damage in athletes occurs after different loading methods. The type of exercise that causes muscle damage the most is methods that include eccentric muscle contractions (Proske and Allen, 2005; Banfi et al., 2010). When serum levels are examined, the damage is primarily observed in serum levels of Creatine Kinase (CK), Aspartate Aminotransferase (AST) and Lactate Dehydrogenase (LDH) (Güzel et al., 2007; Banfi et al., 2007; Nosaka et al., 1992).

When the literature is examined;

In a study investigating the muscle damage, performance and recovery parameters of tennis players during the 4-day tournament, it was determined that the LDH value increased by 15% after the tournament (Çakır and Şenel, 2017). In a study on the effect of muscle damage after intense exercise on 12 young professional football players for the determination of muscle damage, it was observed that LDH and CK values increased (Hazar et al., 2011). In a study on markers of muscle damage after endurance training and amino acid supplementation, it was determined that after 90 minutes of exercise, LDH levels increased 4 hours later and returned to normal after 24 hours (Greer et al., 2007). CK, AST, LDH levels were determined to be higher in the measurement 6 hours after the high-intensity rugby exercise. These enzyme levels of the same athletes reached normal levels only after 24-48 hours (Takeda, 2014). There are other studies in which AST, LDH and CK levels, which are markers of muscle damage, reach their maximum values between 4-6 hours after exercise and within 24 hours, and return to normal within a maximum of 48 hours (Clarkson et al., 2006; Banfi et al., 2010).

In a study conducted on 20 male futsal players to investigate the effects of cold water immersion on muscle damage, it was determined that AST, LDH and CK parameters were lower in the cold water immersion group, which shortened the recovery time. In the measurements 24 hours after the cold water immersion, it was determined that the AST and CK levels of the experimental group were lower than the control group in all (Çakır, 2017). When the difference between the groups was examined in the study on the effect of cold water immersion on recovery, AST and LDH levels were statistically significant ($p<0.05$), while no significant difference was found in CK levels (Bleakley et al., 2012). When the effect of passive, active and contrast water bath application on recovery was investigated, it was determined that the most effective method was the contrast water method (Coffey et al., 2004). In another study, no significant difference was found between the data on active recovery, cold water immersion and cold compression therapy (Chan et al., 2016). In the study conducted on 41 male athletes from football, volleyball and rugby players, the athletes were divided into 4 groups and different recovery methods were applied to each group. Enzyme values, which are a marker of muscle damage, were measured for up to 24 hours in the athletes who were applied hot water immersion, cold water immersion, passive rest and contrast water therapy methods. It was concluded that cold water immersion and Contrast water had a greater effect on recovery (Pournot et al., 2011).

It has been stated that the half-time in blood lactate level after massage application is higher compared to active and passive rest (Medbo and Tabata, 1993). In another study conducted on 30 athletes, it was reported that there was a decrease in fatigue and a significant effect on performance after massage (Robertson et al., 2004; Lane and Wenger, 2004). In the study on the effect of massage on muscle damage, AST, ALT, CK, LDH rates were determined from blood samples taken immediately after training, 3 hours, 48 hours and 72 hours. It was determined that there was a statistically significant difference in AST, CK, LDH and ALT levels between the groups that received and did not receive massage (Korkmaz, 2019). In a study conducted on 19 football players to examine the effect of massage on muscle damage after weight training, it was observed that CK levels improved up to 30% compared to the group that was not massaged (Korkmaz, 2019). In the study, which was applied on thirteen rugby

players and investigated the recovery effects with cold water immersion, hot water therapy and massage, it was determined that the CK level of the cold water immersion group had a greater decrease (Banfi et al., 2007).

Before reaching the final results, considering the universe of the athletes, the analysis of the athletes participating in this study for a certain age group and the evaluation of the athletes only with man volleyball players were determined as a limitation of the research. It was determined that cold water immersion and massage produces effects on reducing muscle damage. However, massage, which is one of the recovery methods applied after high-intensity exercise, was defined to be more effective than cold water immersion in reducing muscle damage. When the general performance of the groups was examined, It was seen that massage provided less muscle damage and therefore more performance improvement in recovery than other groups. When the blood values of the groups were compared from the pre (initial) test to the post-test, It was concluded that the positive change in the massage was more than the other groups.

Conflict of interest

No conflict of interest is declared by the authors. In addition, no financial support was received.

Ethics Committee

The study was approved by the local university Non-Interventional Clinical Research Ethics Committee (Date: 16.04.2021, Number: E-14010876, Meeting number: 2021/05-16)

Author Contributions

Planned by the authors: Study Design, Data Collection, Statistical Analysis, Data Interpretation, Manuscript Preparation, Literature Search. Authors have read and agreed to the published version of the manuscript.

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