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Original Article

Comparison of the Effects of Massage and Cryotherapy on the Knee Extensor Muscles Fatigue and Isokinetic Parameters in Soccer Players

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ABSTRACT

Background: Fatigue can cause a significant effect on the mechanics of complex motor skills and reduce physical and mental efficiency. One of the common ways to reduce fatigue is passive recovering or using massage and cryotherapy after exercise. The present study aimed to compare the effects of massage and cryotherapy on muscles fatigue and isokinetic parameters.
Methods: This study was conducted on 54 healthy athletes aged 20-30 years who were randomly divided into three groups: cooling (ice therapy), massage, and control (resting). Each of the volunteers was evaluated in two sessions. The first session was to familiarize the participants with isokinetic contraction. The second session started with a brief warm up subsequently, using Biodex Isokinetic System Average Peak Torque (APTQ), Average Power (AP), and Total Work (TW) were measured. Then, the fatigue protocol was applied. Afterwards, interventions were performed for 15 minutes. After the intervention, isokinetic parameters were evaluated again. Also, perceived fatigue and Fatigue Index (FI) were recorded before and after the intervention.
Results: APTQ, AP, and TW significantly increased in massage and cryotherapy groups after the intervention, while perceived fatigue and FI decreased significantly in both conditions ($P<0.05$). In the control group, however, no significant differences were observed in APTQ, AP, and TW before and after the intervention ($P>0.05$), but perceived fatigue and FI decreased significantly ($P<0.05$). Moreover, isokinetic variables (APTQ, AP, and TW) were higher in the massage group compared to cryotherapy and control groups ($P<0.05$), but such a difference was not observed between the massage and cryotherapy groups ($P>0.05$).
Conclusion: Massage and cryotherapy could increase isokinetic parameters and decrease FI and perceived fatigue. Therefore, massage and cryotherapy have been more effective than rest as a strategy to return to normal state and no significant difference was observed between these two groups.

Introduction

Muscle injuries caused by muscle stretch or muscle strain are among the most common types of injuries experienced by active non-athletes [1, 2, 3]. As professional athletes strive to improve their performance, they invariably increase the frequency, volume, and intensity of training [4]. This increase in training load can improve athletic performance. However, athletes will inevitably experience fatigue, ranging from short-term ‘‘normal’’ fatigue to longer-lasting ‘‘abnormal’’ fatigue [4]. Muscle fatigue is defined as decline in capacity of a muscle to generate maximum force following execution of an activity [5, 6].

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Fatigue is accompanied by changes at multiple levels in the motor pathway and also by changes in the discharge patterns of muscle afferents [7]. This causes changes in muscle function and lower limb [7, 8]. Progression of fatigue reduces motor unit firing rates and muscle fiber conduction velocity, eventually slowing down motor unit recruitment and leading to dysfunction [9].

Fatigue depends on the type of exercise [10], type of contraction, intensity, and duration of training [11]. Following fatigue changes in muscle tissue occurs and during progressive exercise, the musculoskeletal system may not be able to fully recover and this problem could lead to decline in performance. Obviously, fatigue phenomena affect the accuracy of athletic performance [12]. The onset of fatigue not only reduces the athletes' physical and mental efficiency [13], but it can also cause physical and emotional disorders and sports injuries [14]. On the other hand, fatigue is one of the factors considered to be associated with sports injuries that can have a significant effect on the mechanics of complex motor skills such as walking, running, and jumping [15, 16]. Hence, in order to maintain efficiency, individuals must change their muscle coordination and muscle co-activation patterns [9] that eventually leads to kinematic changes and application of inappropriate force on joints during dynamic activities [17].

Among the skeletal muscles, quadriceps muscle is involved in almost all physical activities, such as running, walking, and shooting. Therefore, repeated contraction of this muscle during various activities can cause muscle fatigue and reduce functional capacity [18].

For treatment and reduction of fatigue, various methods have been proposed such as physical therapy, including electrotherapy, cryotherapy, hydrotherapy, superficial heat, and massage, and active recovery [19, 20]. One of the most common approaches in this regard is passive recovery by massage or cryotherapy after exercise. Massage refers to systematic mechanical manipulation of soft tissues of body by hands which aims at achieving therapy goals and enhancing health [21, 22]. One of the most important applications of massage is in preparation of athletes. The physiological goals of massage include affecting blood flow, removal of blood lactate, and delayed muscle pain [23, 24]. Sports massage is performed for athletes using Swedish massage techniques, such as effleurage (touch), kneading, petrissage, percussion, shaking, and cross friction [25, 26].

Change in body temperature leads to changes in muscle function. In fact, heating and cooling affect maximum power, speed, endurance, and contraction time [27]. Ice therapy is the most common form of recovery from fatigue [28, 29]. Athletes can benefit from the effects of cold therapy, such as pain reduction, vasodilation, and swelling control. Short-term use of local cold therapy could reduce muscle temperature, postpone fatigue caused by work [30, 31], and significantly prolong the period of muscle work.

Although some studies have been conducted on fatigue management following exhaustive exercises, no appropriate method has yet been reported to resolve this consequence of sports. As mentioned above, sports injuries are an integral part of an athletes' performance which could result from muscle fatigue. Therefore, more information is required regarding muscle fatigue and how to return muscle strength to increase performance and prevent injuries [18]. Despite the importance of recovery during athletic training programs, in scientific discussions, more attention has been paid to the training phase and trend of recovery has been less taken into account [32]. Nonetheless, few researches have been performed on the effectiveness of these treatments in muscle fatigue recovery. Thus, the present study aims to compare the effects of massage and cryotherapy on muscle fatigue and isokinetic parameters. Other objectives of this study include finding a way to increase athletes' performance during the rehabilitation period and returning them to private practice and effective competition. In general, injuries resulting from muscle fatigue and functional impairment can delay athletes' return to competition which can eventually cause mental health problems. Therefore, the overall goal of this research is to find ways to improve the fatigue resulting from muscle activity.

Methods

At first, a pilot study was conducted on a group of experimental subjects including 15 athletes. After analysis of the relevant data, a 54-subject sample size was determined for the study. Thus, 54 healthy athletes were recruited into this study. All the participants performed a fatiguing exercise (explained below) and subsequently were randomly divided into one of the three groups of cryotherapy, massage, and control that did not receive any interventions, through blocked randomization method using six blocks. It should be noted that this study was not blinded.

Before the intervention, Body Mass Index (BMI) was recorded. The tests were performed on the quadriceps muscle of the athletes' dominant leg in two sessions and four steps (training session and test session). At the beginning of the first session and before starting the test, the subjects' dominant leg was determined through three tests. The lower limb that the subjects used in two out of the three following tests was considered as their dominant limb:

1. Shoot the ball
2. Climbing stairs
3. Maintaining balance after a push from the back.

To induce muscle fatigue and measure muscle strength, isokinetic dynamometer Biodex System 4 was used. Each of the volunteers was evaluated in two sessions. The first session aimed at instructing the participants on how to perform isokinetic contraction and to perform concentric contraction by isokinetic machine. The subjects got familiar with the original examination and the maximum voluntary contraction of the quadriceps muscle of their dominant limb was recorded. The subjects sat on the device and performed three isometric maximal extension contractions at the angle of 75 degrees knee flexion for 5 seconds with 5 seconds rest between the contractions. It should be mentioned that knee angles were measured by isokinetic dynamometer at all stages.

In the test session, the subjects initially performed a brief warmed up for about 5 minutes. Then, the required assessments were performed by the isokinetic system. Knee flexion range of motion for the test was between 10 and 90 degrees. Besides, reciprocating motion included three maximal isokinetic concentric contractions of the knee extension followed by three maximal isokinetic concentric contraction of the knee flexion in order to return the organ to the starting position (90° of flexion) [8]. The evaluated variables included peak torque, average peak torque, average power, and total work at 60 degrees per seconds. Thus, fatigue protocol was imposed on the subjects as maximal concentric isokinetic knee extension contractions (quadriceps muscle) and submaximal concentric isokinetic knee flexor contractions (hamstring) at 60 degrees per second [8]. The beginning and end of the test were announced by the examiner (Figure 1). To maximize the subjects' efforts, the examiner encouraged the subjects verbally and the athletes observed the monitor constantly. The subjects were asked to perform successive maximal quadriceps concentric contractions and submaximal hamstrings concentric contractions by 60 degree/sec velocity until three subsequent quadriceps torque output drops below 50% of maximal torque output were observed on the monitor. After 60 seconds, the fatigue protocol was applied for the second and third time until three subsequent decreases in torque output below 50% of maximal torque output were repeated [8].

Figure 1: The subjects' position for test

After the application of the fatigue protocol on quadriceps muscle, isokinetic variables were measured in sitting position similar to the first stage of the main session and then, appropriate interventions were performed on the subjects. Cryotherapy intervention was performed in the first group, massage was performed in the second group, and the third group received no interventions. Then, as the final step, three successive maximal isokinetic concentric contractions of quadriceps and hamstring muscles were done similar to the previous steps in order to assess average torque, peak torque, and other isokinetic parameters of the quadriceps muscle.

In the first group, for cooling, an ice pack was placed on the knee extensor muscle bulk that covers the entire area for 15 minutes [33]. The size of the ice pack was 17 cm* 31 cm.

In the second group, the subjects laid in supine position and received massage on the front of the thigh from the groin to the top of the patella for 15 minutes; stroking techniques for 2 minutes, effleurage for 3 minutes, petrissage which consists of rolling and ringing each for 2 minutes, compression for 3 minutes, and finally effleurage for 3 minutes [8].

The control group rested for 15 minutes in supine position (passive recovery).

Before and after the intervention (15 minutes), perceived fatigue was measured using Visual Analog Scale (VAS). Also, the Fatigue Index (FI) before and after the intervention was calculated by the following formula [34]:

Fatigue index = (the maximum power - the minimum power) / the maximum power ×100

Besides, the maximum and minimum power was calculated using the following formula and information about the torque and velocity was extracted from the log files:

Power (watt) = torque (N.m) × velocity (deg/sec)

Statistical Analysis

One-way ANOVA was used to compare the three conditions (massage, control, and cryotherapy) regarding the changes in Average Peak Torque (APTQ), Average Power (AP), and Total Work (TW), VAS and FI before and after applying the fatigue protocol and post intervention. When the results of one-way ANOVA showed a significant difference among the conditions, LSD post hoc test was applied to find the location of the significance. Moreover, paired t test was used to assess the differences in all the study variables pre and post applying the fatigue protocol and pre and post intervention. All the analyses were undertaken using IBM SPSS Statistics (version 21.0) and P-value <0.05 was considered as statistically significant.

Results

The subjects' mean of BMI was 22.30±0.91 Kg/m^2 and their average maximal isometric strength was 266.53±50.45 N.m. The participants' demographic characteristics have been presented in Table 1.

Base Stage

Statistical analysis of the base average peak torque,

Table 1: Demographic characteristics of the subjects

Variable	Mean	SD
Age (year)	22.44	1.90
Weight (kg)	66.83	9.78
Height (cm)	172.66	9.42
BMI (kg/m^2)	22.30	0.91
Number of exercises per week (day)	4.11	0.92
Number of matches per week (day)	1.41	0.49
Activity level	8.06	0.71
Average peak torque of isometric contraction (N.m)	266.53	50.45
Average peak torque of isokinetic contraction (N.m)	210.50	45.49
Average power (watt)	126.26	31.76
Total work (J)	425.54	111.03

average power, total work, and fatigue index indicated that the mean of average peak torque was 213.21 N.m in the cryotherapy group, 205.09 N.m in the massage group, and 186.19 N.m in the control group. Also, the scores of average power were 137.72, 128.07, and 119.59 watt in the cryotherapy, massage, and control groups, respectively. Besides, the mean total work values were 489.48 J in the cryotherapy group, 446.8 J in the massage group, and 421.35 J in the control group. Finally, the average fatigue index was 98.60% in the cryotherapy group, 98.67% in the massage group, and 98.58% in the control group. The results showed no significant differences among the three groups concerning the study variables at baseline.

Before and After Fatigue

The results revealed a significant difference in all the study variables before and after fatigue. Accordingly, a significant decrease was observed in APTQ, AP, and TW in the three groups due to application of the fatigue protocol (P<0.05). On the other hand, perceived fatigue and fatigue index increased significantly after fatigue (P<0.05) (Table 2).

Before and After the Intervention

The results showed that the three groups' average peak torque, average power, and total work were higher after the intervention compared to before the intervention. VAS and FI, on the other hand, were lower after the intervention compared to before that.

In the massage and cryotherapy groups, the average peak torque, average power, and total work increased significantly (P<0.05), while VAS and fatigue index decreased significantly (P<0.05) after the intervention (Table 3). In the control condition, no significant differences were observed in APTQ, AP and TW before and after the intervention (P>0.05), while VAS and fatigue index decreased significantly (P<0.05) after 15 minutes of passive rest (Table 3).

APTQ, AP, and TW were higher in the massage group compared to cryotherapy, but the difference between massage and cryotherapy groups was not statistically significant (P>0.05) (Table 4). In addition, the means of APTQ, AP, and TW were significantly higher in the massage group compared to the control group after the intervention (P<0.05) (Table 4). In the cryotherapy group also, the mean of AP was significantly higher than that in the control group after the intervention (P=0.012). Nevertheless, no significant difference was observed between cryotherapy and control groups regarding the means of APTQ and TW (P>0.05) (Table 4).

The study results showed a significant decline in VAS in all the three groups after the intervention (P<0.05) (Table 3). Additionally, this reduction in VAS values was greater in the cryotherapy group compared to massage and control groups. Furthermore, a significant difference was found between cryotherapy and control groups and between

Table 2: Changes in all the variables from pre-fatigue to post-fatigue in the three groups (massage, cryotherapy, and control)

Variables	Intervention	Before fatigue	After fatigue	Mean differences	P value
APTQ	Massage	205.09±45.69	154.17±43.16	50.91±16.55	0.000
	Cryotherapy	213.21±47.04	149.8±40.40	63.41±22.52	0.000
	Control	186.19±41.75	145.16±45.46	41.03±23.00	0.000
AP	Massage	128.06±29.50	90.37±27.83	37.68±14.56	0.000
	Cryotherapy	137.72±33.64	91.36±28.28	46.36±15.06	0.000
	Control	119.56±22.49	83.15±30.83	36.40±14.31	0.000
TW	Massage	446.80±102.44	269.09±84.65	177.70±61.52	0.000
	Cryotherapy	489.48±118.17	274.68±83.33	214.69±55.27	0.000
	Control	421.35±107.08	274.75±101.94	146.60±50.04	0.000
VAS	Massage	0	7.00±0.97	7.00±0.97	0.000
	Cryotherapy	0	7.44±1.14	7.44±1.14	0.000
	Control	0	7.56±0.92	7.56±0.92	0.000
FI	Massage	98.67. ±0.37	99.70±0.34	1.03±0.05	0.000
	Cryotherapy	98.60±0.48	99.60±0.49	0.99±0.03	0.000
	Control	98.58±0.66	99.59±0.66	1.01±0.04	0.000

Data presented as mean±SD; Statistical significance: P<0.05

Table 3: Changes in all the variables from before-intervention to after- intervention in the three groups (massage, cryotherapy, and control)

Variables	Intervention	Before the intervention	After the intervention	Mean differences	P value
APTQ	Massage	154.17±43.16	181.01±45.73	26.83±9.53	0.000
	Cryotherapy	149.8±40.40	178.17±47.83	28.37±16.85	0.000
	Control	145.16±45.46	148.31±45.75	3.15±6.61	0.059
AP	Massage	90.37±27.83	111.36±32.02	20.98±10.92	0.000
	Cryotherapy	91.36±28.28	111.09±30.08	19.73±9.64	0.000
	Control	83.15±30.83	84.27±31.04	1.12±2.55	0.080
TW	Massage	269.09±84.65	363.91±87.83	94.82±48.62	0.000
	Cryotherapy	274.68±83.33	340.14±107.42	65.36±64.14	0.000
	Control	274.75±101.94	277.08±100.78	2.33±5.72	0.102
VAS	Massage	7.00±0.97	2.72±0.89	4.27±1.36	0.000
	Cryotherapy	7.44±1.14	2.22±1.00	5.22±1.06	0.000
	Control	7.56±0.92	3.56±0.85	4.00±0.97	0.000
FI	Massage	99.70±0.34	99.08±0.68	0.62±0.73	0.000
	Cryotherapy	99.60±0.49	99.30±0.59	0.29±0.51	0.003
	Control	99.59±0.66	99.45±0.70	0.14±0.30	0.000

Data presented as mean±SD; Statistical significance: P<0.05

Table 4: Comparison of all the variables between groups after the intervention (ANOVA-LSD)

Groups	Variable	Mean difference	P value
Massage – Cryotherapy	Avg peak torque	2.83	0.855
	Avg power	0.26	0.980
	Total work	23.77	0.475
	Perceived fatigue	0.5	0.109
	Fatigue index	0.22	0.367
Massage – Control	Avg peak torque	32.70	0.040
	Avg power	27.08	0.012
	Total work	86.82	0.011
	Perceived fatigue	0.83	0.009
	Fatigue index	0.37	0.043
Cryotherapy - Control	Avg peak torque	29.86	0.059
	Avg power	26.81	0.012
	Total work	63.05	0.062
	Perceived fatigue	1.33	0.000
	Fatigue index	0.14	0.255

Statistical significance: P<0.05

massage and control groups in this respect (P<0.05). However, no significant difference was observed between cryotherapy and massage groups concerning the mean of VAS (P>0.05) (Table 4).

The mean of fatigue index also decreased in massage, cryotherapy, and control groups, but this reduction was significant only in cryotherapy and massage groups (P<0.05) (Table 3). Besides, no significant difference was found among the three groups with regards to the mean of FI (P>0.05) (Table 4).

Discussion

In this study, isokinetic variables, perceived fatigue, and fatigue index were measured before and after the intervention. The results showed that massage and cryotherapy were effective interventions in enhancing muscle performance and recovery from fatigue, but rest did not have such an effect. Massage and cryotherapy could increase isokinetic parameters and decrease FI. On the other hand, recovery modality (massage, cryotherapy, or rest) caused a significant change in perceived fatigue in the three conditions. Therefore, massage and cryotherapy have been more effective than rest as a strategy to return to normal state and resulted in more relief in perceived fatigue and fatigue index. However, no significant difference was observed between these two groups.

Application of cold could increase isometric muscle strength [35]. This effect is limited to a short period and is diminished with muscle re-warming [36]. Higher and longer cooling rates may decrease muscle strength [37]. Available evidence indicated that skin cooling led to an increase in superficial muscle strength although there are conflicting reports that have demonstrated a decrease in muscle strength after cryotherapy. These differences might be attributed to differences in the amount of cold and depth of the tissue which was under cold [37].

The study results also indicated that massage could improve fatigue and decrease perceived fatigue. Our findings were similar to those obtained by Rinder and Sutherland [38], Balke et al. [39], and Rogai [40] which disclosed that massage after fatigue improved muscle strength. However, our findings were inconsistent with those of the studies conducted by Dawson et al. [41], Robertson et al. [42], and Barlow et al. [43]. Moreover, the current study indicated that cryotherapy could increase muscle strength by decreasing fatigue. Similar results were also obtained by Hausswirth et al. [44] and Verducci [33]. However, these findings were in contrast to those of the studies by Kimura et al. [45], Ruiz et al. [46], and Mattacola and Perrin [47].

Evidence has shown that having good motivation and not feeling tired can affect athletes' working capacity [48]. Therefore, if any intervention could improve physical and mental fatigue, athletes can improve fatigue induced by the central nervous system, focus on its performance, and eventually succeed [48]. Physical and mental fatigue not only reduces athletes' performance, but it also causes physical and mental disorders and influences the accuracy of athletic performance. Evidences indicated that the proper motivation and lack of fatigue could affect the capacity of athletes, because both physical exhaustion and mental fatigue can impact athletic performance. Thus, if interventions simultaneously stimulate the central nervous system and improve physical, mental, and muscle fatigue, athletes can be replenished and focusing on performance is adequate to improve physiological fatigue and fatigue index. The results of the present study showed that massage and cryotherapy reduced fatigue and improved performance. However, no significant difference was found between cryotherapy and massage groups. Yet, comparison of the effects of these two conditions on fatigue requires further research.

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