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Muscle fatique and muscle damage in strength training

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Authors' Contribution: A – Study design; B – Data collection; C – Statistical analysis; D – Manuscript Preparation; E – Funds Collection.

Abstract

Background and Study Aim The aim of this study is to investigate the effects of different types of contractions on muscle damage and muscle fatigue in sedentary individuals.

Material and Methods Thirty healthy male sedentary individuals participated in the study. Strength training in different types of contractions applied in the study was applied 3 times a week for 8 weeks. Before the study, the training loads were determined by making maximal force measurements of all subjects. The 30 subjects participating in the study were divided into 3 groups: isometric (n = 10), concentric (n = 10) and eccentric (n = 10) contraction group. Appropriate amount of blood samples was taken from the elbow vein 2 times from all subjects, before the studies and at the end of the 8-week strength training.

Results It was observed that eight-week strength training did not cause muscle fatigue in all groups and did not create a statistically significant difference (P> 0.05). Strength training with isometric and concentric contractions for eight weeks significantly increased serum lactate dehydrogenase (LDH), C-reactive protein (CRP), myoglobin (Mb), interleukin 6 (IL-6) levels, while concentric strength training significantly reduced serum aspartate amino transferase (AST) levels. Strength training with eccentric contractions significantly increased serum LDH, CRP, AST, Mb and IL-6 levels, while significantly reducing serum tumor necrosis factor alpha (TNF-α) levels. Strength training with eccentric contractions significantly increased serum creatine kinase (CK), CRP, AST, IL-6 and Mb levels compared to strength training with isometric and concentric contractions at the end of the eight-week study period, but did not show the same significant effect in other parameters.

Conclusions As a result, it can be said that eccentric strength training performed in sedentary individuals leads to more muscle damage than isometric and concentric strength training.

Keywords: concentric, eccentric, isometric, muscle fatigue, muscle damage.

Introduction

In the world of athletic competition, success is determined by very small details, and in some cases, a fraction of a second or a single motor unit determines the result of the ability to contract more than one [1]. Failure to maintain the physical condition values gained by athletes whose performance parameters have reached the highest level during the preparation period is one of the major problems encountered for coaches and athletes [2,3]

During sporting competitions and training or other intense physical activities, repeated or increased loads on active muscles can cause strain and regional fatigue in the muscle or tendon [4].

Fatigue is an important phenomenon for exercise scientists, coaches, sportsmen and all athletes. With the increase in the amount of energy demanded, we can define a deterioration in the internal homeostasis as fatigue [5]. Exercise-induced fatigue during and after strength training is common for everyone. The workload during exercise is an intense feeling that causes the person to reduce his current load and even end his activity. In addition, it is thought that muscle damage may be effective in fatigue that continues for 24 hours or more following exercise [6].

It has been observed that muscle damage occurs in sedentary individuals with low fitness, especially in athletes who undergo heavy loads at the beginning of the season, in situations where different training programs are applied, in exercises where multiple repetitive eccentric exercises are applied by weight training. The degree of damage and adaptation process varies according to the difficulty of loading [7, 8]. An exercise involving a vigorous and extensive eccentric contraction may initiate a complex chain of events such as myofibril damage, structural proteins, membrane damage and destruction in individuals unaccustomed to such exercises [9].

With this study, the effects of factors such as muscle fatigue and muscle damage after strength training performed with different types of contractions on organism in sedentary individuals have been tried to be determined.

Material and Methods

Participants

Thirty healthy male sedentary individuals living in Konya participated in the study as subjects. The

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average age of the subjects was 23.52 ± 1.23 years, their average height was 180.13 ± 7.68 cm, and their body weight averages were 84.43 ± 9.18 kg. In the selection of the subjects, the criterion for neurological disease, vestibular-visual disturbance in the last year and the absence of a serious limb injury in the last 6 months were sought.

Procedure

Maximal forces of all subjects were determined by using 10 repetition methods, one of the maximal force measurement methods, before starting the studies. Depending on the determined measurements, the strength training loads of the subjects in each group were determined individually and an eight-week strength training program with different types of contractions was applied accordingly.

Active warming was generally performed for the movement group to be applied to the subjects before starting the exercise. In the meantime, attention was paid to the number of heart beats of the athletes to be 120-140 beats / minute.

The movements of the subjects in the isometric contraction group (Group 1, n = 10) were: leg extension, leg squat, bench press, barbell biceps, push down movements. Each movement was applied for 30 seconds and in 3 sets.

The movements of the subjects in the concentric contraction group (Group 2, n = 10): lat pull down, cable seated, leg hamstring curl, leg calf, barbell biceps movements. Each move was done for 10 seconds and 3 sets for 30 seconds. After lifting the weight, the assistants held the force arm of the tool and brought it back to its starting position. During this process, care was taken not to force the subjects.

The movements of the subjects in the eccentric contraction group (Group 3, n = 10): leg extension curl, leg press, incline press, push down, kick back movements. Each movement was applied for 10 seconds and 3 sets for 30 seconds. During the studies, the instruments were removed by holding the force arm and the subject was asked to bring this weight to the starting position by making an eccentric contraction, thus preventing the subjects from concentrating.

1 minute rest between movements and 4 minutes rest between sets were applied. During the finishing phase, the subjects were given 10 minutes of jog and stretching movements. Subjects participated in the studies 3 days a week for 8 weeks. In all groups, the intensity and scope of the training were changed at equal intervals and applied for 8 weeks.

Collection and storage of blood samples

Blood samples taken from all subjects of the elbow vessel after the first training and at the end of the 8-week strength training, were kept at 80°C until the analysis time after the serum was separated. Blood samples were taken by experienced laboratory technicians, and the control of blood tests was done and reported in special Konya Derman laboratories, where accreditation was carried out regularly. Lactate dehydroginase (LDH), creatine kinase (CK), myoglobin (Mb), C-reactive protein (CRP), sodium (Na), potassium (K), calcium (Ca), alanine amino transferase (ALT)), asparta amino transferase (AST) values were tested with Abbott Architect c8000 biochemistry spectrofometer device, lactate (La) Siemens Advia centavur device with chemuliminians method, tumor necrosis factor alpha (Tnf-**α**) and interleukin 6 (IL-6) values were studied by Elisa device with micro eliza method.

Statistical Analysis

The statistical evaluation of the findings was done with SPSS for Windows 21.0 computer package program, and the arithmetic means and standard deviations of all parameters were calculated. The Kruskal-Wallis H test was used to determine the differences between the groups, and the Mann-Whitney U test was used to determine which group the difference originated from. Differences at the level of $P < 0.05$ were considered significant.

Before the study, each subject was given detailed information including risks and ailments that may be encountered related to the study, and the voluntary consent form was taught and signed. It was conducted in accordance with the 'Non-Interventional Clinical Research Ethics Committee' directive. The study protocol was approved by the decision of the ethics committee of Selcuk University Faculty of Sport Sciences dated 20.06.2016 and numbered 40990478-050.99. Also, the study was approved by an ethics board and met the conditions of the Helsinki Declaration.

Results

Table 1 shows that descriptive statistics of participants. Table 2 shows that the serum LDH, CRP, Mb and IL-6 levels of the subjects increased significantly after 8 weeks of strength training with isometric contraction ($P < 0.05$). In other parameters (Na, K, Ca, AST, ALT, La Tnf-α), the same significant increase was not seen before and after the study ($P > 0.05$). In strength training performed with concentric contraction for eight weeks. While serum LDH, CRP, Myb and Il-6 levels of subjects increased significantly compared to before, only serum AST level decreased significantly ($P < 0.05$). No significant difference was observed in other serum CK, Na, K, Ca, ALT, La and Tnf-α levels before and after the study ($P > 0.05$). At the end of the strength training performed with eccentric contraction for 8 weeks. Serum LDH, CRP, AST, Mb and IL-6 levels increased significantly after the study, while serum Tnf-α levels decreased significantly ($P < 0.05$). There was no significant change in other serum CK, Na, K, Ca, ALT and La levels ($P > 0.05$).

Table 1. Descriptive statistics of participants

Variables	N	Mean	Sd
Height (cm)		180.13	7.68
Body weight (kg)	30	84.43	9.18
Age (years)		23.52	1.23

Table 2. Comparison of pre-study and post-study biochemical parameters of groups

Parameters	Isometric Contraction(n=10)			Concentric Contraction (n=10)			Eccentric Contraction (n=10)		
	Pre	Post	P	Pre	Post	P	Pre	Post	P
LDH (U/L)	62.90±5.36	71.60±13.76	0.036*	65.60±14.23	75.50±12.73	0.005*	67.60±5.36	76.00±4.83	0.015*
CK (U/L)	82.80±5.43	88.50±10.17	0.126	86.50±9.03	89.60±10.13	0.609	91.00±12.73	98.70±5.50	0.850
CRP (mg/L)	1.06±0.34	2.01±0.75	0.011*	1.34±0.41	2.03±0.88	0.049*	1.36±0.40	3.47±0.66	0.005*
Na (mmol/L)	134.1±3.03	135.3±2.95	0.151	133.9±3.47	134.3±3.27	0.932	135.9±3.21	136.1±2.64	0.605
K (mmol/L)	3.50±0.67	2.83±0.93	0.113	3.04±0.89	3.02±0.74	0.507	3.64±0.48	2.96±0.86	0.152
Ca (mg/dl)	8.24±1.06	8.59±0.88	0.513	8.45±1.44	8.15±2.20	0.386	8.37±0.91	8.10±1.10	0.646
ALT (U/L)	5.20±2.35	9.30±3.40	0.084	6.40±2.55	5.70±2.83	0.552	6.07±2.29	5.00±2.39	0.172
AST (U/L)	9.30±3.40	7.10±4.46	0.150	9.30±2.41	7.20±3.43	0.032*	8.80±3.58	14.90±7.28	0.013*
Mb (ng/ml)	44.93±10.15	66.71±19.13	0.013*	50.18±6.48	70.15±14.97	0.017*	48.67±8.11	91.72±8.00	0.005*
La (mmol/L)	2.17±0.58	2.11±0.40	0.799	2.46±0.66	2.05±0.55	0.169	2.50±0.73	2.71±0.83	0.444
IL-6 (pg/ml)	9.06±3.85	18.57±10.95	0.022*	9.13±4.81	14.90±6.61	0.022*	11.52±5.53	29.05±13.6	0.005*
Tnf-α (pg/ml)	1.11±0.51	0.72±0.46	0.092	1.42±1.00	0.98±0.35	0.357	1.28±0.25	0.84±0.38	0.041*

* - p <0.05.

Table 3 shows that after the strength training performed with the isometric, concentric and eccentric contractions performed by the subjects participating in the study for eight weeks, no significant difference was found between the groups in serum NA, K, CA and La levels (P> 0.05).

Table 4 presents the differences between the groups were analyzed both before and after the study. After the study, it was observed that serum CK and Mb levels created a significant difference in the eccentric group compared to other groups (P <0.05), while the serum levels in the isometric and concentric groups did not make a significant difference (P> 0.05). There was no difference between serum groups in serum LDH levels after the study (P> 0.05).

Table 5 shows that after the eight-week strength training period, the serum AST level of the eccentric contraction group differed significantly from other groups (P <0.05), while the AST levels of the isometric and concentric contraction groups did not differ significantly (P> 0.05). There was no difference in serum ALT levels between the three groups after the study period (P> 0.05).

Table 6 shows that while no significant difference was determined in the serum IL-6 and Tnf-α levels between the subjects before the study period (P> 0.05), the serum IL-6 level of the eccentric contraction group was significantly higher than the other groups (P <0, 05), IL-6 levels of isometric and concentric contraction groups were determined to be similar to each other (P> 0.05). There was no difference in serum Tnf-α levels between the three groups after the study period (P> 0.05). Similarly, while no significant difference was determined in the serum CRP levels of the subjects before the study period (P> 0.05), the serum CRP level of the eccentric contraction group after the study period was significantly higher than the other groups (P <0.05), isometric and concentric contraction groups.

Table 3. Comparison of Serum Na, K, Ca and La levels between groups before and after the study period

Parameters	Groups	Pre-Study	Post-Study
Na (mmol/L)	Isometric	134.100±3.03 **a**	135.300±2.945 **a**
	Concentric	133.900±3.47 **a**	134.300±3.267 **a**
	Eccentric	135.900±3.212 **a**	136.100±2.643 **a**
K (mmol/L)	Isometric	3.500±0.670 **a**	2.830±0.933 **a**
	Concentric	3.040±0.885 **a**	3.020±0.743 **a**
	Eccentric	3.640±0.483 **a**	2.960±0.857 **a**
Ca(mg/dl)	Isometric	8.240±1.060 **a**	8.590±0.880 **a**
	Concentric	8.450±1.440 **a**	8.150±2.198 **a**
	Eccentric	8.370±0.906 **a**	8.100±1.096 **a**
La (mmol/L)	Isometric	2.17±0.575 **a**	2.11±0.402 **a**
	Concentric	2.46±0.655 **a**	2.05±0.546 **a**
	Eccentric	2.50±0.731 **a**	2.710±0.834 **a**

a,b,c: The difference between the means carrying different letters in the same column is important (P<0.05)

Table 4. Comparison of Serum LDH, CK and Myb levels before and after the study period between groups

Parameters	Groups	Pre-Study	Post-Study
LDH(U/L)	Isometric	62.90±5.36 **a**	71.60±13.76 **a**
	Concentric	65.60±14.23 **a**	75.50±12.73 **a**
	Eccentric	67.60±5.35 **a**	76.00±4.83 **a**
CK(U/L)	Isometric	82.80±5.43 **a**	88.50±10.17 **b**
	Concentric	86.50±9.03 **a**	89.60±10.13 **b**
	Eccentric	91.00±12.72 **a**	98.70±5.49 **a**
Mb(ng/dl)	Isometric	44.92±10.14 **a**	66.70±19.13 **b**
	Concentric	50.18±6.48 **a**	70.15±14.97 **b**
	Eccentric	48.66±8.11 **a**	91.71±8.00 **a**

a,b,c: The difference between the means carrying different letters in the same column is important (P<0.05).

Table 5. Comparison of Serum AST and ALT levels between groups before and after the study period

Parameters	Groups	Pre-study	Post-study
AST (U/L)	Isometric	9.30±3.40 **a**	7.10±4.45 **b**
	Concentric	9.30±2.40 **a**	7.20±3.42 **b**
	Eccentric	8.80±3.58 **a**	14.90±7.27 **a**
ALT (U/L)	Isometric	5.20±2.34 **a**	4.30±2.49 **a**
	Concentric	6.40±2.54 **a**	5.70±2.83 **a**
	Eccentric	6.06±2.28 **a**	5.00±2.39 **a**

a,b,c: The difference between the means carrying different letters in the same column is important (P<0.05).

Table 6. Comparison of Serum Tnf-α and IL-6 stokin levels between groups before and after the study period

Parameters	Groups	Pre-study	Post-study
IL-6 (pg/ml)	Isometric	9.06±3.84 **a**	18.57±10.94 **b**
	Concentric	9.13±4.81 **a**	14.90±6.61 **b**
	Eccentric	11.52±5.53 **a**	29.05±13.60 **a**
TNF-α (pg/ml)	Isometric	1.11±0.50 **a**	0.72±0.46 **a**
	Concentric	1.42±1.00 **a**	0.98±0.34 **a**
	Eccentric	1.28±0.25 **a**	0.84±0.38 **a**
CRP (mg/L)	Isometric	1.060±0.342 **a**	2.010±0.754 **b**
	Concentric	1.340±0.408 **a**	2.030±0.880 **b**
	Eccentric	1.360±0.395 **a**	3.470±0.660 **a**

a,b,c: The difference between the means carrying different letters in the same column is important (P <0.05).

CRP levels were determined to be similar to each other (P> 0.05).

Discussion

In this study, it was tried to evaluate the signs of muscle damage and muscle fatigue in eight-week strength training performed with different types of contractions.

Fatigue resulting from strength training reduces the capacity to produce strength or power [10, 11]. The accumulation of chemicals such as Hydrogen (H), Potassium (K), Lactate (La) in the muscle and emptying of energy stores plays a role in the formation of acute fatigue [12]. While strength training performed for eight weeks did not significantly affect serum K levels, no significant difference was found between the groups in terms of serum K levels before and after the study. The study findings, which Costill et al [13] reported that their blood potassium levels decreased after an acute exercise, differed from our study. In the measurements made after the study, no significant difference was found between the isometric, concentric and eccentric contraction groups in terms of serum Na levels. Unlike the study we have done. Aslankeser [14], in her study on 16 male subjects, investigated the effect of sprint training on acute fatigue and stated an increase in serum sodium levels. In addition, Patlar et al [15] revealed that there was a significant increase in Na levels as a result of the night exercises performed until 10 sedentary individuals had moderate fatigue. Lara et al [16] reported that a significant decrease in serum sodium concentrations occurred in a study on marathoners. It can be thought that these differences in K and NA are caused by the adaptation process created by eight-week workouts.

Some researchers have reported that if the amount of Ca^{+2} in Sarcoplasmic Reticulum falls below the normal level, Ca^{+2} release decreases in every action potential, causing fatigue [17, 18]. Isometric, concentric and eccentric strength training performed for eight weeks in our study did not significantly affect Ca^{+2} levels. There was no difference in Ca^{+2} levels between the groups before and after the study. In the measurements made before and after the study, no significant difference was found between the serum La levels of the groups. In the literature, similar studies have shown that there is no change in La carrying capacity after training stimuli [19, 20] but there are studies indicating that lactate carrying capacity has increased [20, 21]. It is thought that such differences occurring at La and Ca^{+2} levels may be caused by changes in duration and intensity of the exercise during the study.

In the study performed, the strength training performed for eight weeks showed a slight increase in serum CK levels, but this increase was found to be insignificant. In studies conducted by some researchers, no differences were observed in serum CK levels in concentric contractions, similar to our study [22, 23]. However, when the differences between the groups were examined after the study, serum CK levels were found to be significantly higher in the eccentric group than in the other groups. As a matter of fact, in some researches; A significant increase in CK levels [24] has been reported after strength training with isometric and eccentric contractions. Likewise, Lippi et al [25] determined CK values as high after 15 athletes after training. In their study, Burt et al [26] found a significant increase in CK rates after 10 minutes of sub-maximal running. In our study, the CK levels reached the highest level in 48 hours, which caused differences in some studies in the literature [27, 28], but in our study, blood samples taken immediately after eight weeks of strength training were determined to determine serum CK concentrations. It is thought

to cause such findings. Mb, which has a lower molecular weight than the CK enzyme, is known to reach its highest value more quickly [29, 30], and in this respect, our study increased Mb in all groups compared to CK values. According to Childs et al [31], studies performed with eccentric contractions showed an increase in Mb levels, and similarly, in our study, it was observed that Mb levels increased more than concentric and isometric groups at the end of the strength training performed by eccentric contraction. In another study, it was stated that myoglobin values increased as a result of the exercise protocol, which was arranged in a bicycle ergometer, containing high-density eccentric contractions [32].

In this study, no significant difference was observed in serum LDH levels between the groups before and after the training period. Strength training performed for eight weeks in the study did not change the serum AST and ALT levels of the isometric contraction group, while significantly increasing the serum AST levels of the concentric and eccentric groups. However, the same significant effect was not seen at serum ALT levels. The significant increase in serum AST levels in the study was also noted in studies investigating the effect of liver enzyme activity associated with exercise [33, 34]. While serum AST and ALT levels were not significantly different between the groups before the study period, serum AST level of the eccentric contraction group was found to be significantly higher than the other groups after the study period. There was no difference in serum ALT levels between the three groups after the study period. Unlike the findings of our study, ALT levels significantly increased after exercise in a study [35]. Studies that some researchers [36, 37] reported that there was no change in ALT enzyme levels are important in terms of similarity with our findings.

IL-6 and CRP levels increased significantly in all groups at the end of the study period and IL-6 and CRP levels of the subjects who performed strength training with eccentric contraction increased more than the other groups. The finding that the eccentric group in our study caused an increase in IL-6 level also coincides with the studies of many researchers [38, 39]. There are some studies that indicate otherwise and report that there is no change in IL-6 levels as a result of eccentric contractions [40, 41]. Although studies that overlap with our study and indicate that IL-6 level increases with strength training are included in the literature [42, 43], some researchers that contradict our study also reveal that strength training does not cause any increase in IL-6 levels [44, 45]. C-reactive protein, which is active in cleaning the damaged necrotic tissue, is responsible for controlling the destruction that may occur during inflammation [45, 46]. In our study, increased serum CRP levels after exercise in all groups are similar to the finding that indicates that serum CRP levels increase 24 hours after strength training [45, 47]. As a contrary opinion, Allen et al [48] stated that CRP values did not change after exercise. It is thought that this difference between the literature may be due to the duration, intensity and method changes of the exercise.

While the strength exercises of the isometric and concentric groups did not change serum Tnf-α levels after the study, they significantly decreased the Tnf-α levels of the eccentric group. Tnf-α levels have been observed to increase as a result of training in a study that performed strength training and contradict our study [49]. In another study shows that 8 weeks high intensity interval training (HIIT) can significantly increase the Tnf-α levels [50].

Conclusions

The present study demonstrates that eight-weeks strength training with different types of contractions causes some changes in sedentaries on muscle fatigue and muscle damage. Although such changes in strength training can be happen eccentric contractions cause more muscle damage than isometric and concentric group.

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