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The Effects of Magnesium Supplementation on Electromyography Indexes of Muscle Fatigue after Intense Anaerobic Exercise

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Abstract

This study was conducted to examine the effect of magnesium consumption on electromyography indexes of muscle fatigue after intense anaerobic exercise. The participants in this experiment were 16 volunteers of college-aged males. These subjects were divided randomly into two supplement and placebo groups. The electrodes of electromyography for the muscles were located according to SENIAM procedure. Test was carried out on ergometric bicycles (Lode, made in Netherlands) and the muscles' activity of right leg was recorded by EMG device, simultaneously. Independent and paired t-test were used to identify inter and intragroup differences. The significance level of the tests was assumed as 0.05. Consuming magnesium supplement reduced RMS of interior and external wide muscles and interior twin muscles (P=0.001, P=0.05, P=0.05, respectively), and increased MPF of interior and external wide muscles and interior twin muscles (P=0.001, P=0.05, P=0.05, respectively). According to the findings of the present study, utilizing magnesium sulfate supplement about 350 mg can be prescribed to enhance performance of healthy subjects in severe short-term activities, i.e. Wingate test.

1. Introduction

Muscular fatigue resulting from exhausting activity is a common phenomenon created by exercise and makes some difficulties in individual's motor performance. There are several stages when intentional activities of muscles start. They begin with cortical control in brain and end in crossing bridges in the muscular fibers. Thus, muscular fatigue may result from any failure involving muscular contractions. Created fatigue depends on type of exercise, contraction, intensity and duration of the exercise. Potential factors causing fatigue include central factors (i.e. fatigue resulted from neuromuscular system malfunction) and environmental factors (i.e. fatigue resulted from failure of muscles' contraction).

Nowadays, our knowledge about muscular metabolism during fatigue has been increased by using methods such as muscle biopsy, spectroscopy and providing tissue section. Muscular fatigue seems to be related to lack of glycogen, keratin phosphate, adenosine three phosphate and oxygen and/or accumulation of metabolites such as lactic acid, hydrogen ion and so on. Furthermore, malfunction of t tubes and sarcoplasmic network, relation between actin-myosin, re-distribution of calcium ions and activation process of calcium in pairing of actin-myosin system may be considered reasons for muscular fatigue. Different approaches were used to study central or environmental fatigue some of which were invasive and required blood or tissue sampling. However, they have some weaknesses as well such as considerable costs and causing pain in the subjects, therefore, we considered other noninvasive methods. Surface electromyography (EMG) is a noninvasive method to evaluate neuromuscular system performance. Recorded electromyography can be divided into two types depending on the record location. If the electrodes are located on skin, the method will be called surface electromyography and if they are located on muscle, it will be called intramuscular electromyography. Surface electromyography can be used for analyzing muscular activities and intramuscular electromyography can be used to evaluate fatigue or time endurance. Recorded EMG during intentional muscular contraction was studied in order to examine its relationship with muscular fatigue. Using surface electromyography technique Piper conducted one of the earliest works on track myoelectric to present muscular fatigue. He noticed gradual reduction of EMG signal during steady isometric contraction which included transmission of spectrum components of EMG signal to lower frequencies. Following him many scholars used EMG to evaluate muscular fatigue. Generally, this situation is accompanied by increasing Root Mean Square (RMS) of EMG, since the shooting speed of all motor units in muscular fatigue is simultaneously high. For frequency, reduction in the speed of guiding potential leads tense action of EMG exponent to lower frequencies across static and dynamic contractions in low maximum contractions with longer time. Some studies found that the more fatigue extended the greater progressive increasing in amplitude of RMS will be occurred. This finding shows empowering impulse. heightened activation which is resulted from progressive increase in number of active motor units with increased simultaneous shooting, may cause RMS to be risen. A similar increase by surface EMG has also been shown which indicates that environmental mechanism are not the only factors responsible for increasing RMS. Moreover, another study by Gayda et al. (2005)

showed a weak increase of RMS value per muscle (1). These researchers concluded that calling a motor unit depends on force surface and it could be risen by increasing exercise intensity of exercise. And when the severity of contraction amounts to 75 %of its maximum contraction, all motor units in many muscles are called.

Nutritional status affects the ability to do intense exercise. One of these nutrients is magnesium that the relation between its status and exercise or physical activity.

In a study by Cinar V et al. (2008) the effects of magnesium supplementation on adrenocorticotropic hormone and cortisol levels in athletes and sedentary subjects at rest and exhaustion were investigated and the results showed that ACTH levels and cortisol in two groups of male athletes and sedentary subjects after magnesium supplementation were increased not only in sedentary but also in exhaustion times (2). The results were also showed that hormone level can be increased by magnesium supplementation and exercise through activating pituitary-adrenergic system. Other research by Newhouse et al. (2000), examined the effects of magnesium supplementation on exercise performance and concluded that magnesium supplementation of 212 mg for 4 weeks increases significantly the sedentary levels of magnesium ion, but, recovery or implementation concerning the active women was not improved (3).

The reported research did not compare the relationship between magnesium supplementation and electromyography indexes. Considering knowledge and information in research literature we tried to study effects of magnesium supplementation on electromyography indexes of muscle fatigue after intense anaerobic exercise. The objective of the research was to examine the effect of magnesium sulfate supplementation for two weeks on muscular fatigue using electromyography indexes following a severe short-term test.

2. Materials & Method

2.1 Subjects

The method of research was semi-experimental. The statistical sample of research was 16 active college-aged males whose attributes are shown in table 1. The subjects participated in the experiment voluntarily following a calling for. All of them had no damage in muscles of their lower organs and joints and signed consent form of conscious participation. There were conditions for participants including not to have magnesium supplementation, smoking, heart disease and liver and thyroid dysfunctions and skin allergy. The subjects of this research exercised regularly 30 Min/day for four days a week Over a period of three months. Then the subjects were divided randomly into two supplement and placebo groups.

2.2 Implementation protocol of anaerobic test

Wingate test in this study was exhausting physical anaerobic activity. According to previous arrangements, the subjects attended laboratory at a specific time (all tests took place from 8 AM to 12 AM) and blood samples were taken from front vein of arm while they were sitting. The test was conducted on ergometer bicycle marked as Monark (Lode, made in Netherland). Information such as age, sex and weight of the subjects was fed to the bicycle and before starting the test, the height of the seat was regulated according to each subjects so that a 10-degree bend of knee could be observed for each subjects. The wheel of the bicycle was also regulated so that all subjects could feel Comfortable. Then the participants' leg was fixed on pedals in order to avoid other intervening factors, such as Leg escapement from pedals, while the test was conducted. First, the subjects warmed up for 5 minutes with 50 watts and 60 circles per minute. After warming up, when countdown reached zero, the subject pedaled as possible as he could for 30 seconds. Meanwhile he was encouraged to do his best. Recovery time was indicated as 30 seconds at the end of the test. Then the subject dismounted from the ergometer bicycle and immediately prepared for second blood taking.

In this study the activity of 3 muscles including interior wide, external wide and interior twin muscles of right leg were studied. First, the place indicated to set electrolytes was cleaned by Gillett and washed by alcohol. Then the electrodes were placed on the muscles by using the site of European protocol guide (SENIAM) (center to center distance of the electrodes was 2 cm and the earth electrode was set on tibia bone. Sampling frequency was considered as 1000 Hz). At the same time, muscular activity of right leg was recorded by EMG device (Biovision, made in Germany). Given the program written previously for Dasylab software, a down pass filter of 500 Hz and a high pass filter of 10 Hz were established. MPF data was gathered through Dasylab software, but, MATLAB 2000 software was used to calculate RMS. Excel software was used to analyze MPF data and 30 second time duration of Wingate test was selected then a line chart was used to find gradient line which shows muscular fatigue degree. First, filtered data was used according to the program written in MATLAB software then RMS of data was gained. After that, the first and second 30-second time durations were indicated and the mean for each was calculated by Excel software. We the mean of the second time duration (data of Wingate test) by the first time duration (the last 30 seconds dealing with warming up) to make data comparable and usable. Then we multiplied it by 100. The resulted number showed the degree of muscle activity which is presented as a percent of that activity.

Program of supplementation: In this study, magnesium sulfate supplementation was used (produced by Kimiyagare Tous, with health code of B/11/100 by Ministry of Public Health, Medical Care and Medical Education).

Furthermore, flour was used as placebo. Magnesium sulfate supplementation and placebo were packed in yellow capsules which had identical taste, color and shape and delivered to a non-participant person so that the researcher himself was unaware whether they are supplement or placebo. Each capsule contained 350 mg supplement or placebo. After pretest, the subjects started to use supplementation or placebo with warm water before having dinner. Supplementation stage continued for 14 successive days (generally, each subject received 4900 mg supplementation or placebo). The subjects maintained their usual diet during the supplementation process and were asked to record what they eat during the study period. They were also forbidden to take any other supplements or medicine which might cause interference in the research results (i.e. drugs causing diarrhea or having magnesium in their structure). On the other hand, they were asked to maintain their usual diet and follow the menu of the university restaurant. Posttest, completely similar to the pretest, was done 24 hours after the last capsule was taken and the supplementation period (14 days) completed by the subjects.

2.3 Statistical methods

Kolmogoroff-Smirnoff test was used to analyze data and make sure data distribution is normal. After being sure of data to be normal we used square t and correlated t method ($0.05 \leq p$). Calculations were done by SPSS 21 software.

3. Results

Table 1 shows the subjects' features before dividing them into two groups and table 2 shows then after dividing. According to table 3, there is a significant difference between RMS values of interior wide muscle (P=0.001), external wide muscle (P=0.05), and interior twin muscle (P=0.001) in supplementation group. There is also a significant difference between MPF of interior wide muscle (P=0.001), external wide muscle (P=0.05), and interior twin muscle (P=0.05) in supplementation group. However, there is a significant difference only in external wide muscle of placebo group (P=0.026).

Table1: The subjects' features before dividing them into two groups (Mean ± SD).

Age	Weight (kg)	Height (cm)	Fat mass	Body mass
21.75 ± 1.43	71.12±8.44	178±2.27	9.08±2.71	22.4±1.78

Table2: The subjects' features after dividing them into two groups (Mean ± SD).

Groups	Age	Weight (kg)	Height (cm)	Fat mass	Body mass
Magnesium sulfate	21.37±1.60	74.37±8.24	178.75±8.43	10.61±1.19	23.26±1.66
placebo	22.12±1.72	67.87±7.79	177.25±6.40	7.55±3.00	21.53±1.51

Table 3. Mean and standard deviation of RMS and MPF in interior wide muscle, external wide muscle, and interior twin muscle of two groups of Magnesium sulfate and placebo in two stages of post and pretest.

Muscle index		RMS		MPF	
		Supplementation	placebo	Supplementation	placebo
Interior wide	pretest	555.09±134.89	575.170±97.38	-0.16±0.11	-0.04±0.28
	posttest	437.61±78.68*	483.111±25.08	-0.06±0.07*	-0.13±0.20
External wide	pretest	513.187 ±98.46	512.129±71.70	-0.20±0.11	0.009±0.28
	posttest	349.71±89.44*	3.184±21.37	-0.07±0.08*†	-0.12 ±0.12
Interior twin	pretest	354.26±66.99	3.102±14.54	-0.25±0.29	-0.03±0.29
	posttest	279.48±03.94*	3.147±16.89	0.03±0.32*	-0.31±0.29

4. Discussion

The objective of this research was to study the effect of magnesium supplementation on electromyography indexes of muscular fatigue following a period of anaerobic intense exercise. We observed reduction in RMS values in muscles (interior wide, external wide, and interior twin) following fatigue. In line with data of the present study, Hostens, (2005) who studied a dynamic and continuous activity resulted in muscular fatigue, witnessed reduction in RMS values (4). He used simultaneous analysis of spectrum and amplitude (JASA) to explain this reduction and regarded it as a sign of power reduction in the muscle. Possible reasons for RMS reduction can be potential reduction in number of active muscular fibers during its work. Another reason for reduction of EMG amplitude can be the fiber of muscle since it produces too power against certain stimulus. Oliveira et al. (2009) observed that training responses of RMS in isometric contraction is different dealing with biceps extensor carpi ulnaris and digitorum muscles, that is, reduction in extensor carpi ulnaris and increasing in extensor digitorum (5). The difference in RMS may be related to simultaneous increasing of motor units, thus it is motion learning that reduces EMG activity. On the other hand, it is possible that neural activation is increased because of hypertrophic compatibility which causes RMS to be increased during maximum contractions. However, exercise property or specialty (being dynamic) may be resulted in improper neural-muscular response. Former researches admitted that there is no relation between increasing isometric power and EMG activity in resistance training. Furthermore, increasing in EMG activity of muscles was not observed rather it reduced. Reduction in RMS domain may be influenced by increasing in output power, movement learning and reduction of median frequency inclination because of these factors and this, in turn, may be influenced by changes in metabolites relating to fatigue as well as type of muscular fibril.

In a study by Khatamsaz et al., in line with the findings of the study by Jennet and Thomas, MPF was reduced in isometric dynamic contraction following fatigue. This along with variations in the activity may show reduction of muscle power and the speed of leading muscle fiber. Our results, however, show that MPF of lateral wide muscles, interior wide and twin was increased and as a result it seems to be a sign of increasing the leading speed of muscle fiber. On the other hand, the speed of reduction in MPF during fatigue shows the difference in profile of metabolism of individual muscular fibril. It was shown that reduction in frequency spectrum of electromyography power down to lower frequencies may be resulted from accumulation of metabolic products (i.e. lactate) which causes a significant reduction in the speed of frequency leading. A strong relation between produced lactate and MPF change during the muscular fatigue was shown. Reduction in slope reported in

Oliveira et al. (2009) is related to training and can be explained through increasing in output power and movement learning because of producing lower levels of muscular activity in certain load (5).

Despite the findings of the present study, Gayda et al. (2005) in their research on assessing skeletal muscle fatigue in men with coronary artery disease using surface electromyography during isometric contraction of quadriceps muscles observed that the mean of median frequency in all coronary artery patients was lower in comparison with healthy subjects which shows increasing in muscular fatigue may be resulted from malfunction of skeleton muscles (1). Generally, a little difference has been observed between men and women concerning EMG variables. The most significant difference observed includes increase in RMS amplitude electromyography for each three quadriceps muscles of men associated with power increasing in comparison with women and increasing in MF or MPF for lateral wide muscle of men with power increase compared with women. The difference between these results and findings of other studies can be resulted from variability in properties of individual fibril and even in one muscle for quadriceps, and the effect of electrode location on the muscle on MF or MPF. Finally, the main reason of MPF increasing can be explained by increasing the speed of frequency leading of fibril action.

Using magnesium supplement with the properties of the present research can reduce neural muscle fatigue with the electromyography indexes. This finding can be explained by the fact that magnesium cofactor keratin kinase is a key enzyme of anaerobic metabolism. Thus, providing much magnesium can supply needed energy for short-term movements with high watt, i.e. vertical jump.

Results from this study shows that magnesium sulfate supplementation delays fatigue in active individuals following a severe short activity on ergometer bicycle. This result came from the way assessing electromyography indexes of fatigue. Generally, analyzing data of electromyography indicated fatigue signs of leg muscles following the supplementation process. Thus, magnesium sulfate supplementation of 350 mg is recommended to improve performance of the healthy subjects who are active in short-term exercises such as Wingate test.

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