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EMG and Muscle Force of Intermittent Submaximal Constructions between Weight Lifters and Non-Weight Lifters

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국문초록

Weight Lifters와 Non-Weight Lifters 사이의 간헐적인 최대하 수축에서 근전도와 근력의 비교

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인간의 수행 요소인 국소 근육의 피로는 만성적인 손상을 초래한다. 이 연구는 근전도의 진폭(amplitude)과 근력(muscle force)에서 피로의 영향을 WL과 NWL로 비교하여 조사하였다. 손목 굽힘근의 근력은 시간이 흐름에 따라 WL과 NWL 모두에서 감소되었다.그러나, WL과 NWL는 시간 경과에 따른 근전도 진폭에서는 차이를 보였다. WL의 근전도 진폭에서는 운동 후 48분에 가장 높은 변화를 보였다. 이를 통하여 근전도의 진폭과 근력이 근피로에 중요한 인자임을 알 수 있다. 이 연구에서 WL은 높은 근전도 진폭을 적용했을 때와 같이 시간이 경과할수록 오랜 효과를 얻을 수 있었다. 그것은 훈련을 통해 보다 많은 운동단위를 동원할 수 있다는 것을 보여준다. 신경근 피로 정도와 이를 회복하기 위해 필요한 기간은 중요하다. 개인적인 훈련량과 적절한 근력 훈련계획을 위한 작업 - 휴식 반복빈도, 그리고 다른 성격의 집단에서 필요한 재활 지침서를 만드는데 필요하기 때문이다.

Skeletal muscle fatigue is often associated with diminished athletic performance and inability to maintain an expected force output as a function of time. The purpose of this study was to compare the effect of duration of exercise on skeletal muscle fatigue betw-een Weight Lifters(WL) and Non-Weight Lifters(NWL). There were twelve normal healthy adult volunteers, ranging in age from 18 to 35 years. The group consisted of six NWL and six WL. Randomized cross-over design was set up and work-rest cycle was 8 minutes work and 1 minute rest based on 15% MVC. Muscle fatigue was measured by the amount of force produced by the wrist flexor muscle and EMG amplitude over time. Repeated measures ANOVAs(2X4) were used to determine two types of subjects(WL, NWL) during four different duration of exercises(16, 32, 48, 64 minutes). The force decreased over time in NWL and WL, but there was no significant difference($F=2.83$, $p>0.05$). However, the EMG amplitude increased in WL(0.8200) and NWL(0.6348). The WL exhibited an increase in EMG at the end of the period, especially at 48 minutes of exercises than did the NWL($F=9.58$, $p<.05$). This suggests the WL were able to adjust to prolonged effort with adaptations in neural effect over time, resulting in higher EMG amplitude. That is, WL may be able to learn to recruit more motor units with training. It is important to the degree of neuromuscular fatigue and the time needed for recovery may differ considerably between WL and NWL, there is a need to plan proper strength training or rehabilitation protocols to match with the requirements in different characteristics of groups.

Key Words: Muscle fatigue; EMG; Muscle force.

Introduction

Muscle fatigue is one of the important risk factors for cumulative trauma (6). Fatigue is characterized by an increase in the effort required to produce a desired muscular force or an inability to maintain an expected force output (4). Skeletal muscle fatigue has been studied mostly under very strict conditions of either isometric or concentric actions (8). However, the modern work place has evolved into an arena of physical tasks which require repetitive, dynamic contractions at variable rates and loads (7).

It is necessary to be focused on how to improve the job for most people so they can work productively and without injury or excessive fatigue (1, 19). However, these studies were done only with limited subjects or mostly under isometric contractions. It is difficult to apply these results to sports or industrial types of study in which most intermittent and dynamic activity may be involved.

Experiments concerning the identification of the fatigue mechanisms will add a great deal of understanding how muscle functions under acute stress and how it adapts to chronic activity. This knowledge would have implication for improving physical performance and work productivity.

Highly repetitive upper extremity work can lead to negative outcomes such as local muscle fatigue and a range of occupational injuries referred to as cumulative trauma disorder(18). Also, with productivity demands and the change in work habits, there has been a significant increase in the reporting of cumulative trauma in the wrist (16). In the U.S. it is common for repetitive work to be done continuously for two hours followed by a ten to fifteen minute break (3). However, there is no fatigue study which is related this kind of working condition.

This background information has raised some questions regarding the effects of muscle fatigue in repetitive tasks with different work cycles. This study attempts to characterize functional muscle fatigue between WL and NWL. The purpose of this study was to compare the effect of duration of time exercised on muscle fatigue and how it relates to variables in work-rest cycle.

METHODS

Subjects

Twelve normal volunteers(6 WL, 6 NWL) were randomly assigned into the work experiment. All subjects completed university approved human subjects consent forms. Prior to the initial testing session each subject was given a verbal and written explanation of the study. The subject information sheet was completed to record their age, height, weight, hand dominance, and medical history related to their upper extremities and cervical area. In this study, WL was defined as those who attended exercise session at least three times a week on a regular basis.

Instrumentation

The experimental set-up for this study included exercise equipment of a bench seat, a table and a load cell. A height adjustable padded platform was constructed for the elbow to rest upon. A web strap was used to stabilize right shoulder against the seat back and prevent movement during MVC was measured.

A genisco load cell was calibrated and was placed in line between the wrist loop and the steel cable. The surface EMG was recorded using electrodes on the subject's dominant forearm. Surface EMG was picked up from the wrist flexor by electrode assemblies. The assemblies were used to standardize the inter electrode distance of the silver-silver chloride electrodes and provide on-site amplification to improve signal quality. The output from the force and EMG amplifiers was digitized, sampled at 1 KHZ, and recorded on an IBM XT personal computer.

The exercise equipment was then adjusted so that the subject's shoulders were level, the dominant elbow was at 90 degrees with the wrist in the supinated position in the loop, and the shoulder in neutral position. The hand was fixed in a supinated position.

The forearm was located horizontally, parallel to the sagittal plane, directly in front of the subject. The height of the working table and the chair was adjusted according to the height of the subject. The experiments were done on the dominant arm only.

Procedure

The work-rest cycles were combinations of 8 minutes repetitive work periods with 1 minute rest. This work was performed rhythmical contraction to exhaustion (frequency 30/min) at 15% MVC. The wrist flexor muscle force and EMG amplitude was checked at each cycles. All scores of EMG amplitude and force were normalized to compare with other subjects.

Data Analysis

Repeated measures analysis of variance was used to determine the difference between the mean force and amplitude as a function of time. All data analysis was performed using the SAS statistical software package (SAS institute, Inc, Cary, NC) and was used to test for the specific force and EMG difference based on time function. All tests of significance used an overall significance level of less than or equal to 0.05.

RESULT

Skeletal muscle fatigue can be a significant clinical problem in that it compromises exercise tolerance and work productivity while retarding rehabilitation of diseased or damaged muscle.

In this study, there is some degree of individual variation involved within the general results. When comparing wrist flexor force and EMG as function of time, it becomes apparent that some individuals performed in a remarkably consistent fashion. Others showed some variability. According to Table 1, the wrist flexor muscle force was decreased as a function of time in both WL and NWL. The repeated ANOVA test shows that there was no statistical difference between groups($F=2.83$, $p>0.05$).

Table 1. Description amplitude changes of repeated measured ANOVA between WL and NWL.

	DF	SS	MS	F	P
Type	2	0.3591	0.1796	5.41	0.0089
Error	35	1.1609	0.03314		
Corrected Total	37	1.5201			
R-Square	0.2362	***C.V.***	25.5517	***Root MSE***	0.1821
Source	**DF**	**TypeI SS**	**MS**	**F Value**	**P**
Grp	1	0.3178	0.3178	9.58	0.0039
Time	1	0.0413	0.0413	1.25	0.2716
Source		**Type III SS**	**MS**	**F Value**	**P**
Grp	1	0.2892	0.2892	8.72	0.0056
Time	1	0.0424	0.0413	1.25	0.2716

Table 2. Description wrist flexor muscle force changes of repeated measured ANOVA between WL and NWL.

	DF	SS	MS	F	P
Type	2	0.0924	0.0462	2.83	0.0726
Error	35	0.5718	0.0163		
Corrected Total	37	0.6643			
R-Square	0.1392	***C.V.***	18.7016	***Root MSE***	0.1278
Source	**DF**	**TypeI SS**	**MS**	**F Value**	**P**
Grp	1	0.0125	0.0125	0.77	0.3864
Time	1	0.0799	0.0799	4.89	0.0336
Source		**Type III SS**	**MS**	**F Value**	**P**
Grp	1	0.0203	0.0203	1.24	0.2722
Time	1	0.0799	0.0799	4.89	0.0336

However, there was a difference between WL and NWL in terms of EMG amplitude change based on the time function($F=5.41$, $p<0.05$). Fig. 2 shows increased EMG amplitude at 48 minutes after exercises in WL (0.9778). At 64minutes, the EMG was decreased(0.6273) and most of volunteers were unable to perform exercises.

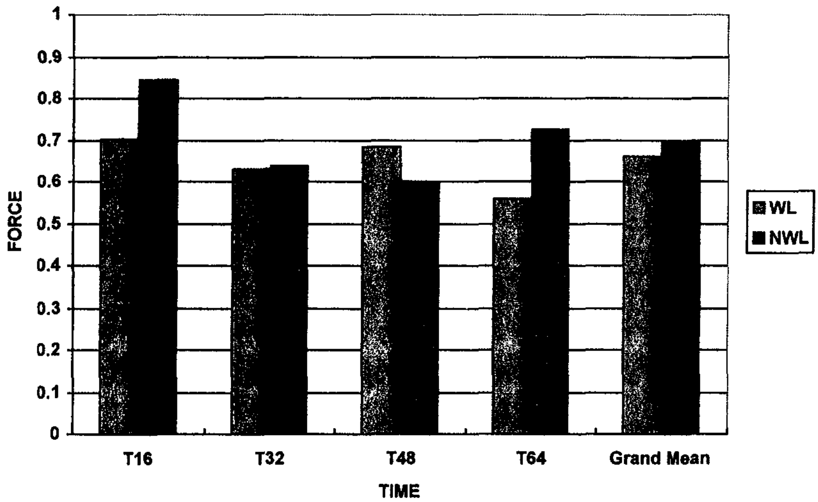

Fig. 1. Descriptive force change between WL and NWL.

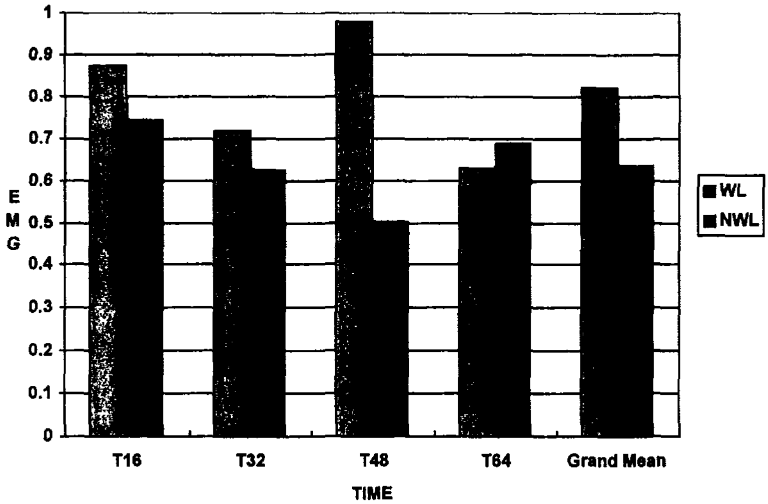

Fig. 2. Descriptive EMG changes between WL and NWL.

Discussion

The major finding of this study was that WL who exercised on a regular basis experienced substantially greater increases in EMG amplitude than NWL. This indicates that, the processes which bring about fatigue during muscle contractions provide decreased muscle force and increased EMG amplitude. EMG indicators of fatigue are well recognized but their use is limited because they can not alone indicate whether alternative in excitation contraction coupling underlie fatigue.

The muscle failure may ensue due to either (i). an insufficient delivery of electrical excitation to the muscle or (ii). insufficient metabolic energy to perform the contraction. The former involves such phenomena as failure of neuro muscular transmission, depressed muscle membrane excitability, and/or failure of muscle action potential propagation.

It is clear that the development of fatigue probably involves several factors which influence force production in a manner dependent on muscle fiber type and activation pattern and that one of these factors may be the regulation of calcium ion by sarcoplasmic reticulum.

Viitasalo(21) cited multiple references in which fast twitch(FT) fibers accumulate more lactate under similar conditions than slow twitch(ST) fibers. This causes the FT firing frequency to decrease, since ST fibers can utilize lactate as fuel, whereas FT fibers can not. Thus exercises more repetitive in nature may recruit more FT fibers initially.

Then, as lactate builds, increasingly more FT fibers must be recruited to substitute for fatiguing ones until, ultimately, all FT fibers are exhausted and ST fibers must attempt to meet the task's demands. This may explain the increased EMG amplitude, especially in WL.

Fatigue due to insufficient energy stores involves more metabolic and enzymatic processes. When utilizing EMG amplitude measures, one may find that decreases in a muscle's ability to generate a force are accompanied by a subsequent decrease in EMG amplitude for failure originating, predominately, from insufficient electrical excitation.

Accumulation of lactic acid inside muscle decreases its Ph level resulting in inhibited resynthesis of ATP in glycolysis(17). The calcium pump removing Ca++ from muscle is affected by this lack of ATP. As a result, intramuscular Ca++ is abnormally high, thus in prolonged condition, the muscle can not achieve former levels of relaxation, resulting in higher values as compared to the NWL.

Sufficient rest time allows more (i). Ca++ to be removed, (ii). nutrients provided, (iii). K+ for muscle uptake, and (iv). heat to be dissipated(15). The 8 minute exercise with 1 minute rest, the lactate may build up gradually and fast twitch(FT) muscle fibers cannot utilize lactate due to poor fast twitch muscle recovery. This results in an increase of more FT units recruited initially, and a decrease in firing frequency. As lactate decreases, ATP for Ca++ pump also decreases and exhibits slower recovery time.

Viitasalo and Komi(21) cite multiple references in which FT fibers accumulate more lactate under similar conditions than ST fibers. This causes the FT firing frequency to decrease.

Thus, exercises more repetitive in nature may recruit more FT fibers initially. Then, as lactate builds, increasingly more FT fibers must be recruited to substitute for fatiguing ones until, ultimately, all FT fibers are exhausted and ST fibers must attempt to meet the task's demands.

These findings underscore the need for fatigue prediction models to consider varied percentages of MVC in characterizing EMG development. As contractions become more continuous-like, it may appear that lactate will have a greater impact on EMG amplitude.

Muscle fibers of the same motor unit contain identical isomyosins suggesting that the neural input determines the phenotypic expression (5). Pette(14) states that neural activity is probably the major factor influencing the characteristic properties (contractility and fatigue resistance) of skeletal muscle.

In this study, the amplitude of WL exhibits significantly higher than WNL. As WL was defined those who attended exercise session at least three times a week on a regular basis, they may have different neural effect than WNL.

Strenuous heavy resistance loading such as used is strength training leads to acute decrease in the maximal neural activation, in maximal strength and in force-time characteristics of the loaded muscle (9, 11).

This study demonstrated that the intermittent submaximal exercise led to considerable acute in the neuromuscular system in WL. Fatigue in the neuromuscular system was observable not only by great acute decreases in maximal force but also by significant increases in the EMG amplitude of the exercised muscles. This can be demonstrated by the decreases not only in maximal force and force-time characteristics but also in the maximal voluntary neural activation of the loaded muscles (10, 20).

Conclusion

As a human performance factor local mu-scle fatigue results in chronic impairment. This study was to investigate the effects of fatigue on EMG amplitude and muscle force between WL and NWL. The wrist flexor muscle force was decreased as a function of time in both WL and NWL.

However, there was a difference between WL and NWL in terms of EMG amplitude change based on the time function. At 48 minutes after exercises in WL the EMG amplitude increased highest. This indicates that EMG amplitude and muscle force may be important indicators of muscle fatigue.

From this study, the WL were able to adjust to prolong effect over time, resulting in higher EMG amplitude. That is, WL may be able to learn to recruit more motor units with training. It is important to the degree of neuromuscular fatigue and the time needed for recovery may differ considerably between WL and NWL, there is a need to optimize not only the contents of individual training but also the frequency of work-rest cycles in order to plan proper strength training or rehabilitation protocols to match with the requirements in different characteristics of groups.

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