POOR FORCE CONTROL PERFORMANCE AND UNVARIED EMG PATTERN AFTER AGONIST MUSCLE FATIGUE IN HUMANS

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Ballistic and accurately control of a targeted fast contraction relies on phasic activations of the agonist and antagonist muscles. The purpose of the study was to investigate the effect of tibialis anterior (TA) fatigue on the systematic bias and the consistence of the net dorsiflexion torque generation and the controlling pattern of the agonist- antagonist muscles. Ten subjects were tested twice with a week apart. Fast and slow dorsiflexion at 40%-MVC were measured before and after fatigue of the TA by voluntary isometric dorsiflexions. The EMG of the TA and soleus (Sol) were recorded. The results revealed that more post-fatigue increment of the systematic error was in the fast dorsiflexions, random error increment were similar in both speeds of isometric dorsiflexions, the co-contraction ratio increased after fatigue only in the slow dorsiflexions. Our results suggested that precision of the fast targeted isometric contractions was reduced after fatigue because of unvaried agonist-antagonist control strategy.

KEY WORDS: fatigue, ballistic contraction, isometric contraction

INTRODUCTION: Ballistic and target orientated movement is common in sports. Muscle fatigue is defined as the failure to maintain required or expected torques or the increasing efforts to maintain the same torque output level. There are several mechanisms contribute to the generation of peripheral muscle fatigue including impaired neuromuscular transmission and deficit in the propagation of the muscle action potential (Binder-Macleod & McDermand 1992). Previous study has shown that torque of maximal voluntary contraction (MVC) declined and the contraction and relaxation prolonged after fatigue (Buttelli et al. 1996). Co-contraction has been observed during movements in which the torque must be generated very quickly. It is not clear whether this increased movement error can be corrected by adjusting the control pattern of agonist- antagonist muscle pairs. Accordingly, our purpose in this study was to investigate the effect of tibialis anterior (TA) fatigue on the controlling pattern of the agonist- antagonist muscles and on the consistence of the net dorsiflexion torque generation.

METHODS: Ten volunteers with averaged age 22.9 ± 1.97 participated. Only one leg of each subject was tested in two separated weeks and the testing leg was randomly determined. The isometric dorsiflexion torque was measured by torque measurement system (Figure 1). The electromyography (EMG) was recorded on the soleus muscle and (Sol) tibialis anterior muscle (TA) belly. After warm up, the test was started with 5 maximum voluntary contractions (MVC) of dorsiflexion. Forty percent of the averaged MVC was calculated to set the target line on screen and the target line was utilized for the whole session. Muscle fatigue was induced by intermittent maximal isometric dorsiflexions with on/off equal to 1s /1s. All subjects were verbally motivated to the development their maximal voluntary torque during the whole fatigue protocol. Post-test was started immediately which was the same as the pre-test protocols that contained five trials of fast and slow targeted isometric dorsiflexions. In the fast targeted isometric contractions, the subject was asked to generate the dorsiflexions torque as quickly as one can. In the slow targeted isometric contractions, the subject was asked to generate the dorsiflexions torque in a comfortable speed.

Figure 1 Torque measurement system.

Data analysis: The error was calculated by the following step: The target torque value was substrate from the peak torque of the dorsiflexion and then divided by the target torque value to obtain the raw percentage error. The mean and the standard deviation of the raw percentage error of five contractions in one trail were calculated. The absolute value of the mean was defined as the systematic error and the standard deviation was defined as the random error. The EMG was processed by full-rectified and linear envelope. The co-contraction ratio was calculated by dividing the Total EMG firing time from the Overlap EMG firing time. Two-way repeated-measure of ANOVA was used to examine the effects of fatigue and speed on systematic error, random error, co-contraction ratio. A significance level of $p < 0.05$ was used.

RESULTS: Subjects showed a significant fatigue in the study. To verify the fast and slow targeted isometric dorsiflexions were different in contraction speed, the time to peak torque (TPT) were analyzed. The result revealed that averaged TPT was significantly longer ($p < 0.05$) in the slow targeted isometric dorsiflexion than in the fast one. In the fatigue session, the TPTs of both slow and fast dorsiflexion were significantly prolonged after fatigue contractions ($p<0.05$), whereas in the control session, the TPTs were not changed. The result of ANOVA showed that the systematic error had a significant interaction between fatigue and speed ($p<0.05$) (Table 1). In the fatigue session, indicating that the fast and slow dorsiflexions responded differently to fatigue. The result of ANOVA showed that the random error had no significant interaction between fatigue and speed ($p > 0.05$) in the fatigue session. The main effect of the ANOVA revealed that the random error increased ($p < 0.05$) in the same manner (Table 2) after fatigue in both fast and slow dorsiflexions.

Table 1 Systematic error (mean ± Std.) in the fast and slow targeted isometric dorsiflexions.

	Fatigue session (%)		Control session (%)	
	Fast	Slow	Fast	Slow
Pre	11.69 ± 4.80	4.55 ± 2.16$^{\#}$	9.10 ± 3.91	3.3 ± 0.9$^{\#}$
Post	24.31 ± 6.53†	10.27 ± 4.1$^{\#\dagger}$	8.16 ± 3.77	4.6 ± 1.9$^{\#}$

†: significantly different from the fast targeted isometric contractions, $p < 0.05$;
$^{\#}$: significantly different from the pre-test, $p < 0.05$

Table 2 Random error (mean ± Std.) in the fast and slow targeted isometric dorsiflexions.

	Fatigue session (%)		Control session (%)	
	Fast	Slow	Fast	Slow
Pre	8.47 ± 3.73	2.82 ± 1.36$^{\#}$	6.03 ± 3.23	2.08 ± 0.9$^{\#}$
Post	17.23 ± 9.02†	6.71 ± 2.72$^{\#\dagger}$	4.91 ± 2.47	3.11 ± 1.6$^{\#}$

The co-contraction ratio result showed a significant interaction between fatigue and speed ($p<0.05$) (Table 3). The result revealed no significant difference between pre- and post-fatigue on fast dorsiflexion ($p > 0.05$). The co-contraction ratio significantly increased after fatigue in the slow targeted isometric dorsiflexions ($p < 0.05$).

Table 3 Co-contraction ratio (mean ± Std.) in the fast and slow targeted isometric dorsiflexions.

	Fatigue session (%)		Control session (%)	
	Fast	Slow	Fast	Slow
Pre	0.81 ± 0.14	0.67 ± 0.2#	0.76 ± 0.1	0.67 ± 0.28#
Post	0.82 ± 0.10	0.80 ± 0.2#†	0.80 ± 0.1	0.58 ± 0.34#

DISCUSSION: In this study, we found the TPT increased after fatigue. The increase of contraction time was also observed by the previous researches in the human adductor pollicis muscle and soleus muscle (Bigland-Ritchie et al, 1983; Shields et al. 1998).Previous researchers believed that the co-activation of the agonist and antagonist muscle was central programmed (Sanes & Jennings, 1984) and controlled by a common drive (Psek et al. 1993). This is evidenced by the result that the EMG amplitude of Sol increased after fatigue of TA. According to the result, the co-contraction ratio was only increased in the slow contractions but was unvaried in the fast contractions. It is possible that the change of co-contraction ratio in the slow contractions was for increasing the accuracy of movement. The increase of systematic error after fatigue can be explained by insufficient agonist muscle firing or excessive antagonist muscle firing after fatigue because the subjects' setting targets were lower after fatigue than before fatigue. The increase of random error might be attributed to the instable condition of muscle after fatigue. The consistent performance of the force generation would be difficult during this unstable period.

CONCLUSION: The slow targeted isometric contractions had smaller increment in the systematic error related to the change of the agonist-antagonist activation patterns. The random error cannot be compensated by the change of the agonist-antagonist activation patterns. Further studies about the motor learning during fatigue to reduce random error are suggested.

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