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CENTRAL AND PERIPHERAL FATIGUE IN WOMEN ATHLETES

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The purpose of this study was to compare the EMG activity in central and peripheral fatigue protocols with the knee's dynamic stabilizers. Twelve women in the central fatigue group completed a soccer game simulation protocol, while 13 women completed a maximal weight lifting protocol. EMG of the rectus and bicep femoris were taken in a rested and fatigued state. A repeated measures 2x2 ANOVA (α = 0.05) were used for comparison of average rectified values (ARV) and frequency data. The rectus femoris saw decreases in ARV and increases in frequency with fatigue with both central and peripheral fatigue. The bicep femoris had decreases in ARV and frequency with fatigue in central fatigue, while with peripheral fatigue both ARV and frequency increased.

KEY WORDS: knee stabilizers, EMG, instep-kick.

INTRODUCTION: Most studies on the relationship between muscle activity and fatigue have only examined isometric contractions, which may not represent the events of fatigue progression during dynamic activities, such as a soccer game (Rahnama et al., 2005). Although certain limitations are present with the use of surface electromyography (EMG) (including interference between neighboring muscles, inability to access deep muscle tissues, and a lack of linear signal output), this method of measurement remains useful in its application (Alkner et al.,, 2000). Rozzi et al., (1999) found that using surface EMG provided valuable information on the effects of fatigue on muscle activity of the knee's dynamic stabilizers (the hamstrings and quadriceps muscles). Over the past decade, studies utilizing EMG to measure muscle activation sequences and the effects of fatigue during functional tasks have emerged (Rozzi et al., 1999; Kellis et al., 2006).

Fatigue causes a general reduction in force from the muscles. Peripheral fatigue is generally thought to occur below the neuromuscular junction, while central fatigue is associated with reduction in the ability to fire voluntary contractions of the muscle (Boerio et al., 2005). Few studies have compared fatigue protocols that are not isometric contractions, but more based on game or workout conditions. The purpose of this study was to compare the EMG activity in central and peripheral fatigue protocols with the knee's dynamic stabilizers.

METHODS: Two groups of NCAA Division III varsity female athletes participated in this study. The first group consisted of 12 varsity soccer players (mean age = 21.3 ±1.6 years, mean mass = 64.0 ±8.6 kg) who completed a central fatigue protocol, while the second group included 13 athletes who participated in volleyball, soccer, softball or crew (mean age = 20.9±2.1 years, mean mass = 68.7 ±8.5 kg) who completed a peripheral fatigue protocol. These particular athletes were chosen because these sports were considered weight bearing or leg strength dependent. All subjects provided written consent approved by the University of Puget Sound Internal Review Board prior to participation.

To obtain central fatigue EMG data, the soccer group performed three maximal in-step soccer kicks prior to and following a 90 minute fatigue protocol. Data were collected for the plant leg side only. The fatigue course was designed to simulate an actual soccer game and has been used in numerous studies (Kellis et al., 2006; McGregor et al., 1999; Nicholas et al., 2000). Subjects jogged, sprinted, walked, and changed directions for a total of 9,600 meters. Four sets of 12 repetitions of course completion were accomplished followed by 10 single legged drops (5 on each leg) from a 40 cm high box. These drops were included in the protocol to simulate the ground reaction forces that occur on the plant leg during maximal in-step soccer kicks that take place during a soccer game. After sets 1 and 3, a 3 minute rest period was given while a 15 minute rest period was given between sets 2 and 3. After set 4 was completed, subjects then immediately performed three maximal in-step soccer kicks.

Subjects acted as their own controls so EMG data was collected during the maximal in-step kicks before and after the fatigue protocol without moving the electrodes.
The mixed athlete group completed a peripheral fatigue protocol that consisted of two sessions. During the first session, subjects' one repetition maximum (1 RM) of the leg press was obtained. During the second session, EMG data were recorded during the first (rested condition) and final (fatigued condition) set. Subjects completed multiple sets of the leg press at 85% of their 1 RM until failure. A two minute rest period between each set was given. Once the number of repetitions per set reduced to five or fewer, one final set was completed and EMG data were recorded for the fatigued condition.
EMG data were recorded with a BTS Bioengineering Pocket EMG™ (Milan, Italy). The subjects' skin was shaved, cleansed and abraded before placing the surface electrodes on the muscles. Silver chloride surface electrodes (20 mm in diameter) were placed on the muscle belly of the rectus femoris (RF) and bicep femoris (BF) with an interelectrode distance of 40mm, while the reference electrode was placed on the right wrist. To combat slippage due to perspiration, Tegaderm by 3M™ (St. Paul, MN) was used to hold electrodes in place for the central fatigue (soccer) subjects.
Data were sampled at 1000 Hz and passed through both a high pass filter (10 Hz) and a low pass filter (500 Hz). Average rectified values (ARV) were recorded for the RF and BF during the rested and fatigued condition for both groups of athletes. Mean frequency values were calculated for the rested and fatigued kick, as well as for the first three repetitions during the first and last set during the peripheral fatigue protocol.
Statistical Analysis: a 2x2 repeated measures ANOVA ($\alpha = 0.05$) was used to compare groups across rested and fatigued conditions for ARV and frequency for both the rectus and bicep femoris.

RESULTS: The EMG data can be found in Table 1. The rectus femoris ARV data showed significant decreases with fatigue. The central fatigue group decreased from 0.1874 (±0.1214) mV to 0.1064 (±0.0710) mV, while the peripheral fatigue group decreased from 0.2333 (±0.0959) mV to 0.0887 (±0.1091) mV. The rectus femoris frequency did increase significantly in both groups, with the mean increase in the central and peripheral groups being 9.9 and 5.6 Hz, respectively. The bicep femoris ARV and frequency data were significantly higher in the central fatigue group than the peripheral fatigue group. There was a significant interaction effect in the bicep femoris frequency data (see Figure 1). The central fatigue group saw a slight decrease in muscle frequency with fatigue, while the peripheral fatigue group saw an increase in muscle frequency with fatigue.

Table 1
ARV and Frequency EMG Data

	Central Fatigue		Peripheral Fatigue		
Measurement	Rested	Fatigued	Rested	Fatigued	Interaction p
ARV Rectus F. in mV ^	0.1874 ±0.1214	0.1064 ±0.0710	0.2333 ±0.0959	0.0887 ±0.1091	0.172
Freq Rectus F. in Hz ^	36.9 ±10.7	46.8 ±11.8	45.2 ±9.2	50.8 ±7.0	0.589
ARV Bicep F. in mV *	0.1753 ±0.0952	0.1383 ±0.1141	0.0567 ±0.0231	0.0887 ±0.1091	0.293
Freq Bicep F. in Hz *	51.9 ±14.2	49.7 ±10.4	32.4 ±5.0	37.1 ±6.5	0.005**

***** - significant differences (p < .05) between central and peripheral fatigue groups
^ - significant differences (p < .05) between rested and fatigued conditions
** - significant interaction (p < .05) between groups x condition

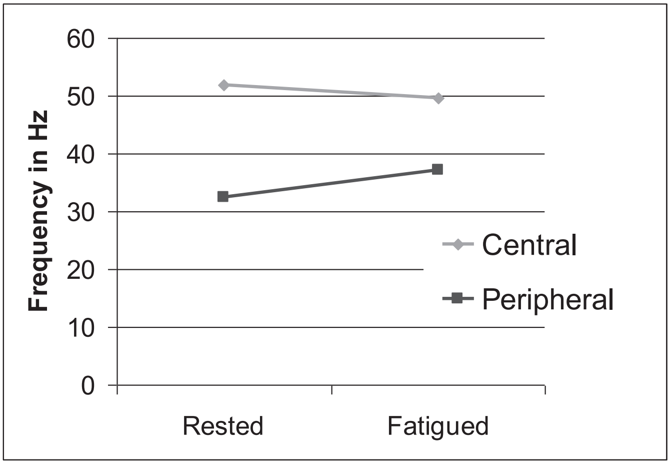

Figure 1: Bicep femoris frequency interaction graph.

DISCUSSION: Fatigue and the amount of strength are not always proportional (Smilios, 1998). Although decrements in performance can be seen with fatigue protocols, strength does not seem to be related to how one's performance is affected late in a contest (Smilios, 1998). For this reason it is important to note how the muscle fatigues in workout like conditions to determine if the joint is left destabilized during central or peripheral fatigue. Taylor and Gandevia (2008) found it very hard to determine if central fatigue occurred during submaximal tasks without noting the disproportionate increase in the subjects' rate of perceived exertion. In the current study it was evident from the subjects' responses that fatigue was achieved in both protocols.

Studies have investigated the increase in muscle activity with single joint knee extension (Babault et al., 2002; Kouzaki et al., 2002), but few studies have looked at multi-joint muscles activity (Alkner et al., 2000). These authors found that there was no difference in maximal EMG activity in single or multi- joint results. In the current study it was found that with fatigue ARV decreased with both central and peripheral fatigue in multi-joint activities. This was similar to what was found by Boerio et al. (2005) who reported a significant decrease in root mean square values (RMS) with fatigue in the rectus femoris. While ARV decreased, an increase in frequency was noted in the rectus femoris with fatigue. This may indicate that the muscle must produce more activity when fatigued to compensate for a loss of force regardless of whether the fatigue occurs above or below the neuromuscular junction (Boerio et al., 2005).

With central fatigue the bicep femoris saw both a decrease in ARV (-0.027 mV) and frequency (-2.2 Hz) with fatigue. This data was similar to the findings of Zory et al. (2005) who found that with isometric contractions the bicep femoris had decreases in RMS values. With peripheral fatigue in the bicep femoris just the opposite happened with increases in both the ARV (+0.032 mV) and frequency (+4.7 Hz). These results seem to contradict other studies (Zory et al., 2005; Boerio et al., 2005). This may have occurred due to the nature of the exercises. In the current study, data was collected with fatigue protocols used in every day activities, where most research is conducted with isokinetic machines. Although some control is lost in the current fatigue protocol, it would mimic the type of fatigue generated in practice or game situations. It is interesting to note that central and peripheral fatigue in the bicep femoris caused significantly different responses in frequency. The central fatigue frequency decreased, while the peripheral fatigue increased in EMG frequency. The peripheral fatigue protocol relied more heavily on the rectus femoris and as the muscle tired the action may have become more dependent on the bicep femoris for support. In the central fatigue testing the landing phase of the plant leg measures about 2.5 times body weight in force, but it may occur so quickly that the bicep femoris does not increase in muscle frequency during the landing phase. This could potentially leave the joint unprotected.

CONCLUSION: The rectus femoris saw decreases in ARV and increases in frequency with fatigue with both central and peripheral fatigue. The bicep femoris had decreases in ARV and frequency with fatigue in central fatigue, while with peripheral fatigue both ARV and frequency increased.

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