A SURFACE ELECTROMYOGRAPHIC ANALISIS ABOUT THE FATIGUE ON WOMEN THROUGH THE MENSTRUAL CYCLE

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Abstract: The scientific community has great interest on the study of lesions and muscle pain, due to its relevance on ergonomics, sports, and chronic pain treatment. Some studies report a higher capacity of muscular resistance on women. This higher endurance can lead to lesions due to the continuous state of activation of the muscles. Prior studies have reported a high level of influence of the menstrual cycle on the probability of lesions. This work investigates fatigue levels along the menstrual cycle. The variation in conduction velocity of surface electromyographic signals (S-EMG) was investigated in a long-term contraction of the biceps brachii muscle on seven women during a four-week protocol. Statistically significant differences between the four weeks of the menstrual cycle were found.

Key words: menstrual cycle, S-EMG, fatigue.

Introduction

There is great interest in the scientific community on the study of injuries and muscle pain, because of its relevance in applications such as ergonomics, sports and treatment of chronic pain. Special attention is being given to injuries of the anterior cruciate ligament (ACL) [1, 2], which is the most common injury in collective sports and athletics. Also, there is special interest on pain in the shoulders and the back [3, 4].

Studies show that women have greater muscular endurance then men [5, 6]. This lower sensibility to fatigue shown by women can contribute to lesions in extreme cases due to continued activation of muscle fibers [7].

The menstrual cycle is an important factor influencing muscle fatigability on women. There is a strong link between hormone levels and laxity of joints, making women more vulnerable to injuries [8]. In the middle of the cycle, the level of estrogen, which strengthens the muscles and tendons, is significantly reduced. At the end of the cycle, the level of the hormone relaxina increases, which also weakens the tendons. Additionally, some of the differences in neuromuscular control reported in the literature can be explained by the difference in concentration of sex hormones [9]. Moreover, greater resistance to fatigue was reported in women in menopause [10], whose hormonal changes are less intense.

During sustained isometric contractions, when the muscle length and tension are held constant, muscle fiber conduction velocity (CV) decreases with fatigue. This phenomenon is correlated with a decrease of the mean (MNF) and median (MDF) frequencies of surface electromyographic signals (S-EMG) [11].

This work investigates the changes on the CV estimator along four phases of the menstrual cycle: beginning and end of the follicular and luteal phases, respectively. For this purpose, the CV estimator was evaluated during four long-term isometric contractions during weekly sessions.

Materials and Methods

Subjects – A protocol was developed to guarantee the same conditions to all the subjects in all the acquisitions: Seven females volunteered to participate in the study (24.0 ± 2.8 yr). All subjects were right handed with no known neurological disorders. All subjects had regular menstrual cycles, the same level of training, and were not using any hormonal medicine or contraceptive for at least 6 months. Prior to the study, all subjects gave informed consent to the protocol approved by the Medicine Ethics Committee of the University of Brasília, Brazil.

Equipment – In the experiment, two types of signals were recorded: the force level and the S-EMG. The force level was recorded to guarantee the isometric characteristic of the S-EMG signal. It was measured with a force cell with 50 kgf of maximal load (model TS, AEPH do Brasil, São Paulo, Brazil), connected to a biomechanics' signal amplifier MISO II (OT Bioelettronica Snc, Italy). The MISO II was set to gain 1.

An electromyographer (EMG 16, OT Bioelettronica Snc, Italy) connected to a laptop computer with a PCMCIA card was used to acquire the S-EMG Signals and the force signals.

For the mapping of the optimal region of the biceps brachii muscle, a 16-electrode array was used (Ag, 5mm inter-electrode distance, OT Bioelettronica Snc, Italy) with a sample rate of 2,048 Hz and an analog gain of 2,000 in the single differential configuration.

S-EMG signals were recorded with an array of eight surface electrodes (Ag-AgCl, 5mm inter-electrode distance, OT Bioelettronica Snc, Italy) placed over the cleaned skin of the short head of the biceps brachii muscle with conductive gel, and using the single differential configuration, resulting in seven S-EMG signals for each acquisition. A reference electrode was placed in the right wrist. A sample rate of 2048 Hz and an analog gain of 2,000 were used.

Experimental protocol – The experimental protocol was executed identically for each subject in all sessions. Each subject performed the experimental protocol in four sessions, with an interval of one week between each session.

First, three 5-second measurements were made to determine the maximal voluntary contraction (MVC). The higher value of all acquisitions of the first session was adopted as the MVC for all sessions. The equipment registered the MCV automatically. Strong verbal encouragement was used.

The 16 superficial electrode array was then fixed in the region of the biceps brachii muscle. A new acquisition was made for mapping the tendons and innervations zones. Then, a flexible array of 8 superficial electrodes was positioned in the optimal region.

Finally, the subjects performed an isometric contraction at 40% MVC, which was sustained for 90s. After 5 minutes of rest.

The follicular and luteal phases were roughly determined and the data was then divided in four groups: F1 and F2 for follicular phase and L1 and L2 for luteal phase, as illustrated in Figure 1.

The four sessions with each subject were scheduled without taking into consideration the current period of the menstrual cycle. The results from the first session with each subject were labeled either F1, F2, L1, or L2, depending on the subject's current period at the time of her first session. The next three sessions were also labeled accordingly. Therefore, the four-week experiment may begin during any of the four phases of the subject's menstrual cycle. This reduces bias as the subject becomes familiarized with the protocol and/or adapted to the exercise.

Data Processing – The main aim of the research was to evaluate the fatigue along the menstrual cycle. To do so, the conduction velocity of the S-EMG was evaluated. This estimator was calculated using the algorithm described in [12], which was based on the method described in [13].

For each subject, CV and cross-correlation coefficient were estimated from the signal of each pair of differential channels. One pair of channels was selected considering a high cross-correlation (greater than 75%) and a CV value close to the physiological value of 4 m/s.

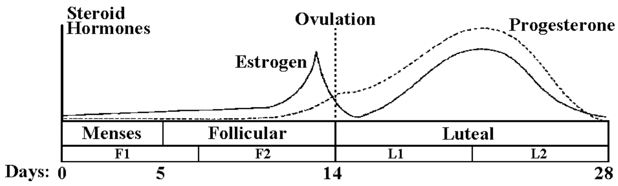

Figure 1: Changes in concentrations of estrogen and progesterone during the menstrual cycle. Estrogen concentration rises and drops sharply by the end of the follicular phase. It rises again along with progesterone, and both drop by the end of the luteal phase. Estrogen and progesterone concentrations are both low during menses. Modified from [22].

Linear regression was performed to determine the ratio of change of each measurement during the fatiguing exercise. To allow comparisons between the slopes of different regressions, the angular coefficient was normalized using the linear coefficient (initial value) of the regression line.

Statistical Analysis – The normalized value of CV of each group of data (F1, F2, L1 and L2) was tested with t-test against all the other groups.

Results

A t-test was performed comparing each period (F1, F2, L1 and L2) to the other periods. Table 1 shows t-test results for each case. Figure 2 shows all the individual values of angle inclination for the regression line of CV data and its behavior along the periods for each subject (points and thin lines), as well as the mean values (stars and ticker line. The results show that females present a greater endurance (high resistance to fatigue) during the F1 and L1 periods (lower angle of inclination). Statistical results show a significant difference between the F1 and F2 periods, and between F2 and L1. Periods F1 and L1 are similar, as well as periods F2 and L2. The p value was considered significant for $p<0,05$.

Discussion

The main goal of this work was to study fatigue in women trough the menstrual cycle. Decreases in conduction velocity (CV) is considered a more robust and reliable fatigue estimator because it provides information not only about changes in characteristic spectral frequencies [11], but also regarding fiber membrane properties, and peripheral muscle fatigue [14]. Also, CV changes are indicative of muscle fiber type constituency and particular muscle training [15].

Table 1: Results of T-test comparing each period of the menstrual cycle

	Mean Group 1	Mean Group 2	t-value	p	Std. Dev. Group 1	Std. Dev. Group 2	F-ratio Variances	p Variances
Folicular 1 Vs Folicular 2	-0.000890	-0.002216	2.254121	0.043672	0.000717	0.001382	3.719324	0.134926
Folicular 2 Vs Luteal 1	-0.002216	-0.000880	-2.38354	0.034540	0.001382	0.000539	6.572068	0.037423
Luteal 1 Vs Luteal 2	-0.000880	-0.002413	3.833156	0.002382	0.000539	0.000910	2.850065	0.228099
Luteal 2 Vs Folicular 1	-0.002413	-0.000890	-3.47726	0.004569	0.000910	0.000717	1.612934	0.576037
Folicular 1 Vs Luteal 1	-0.000890	-0.000880	-0.029784	0.976729	0.000717	0.000539	1.767006	0.506266
Folicular 2 Vs Luteal 2	-0.002216	-0.002413	0.313527	0.759263	0.001382	0.000910	2.305936	0.332770

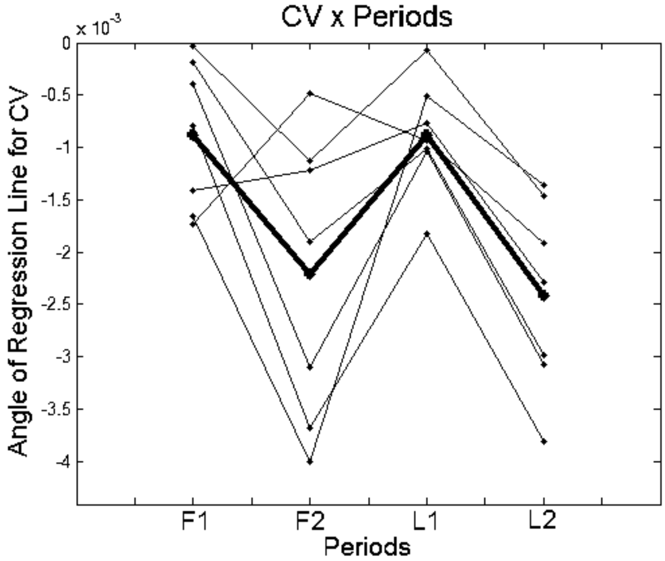

Figure 2: Behavior of CV during menstrual cycle periods (F1, F2, L1 and L2). The thin lines represent the behavior of the angle of inclination of the regression line for CV for each subject. The thicker line represents the mean behavior for all subjects. It is possible to see a higher endurance during the F1 and L1 periods (lower value for angle of inclination).

With respect to the CV estimator, groups F1 and L1 demonstrated a lower level of fatigue (lower decrease of CV over time), while the fatigability of groups F2 and L2 were higher.

The increases in fatigability of females in certain periods indicate the need of special care. According to the overload injury model [16], exercise with fatigue and repetition are related to muscle-tendinous injuries. Repetitive muscle use may eventually lead to inflexibility, muscle weakness, and imbalance in muscle strength in a particular area. Continued use may cause pathological injury. Overuse injuries are the ones most commonly seen in exercising populations.

Figure 1 shows that the phases when higher fatigability is observed (F2 and L2) coincide with sharp estrogen reduction. Estrogen has direct effects on muscle, and fluctuation in estrogen and other female sex hormone levels may play a role in dynamic muscle control [17].

In addition, Florini [18] showed that fluctuations in estrogen levels may affect neuromuscular firing patterns in female athletes [18]. Corroborating, Moller-Nielson and Hammar [19] reported that athletes taking hormonal contraceptives had a lower injury rate. This is because the elevated estrogen and progesterone levels in oral contraceptive pills inhibit ovulatory hormone oscillations and prevent ovulation directed by the hypothalamus.

Conclusion

This study showed that female subjects present a higher sensibility to fatigue during the end of both the follicular and luteal phases of the menstrual cycle (F2 and L2), taking into account the CV estimator. These phases coincide with periods of high reduction in hormone concentration.

According to the results of this work, female subjects demonstrated a different behavior related with muscular fatigue during isometric contraction in different stages of the menstrual cycle. The fatigue levels may be associated with injuries as reported in [20-21].

Ignoring the hormonal fluctuations in females on training programs or in sports may lead to muscular injuries. A individual training program that takes into account the menstrual cycle may lead to better results.

This study will be continued with studies with subjects of different ages and physical characteristics.

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References

[1] Arendt, E., Agel, J., Dick, R. (1999) “Anterior cruciate ligament injury patterns among collegiate men and women”. In: *J Athl Train*, v. 34, n. 2, p. 86–92.

[2] Jones, B. et al. (1993) “Intrinsic risk factors for exercise-related injuries among male and female army trainees”. In: *The American Journal of Sports Medicine, AOSSM*, v. 21, n. 5, p. 705.

[3] Nie, H., Arendt-Nielsen, L, Kawczynski, A, Madeleine, P. (2007) “Gender effects on trapezius surface EMG during delayed onset muscle soreness due to eccentric shoulder exercise”. In: *Journal of Electromyography and Kinesiology*, v. 17, n. 4, p. 401–409.

[4] Kawczyński, A., Nie, H., Jaskólska, A., Jaskólski, A., Arendt-Nielsen, L., Madeleine, P. (2007) “Mechanomyography and electromyography during and after fatiguing shoulder eccentric contractions in males and females”. In: *Scandinavian Journal of Medicine & Science in Sports*, v. 17, n. 2, p. 172.

[5] Hunter, S., Enoka, R. (2001) “Sex differences in the fatigability of arm muscles depends on absolute force during isometric contractions”. In: *Journal of Applied Physiology, Am Physiological Soc*, v. 91, n. 6, p. 2686–2694.

[6] Semmler, J., Kutzscher, D., Enoka, R. (1999) “Gender Differences in the Fatigability of Human Skeletal Muscle”. In: *Am Physiological Soc*, v. 82, n. 6 p. 3590–3593.

[7] Gandevia, S. (201) “Spinal and Supraspinal Factors in Human Muscle Fatigue”. In: *Physiological Reviews, Am Physiological Soc*, v. 81, n. 4, p. 1725–1789.

[8] Sandler, S. (2007), *Changes in Joint Laxity Associated With the Menstrual Cycle, With Pregnancy, With the Post-Partum Period, and With the Menopause*, Tese de Doutorado, The British School of Osteopathy (submitted).

[9] Dedrick, G.S., Sizer, P.S., Merkle, J.N., Hounshell, T.R., Robert-McComb, J.J., Sawyer, S.F., Brismée, J.M., Roger J.C. (2008) “Effect of sex hormones on neuromuscular control patterns during landing”. In: *Journal of Electromyography and Kinesiology*, v. 18, n. 1, p. 68–78, 2008.

[10] Hicks, A., Mccartney, N. (1996) “Gender differences in isometric contractile properties and fatigability in elderly human muscle”. In: *Can J Appl Physiol*, v. 21, n. 6, p. 441–454.

[11] De Luca, C. J., (1984) “Myoelectrical manifestations of localized muscular fatigue in humans,” In: *CRC Crit. Rev. Biomed. Eng.*, v. 11, n. 4, p. 251-279.

[12] Salomoni, S., Soares, F.A., Nascimento F.A.O., Veneziano, W.H., Rocha, A.F. da (2007) “Algoritmo de Máxima Verossimilhança para a Estimação da Velocidade de Condução Média de Sinais Eletromiográficos de Superfície”. In: *IFMBE Proceedings CLAIB 2007* v. 18, p. 1049–1053.

[13] Farina, D., Merletti, R., (2004) “Methods for estimating muscle fiber conduction velocity from surface electromyographic signals”. In: *Med. Biol. Eng. Comput.*, v. 42, p. 432-445.

[14] Farina, D., Arendt-Nielsen, L., Merletti, R., and Graven-Nielsen, T., (2002) “Assessment of single motor unit conduction velocity during sustained contractions of the tibialis anterior muscle with advanced spike triggered averaging,”. In: *J. Neurosci. Methods*, v. 115, p. 1–12.

[15] Sadoyama, T., Masuda, T., Miyata, H., and Katsuta, S., (1988) “Fiber conduction velocity and fiber composition in human vastus lateralis,”In: *Eur. J. Appl. Physiol.*, vol. 57, p. 767–771.

[16] Kibler, W.B., Chandler, T.J., Stracener E.S., (1992) “Musculoskeletal adaptations and injuries due to overtraining”. In: *Exerc. Sport. Sci. Rev.*, v. 20, p. 99-126.

[17] Hewett, T.E., Zazulak, B.T. and Myer, G.D., (2007) “Effects of the Menstrual Cycle on Anterior Cruciate Ligament Injury Risk: A Systematic Review”. In: *Am. J. Sports Med.*, v. 35. P. 659.

[18] Florini, J.R. (1986) “Hormonal control of muscle growth”. In: *Muscle Nerve*, v. 10, p.577-598.

[19] Moller-Nielson, J, Hammar, M. (1991) “Sports injuries and oral contraceptive use. Is there a relationship?”. In: *Sports Med.*, v. 12, p.152-160.

[20] Gefen, A, (2002) “Biomechanical analysis of fatighe-related foot injury mechanisms in athletes and recruits during intensive marching”. In: *Med. Biol. Comput.*, v. 40, p. 302-310.

[21] Stacoff, A., Steger, S., Stussi, E., and Reinschmidt, C. (1996) “Lateral stability in the sideward cutting movements”. In: *Ned. Sci. Sports Exere.*, v. 28, p. 350-358

[22] Warden, S. J., Saxon, L. K., Castillo, A. B., Turner C. H., (2006) “Knee ligament mechanical properties are not influenced by estrogen or its receptors,” In: *Am J Physiol Endocrinol Metab*, v.290, p. 1034-1040.