LACTATE THRESHOLD USING MATHEMATICAL DETECTION OF THE EMG DURING INCREMENTAL PEDALING EXERCISE

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The purpose of this study was to determine the validity of using the EMG as a non-invasive method to estimate LT in non-athletes subjects. Twenty-four non-athletes subjects performed an incremental exercise protocol that consisted of stepwise increases in power output of 25W every 3 minutes until exhaustion at 80 rpm. The EMG was recorded from the right vastus lateralis and right rectus femoris each 15 seconds. Blood samples were taken every 3 minutes. The LT was determined using a log-log transformation model. The EMGT was determined mathemathically using MATLAB® software that models RMS response to gradual exercise using linear regression. The results showed high the correlation coefficients between EMGT and LT, and the validity of using EMG to estimate the LT power output was confirmed.

KEY WORDS: EMG, lactate, exercise.

INTRODUCTION:

The surface EMG has been used as non-invasive method to quantify the level of activation of working skeletal muscles (Moritani et al.,1982, Hug et al. 2006). During exhaustive incremental exercises, although some authors found a linear relation between the RMS of the EMG and workload level, and a non-linear increase of RMS has been considered a typical pattern (Nagata et al., 1981,Lucia et al., 1999, Hug et al, 2003). Although the reason for this breakpoint, the so-called EMG threshold (EMGT) is not clear, for many authors it would represent the point where an increased recruitment of fast twitch motor units occurs to mantain the required energy suplly for muscle contraction (Matsuura et al. 2006). As the recruitment of fast twitch motor units results in a greater lactate production and it has an impact on the amplitude of the EMG signal, various studies have proposed the EMGT could be a new noninvasive estimation of the lactate threshold from the EMG signal during a progressive load protocol (Moritani & Yoshitake**,** 1998, Gladden, 1998, Lucia et al., 1999).
The lactate threshold (LT) represent the exercise intensity that is associated with a substancial increase in blood lactate during an incremental tests (Svedahl & MacIntosh, 2003). There are many reasons for trying to quantify this intensity of exercise, including assessment of cardiovascular or pulmonary health, evaluation of training programs, and categorization of the intensity of exercise (Rowlands & Downey, 2000, Svedahl & MacIntosh, 2003). Thus, several methods have been developed to determine the intensity of exercise associated with LT, especially in athletic populations (Billat, 1996). Each method permits an estimate of intensity associated with LT, but also has consistent problem depending on protocol and criteria esed to identify the apropriate intensity of exercise. The use of detection mathematical of EMGT to predict LT ocurrence could present some practical advantagens, as reproducibility, lower requirement for investigator experience and invasiveness. Also, it would represent an interesting tool for coaches of non athletes peoples who cannot use the very expensive devices (tape lactate), but have access to EMG system. Besides of the practical application, little research has determined the validity of the EMGT method for analyzing LT. Thus, the purpose of this study was to determine the validity of EMG signal as a non-invasive method to estimate the lactate threshold in non-athlete subjects.

METHOD:

Subjects and Protocol: Twenty-four no-athletes subjects with 24.9 ± 3.7 yrs, 72.4± 7.5 kg and 164 ± 18cm volunteered to participate in the experiment. The exercise testing was performed on an electromagnetic bicycle ergometer (model SF, Funbec, Brazil) and the protocol consisted of 3 minutes unloaded pedaling followed by stepwise increases in power output of 25W every 3 minutes until exhaustion while the pedaling cadence was kept constant (80 rpm).

Data Collection: Blood samples (25 μl) for the measurement of blood lactate were taken from fingertips at rest, at the end of each 3 minutes stage and immediately after termination of exercise using an Accusport Lactate Analyzer (Boehringer Mannhein, Mannhein, Germany)(Baldari & Guidetti (2000). The EMG signals were recorded throughout the course of the test. The signals were recorded using a Pentium 200 MHz PC compatible microcomputer, with a converting 12 bit AD board (Lynx Tecnologia Eletrônica Ltda, São Paulo), at a sampling frequency of 1000 Hz per channel. The EMG activity was recorded from the right side vastus lateralis and rectus femoris muscles, in accordance with "Standards for reporting EMG data" [Electromyography and Kinesiology, 1997]. Disposable surface electrodes (Ag/AgCl; 1.0 cm diameter) were placed in a bipolar configuration on the bellies of the muscles, following the supposed alignment of the muscle fibers. The reference electrode was placed on the left wrist. Impedance between electrodes was accepted when below 5 kohms. Recordings were made with the aid of a sixteen-channel EMG system (Model EMG-800C, EMG System do Brasil Ltda, São José dos Campos) comprised of pre-amplifiers (fixed gain of 20) located approximately 10 cm away from the electrodes. The input impedance of the system was 10 Gohms; the common mode rejection rate (CMRR) was greater then 100 dB (at 60 Hz); and the signal to noise ratio was 3.0 μvolts RMS.

Data analysis: The lactate threshold (LT) was determined by examining the relationship between the lactate concentration and power output during the test using a log-log transformation model (Beaver e al., 1985). Two independent experts identified and confirmed the LT. EMG data was analyzed using MATLAB® software (version 5.3, Matchworks, 1966). Raw EMG was initially submitted to a band-pass filter (Butterworth, 3rd order, 20-400 Hz), following which the RMS value from the EMG signal was calculated every 1-second non-superimposing window. Each point on the graph corresponds to one second of EMG (Figure 1). The total points were divided into two groups. A straight regression line was plotted for each set of points and the corresponding determination coefficients (R^2) were calculated. The product of the two coefficients resulted in an index representing the linearity of the two regions. The two sets of points that together formed the highest index were chosen to represent the EMG threshold (EMGT), that is, the intersection of the two straight lines marked the breakpoint at which the EMGT was established. Figure 1 shows the EMGT procedure. The data obtained were analyzed using SPSS 10.0 software. One-way ANOVA was applied in order to identify any possible differences between the EMGT and LT for both the rectus femoris and vastus lateralis muscles. The Pearson product moment correlation coefficient was used to calculate the linear relationship between the EMGT and LT. Significance was set at $p<0.05$ for all statistical analyses.

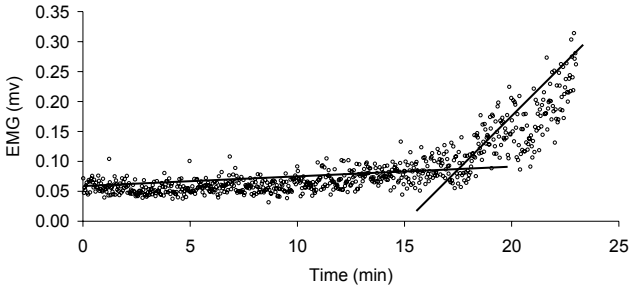

Figure 1 – Determination of the EMGT. The EMG breakpoint is located at the intersection between the two straight lines.

RESULTS:

In 90% of the subjects, the EMG breakpoint was detected in both the vastus lateralis and rectus femoris muscles. Figure 1a shows mean values of power output at the EMGT (in both muscles) and LT. There was no significant difference between power output at the EMGT and LT (p=0.964). Figure 2b illustrates the time-course of blood lactate concentrations and RMS in the vastus lateralis muscle for one subject. Correlation coefficients (r) between EMGT and LT were significant (p<0.01) and high for the vastus lateralis (r=0.826) and rectus femoris (r=0.872) muscles and many subjects showed the same power output: 175 W (n=4); 150 W (n=6); 125 W (n=9); 100 W (n=2) and 75 W (n=3).

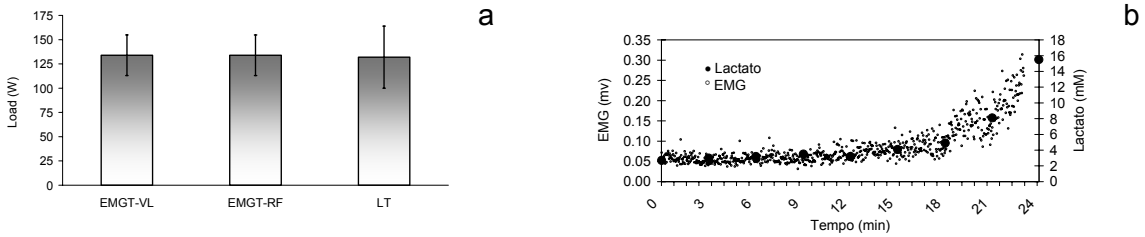

Figure 2 – a) Mean values of power output at the EMGT and LT. b) EMG recording of the vastus lateralis muscle (empty circle) and blood lactate concentration (filled circle) from one subject.

DISCUSSION:

An important finding in this study was that in non-athletes the power output of the EMGT of the VL and RF corresponded to the power output of the LT during a incremental test. A similar response has been reported in previous studies (Nagata et al., 1981, Glass et al., 1997, Chwalbinska-Moneta et al., 1998, Lucia et al, 1999). A possible explanation for EMGT occurrence is the during a incremental test as exercise intensity is increased the force generating requirements is increased. According to the size principle of recruitment more high threshold, fast twitch motor units are recruited which results in a greater lactate production (Lucia et al, 1999, Matsuura et al. 2006). As this recruitment has an impact on the amplitude of the EMG signal, the initial speculation that the LT would be identified using surface EMG was confirmed when the EMGT and LT power outputs were equivalent. In addition, such changes in EMG have been shown to be related to hydrogen ions and accumulation of metabolic by-products, such as lactate ion (Lucia el al, 1999, Matssura, 2006). These changes would in turn affect the muscle excitation-contraction coupling, including the muscle membrane properties and muscle action potential propagation, with a subsequent decrease in the developed force, leading to EMG manifestation of muscle fatigue. Some authors have suggested that the lactate ion itself has no major role in the fatigue process (Brooks, 2001). Thus, a relation of cause and effect must be avoiding. Others studies have found no such correlation between LT and EMGT (Jasen et al., 1997; Pringle & Jones, 2002). The differences found in the results reported in the studies may be attributable, in part, to differences in methodology and make comparison very difficult, but an important fact is that most of these studies used visual detection of the EMGT. According to Hug et al (2006), this method is lesser objective and depending for investigator experience. The results of previous studies using only visual detection of EMGT could be reconsidered. Using a mathematical method of identification of EMGT similar to the present study, Lucia et al. (1999) detected two thresholds in EMG that occurred concomitantly with lactate thresholds. The authors reported that these two thresholds occurred as result of a change in the pattern of motor unit recruitment with possible participation of type IIa and IIb fibers (at the EMGT1 and EMGT2, respectively) producing larger action potentials, followed by some degree of synchronization as these fibers underwent progressive fatigue. The fact that only one EMG threshold was found in no-athletes subjects may indicate that only highly trained subjects are able to effectively recruit a sufficient number of motor units (specially type IIb fibers) at near maximum intensities during incremental testing and thus, induce a second EMG break point.

The results of the present study are in overall agreement with Lucia et al. (1999), because the distinct EMGT may have occurred as result of changes in the pattern of motor unit recruitment from a predominantly slow twitch motor unit to a fast twitch motor unit.

CONCLUSION

The RF and VL muscles showed similar behavior during maximal incremental testing and the EMGT and LT power outputs were equivalent for both muscles. The validity of using EMG to measure the power output corresponding to the LT in no-athletes subjects was confirmed.

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