Chapter 5

Influence of Different Strategies of Treatment Muscle Contraction and Relaxation Phases on EMG Signal Processing and Analysis During Cyclic Exercise

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Additional information is available at the end of the chapter

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1. Introduction

For a long time we work with muscular activity, trying to answer questions related to fatigue, muscle activity and other issues related to neuromuscular system. In this way we started to use the electromyography (EMG) as a tool to achieve better results in our studies, since it appeared to us as a truthful method to access the muscle activity inside a lot of perspectives we had been working with.

In this chapter we will try to bring some research results that we found on the GEPESINE laboratory in the last couple of years about regarding the EMG analysis. Firstly there are relevant issues that arise during the use of EMG as a tool in others works. It is not hard to find studies that use EMG signal as a way to measure the muscle activity [1-3], muscle fatigue [4] and also in studies involving healthy issues [5]. Most of those studies try to access the activity or fatigue slope of the muscle during some motor task, mostly trying to access performance or just to categorize an activity according to the muscle(s) accessed. The real problem is that most of those studies use isometric movements or even isokinetic, leaving a remarkable problem for the researchers who decide to work with dynamic contractions, once the available protocols are most based on and suitable isometric studies.

We have decided to take a different look to the process on how to treat the EMG signal and how to analyze it. For instance, in order to have a more trustful signal, founds in literature recommend filtering, smoothing the raw and also rectifying the signal, which the last step does not affect the signal power. However, the filtered root mean square (RMS) signal could not be the best way to pre-process the EMG signal. Other current concern, in EMG signal pre-processing, is about the use of the total signal against evaluation only the burst-time segments of the signal. Those concerns are explained and analyzed along this chapter. In an epistemological language, we take a more critic look into the EMG signal processing. We hope the reader also to have the same look, not only into the results and conclusions, but also, into methods and thoughts, since the intention herein is not to bring an irrefutable true, but the real intention is to discuss and point out valuable arguments for the reader in order to he/she thinks about it by himself or herself, and apply it properly.

2. Theory

2.1. The importance of electromyography in cyclic exercises

Cyclic exercises correspond to modalities such as bicycle, running, walking and swimming. Inside those we can already imagine a lot of different sports with a great repercussion over the media, a few examples include: street bike, mountain bike and tour, like the famous Tour of France; marathon, 400 meters, race walking and putting in just one thing, the triathlon. You may notice that the swimming sports are not exemplified above, it’s because it is still hard to access the muscle activity through electromyography in those sports due to the environment where they happens. This discussion was set aside for our future work

So, keeping in mind that some of the most important sports have a cyclic dynamic as characterization, for the evolution of them, new technologies need to be able to help the coaches and physical trainers. Nowadays individual time-trial sports are reaching world records that we would never imagine, and every new record is followed by a technology behind it helping in training or even during the task if is not prohibited. To be able to access the muscle activity with a good reliability in different moments of the exercise could give us the weak and the strong moments of one athlete during the task, and allow us to create the better strategy and also create new training cycles that can improve the weakness. It is worth noting the electromyography is useful to access not only muscle activity -- in order to enhance the performance in sports --, but also be deployed in exercises evaluation aiming healthy improvement.

2.2. Time and frequency domain

Talk about frequency domain is talk about: how many times a event occurs in a time space, in this way, to use this component we need transform the signal in different points presented in a frequency spectrum capable to show us the energy of cue obtained in the determined muscle. This energy in the most part of the time appears represented in some bands, where your intensity and duration has more amplitude. To find and use the spectrum, we must find a source that gives us the possibility to produce this figure, when sometimes the Fast Fourier Transform proves as algorithm in a simple calculus to find discrete signals. A series of recommendations are proposed to this technique, since the establishment of sample number, duration intervals, window apply and many aspects as signal stationary is a complicated thing to deal with, which leads us to use a wavelet transform, more appropriate to cyclic activities as cycling and running for example [6-9].

Independently of technique used we should get some variable from this analyses to compare, relate or make our considerations, in this case, the most common variable toke from frequency domain is the median frequency, representative of fatigue aspect in the muscular activity from decrease of conduct fibers velocity, is exactly the point that divided the spectrum in two equal parts and gives us a good representation of reduction in the force produced.

Time domain is used when the intention is to achieve the contractibility of the muscle, meaning that as stronger the signal the most number of motor units are been activated. The most common variable used inside this domain is the Root Mean Square (RMS) [9]. To get this variable some procedures are required, like the filtration, rectification and smoothing, those will be better explained later. Just like the frequency domain, a correct time window is necessary and follows the frequency domain also when talking about the use of wavelet transform.

2.3. Treating the EMG signal

Now you already know about how the domains work and how to use them for different analysis depending on the applications necessity. During the subchapter “Analysis of the EMG signal” we hope it became clear that we have some procedures until the real signal is accessed, especially without noises. The raw signal can already give us some information, like the muscle innervations or even the change in the signal size. Depending of the intention, these qualitative variables can be very useful. An easy and good way to simple control some noises when there is no intention of further computer treatment to remove it, is to be sure to have a good baseline, meaning that the line that should appear at the EMG signal must be as close as it can to zero when the muscle with the electrode connected is not in contraction. That doesn’t mean that when the muscle starts to contract the signal that will appear will only be from the muscle activity, especially in dynamic contractions. There are three main differences in noises on static contractions and dynamic ones, they are: the non-stationarity of the signal for the constant contraction and relaxing of the muscle, the change of the electrode distance relative to the origin of the action potential and the changes in the conductivity of the tissues properties [10].

A better way to understand what a noise is, is looking at it, the figure 1 under is an EMG signal with a closer look in the burst moment. Notice that the areas surrounded with black circles have a peculiar difference, it has a horizontal straight shaped line, which means that those parts don’t have a corresponding negative part, and so, it is considered a noise. Of course in this same image you can find some more of those, not only the surrounded ones, but the intention here is only to show how a noise appears inside an EMG signal.

When the signal appears to us in the computer screen those details are impossible to see without a zoom look. So, lets talk now about how the treatments can influence in the signal value.

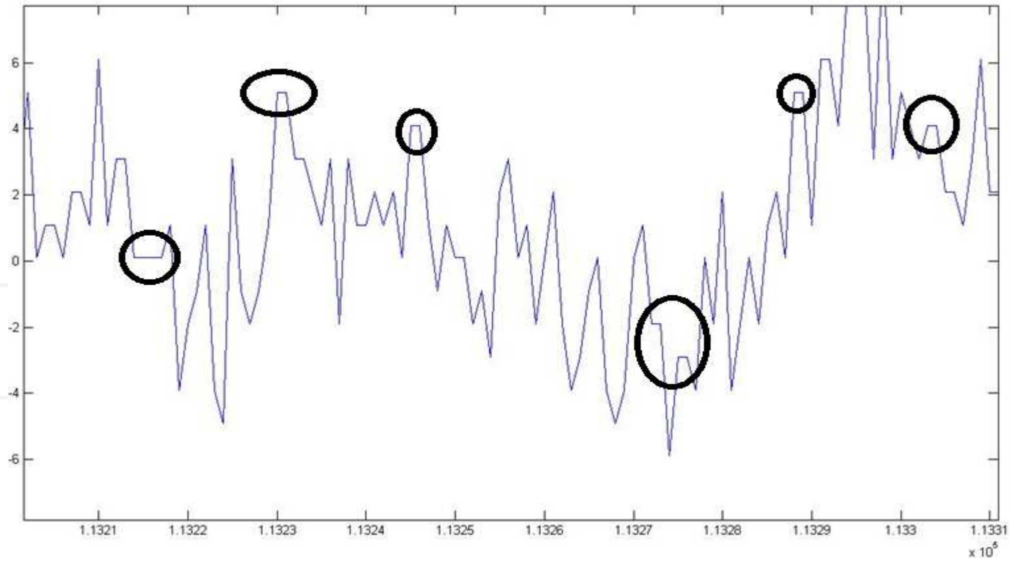

Figure 1. Noises in the EMG signal

Note the figure 2 under, pay even more attention to the baseline in the raw signal, it is close to zero because it almost creates a straight line, considering that the muscle in this case is the vastus lateralis in a bike-like exercise, we can imagine that in the beginning of the exercise he is not much triggered, probably because the recto femuralis is doing almost all the job, but as time goes and also the exercise, its starts to have stronger signal, so we can imagine that the other muscles, like the recto femuralis is entering in fatigue process, so the vasto lateralis as a co-worker has to get part of this charge in order to maintain the exercise, that is the kind of qualitative analyze that was told before, without even knowing the values numbers, we can visually access an ideia about the use of vasto lateralis in a cicliergometer exercise.

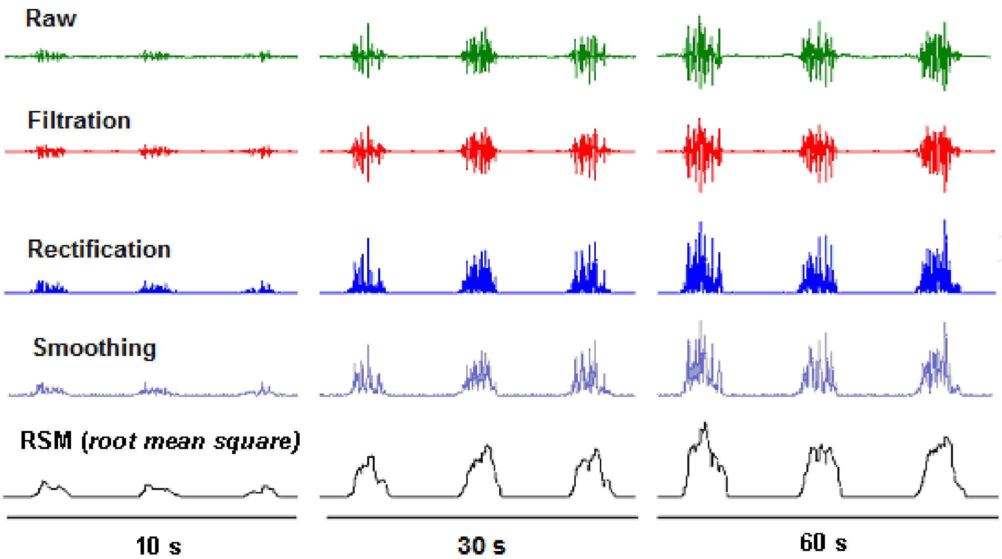

Figure 2. EMG signal process recommended. Green: The raw signal, no treatment was applied until this moment; Red: Filtrated signal, a limit was created for the signal, excluding everything out of it; Blue: Rectified signal, all negative values were transformed in positive ones and added; Purple: the smoothed signal, a linear enveloped was created and the extreme parts of the signal was excluded; Black: The RMS values after all the treatments.

With the intention of clearing the EMG signal, and make it more reliable and truthful, some computer processes are used before analyzes, they are: Filtration, Rectification and Smoothing. The image below shows the same signal from raw until the smoothed in order to obtain the RMS values for the vastus lateralis muscle in an exercise in 100% of the maximal watts in a cicloergometer during 60 seconds. Those process, expecially the Filtration and the Smoothing has the purpose of giving us the possibility to evaluate only the signal coming from the muscular contraction, without mechanical or electromagnetic interferences [2,11].

2.3.1. Signal filtering

In a first moment the filtration occurs when the signal is been collected. With the objective to avoid interferences the EMG signal passes through a 50 to 60 Hz filter (notch filter), if it's necessary. This filter already starts rejecting the frequency band of 60 Hz once that in this band is where the ambient interferences like pressure appear, arrangement or closer apparatus. In a second moment, the EMG signal must pass through a pass-band; this pass-band frequency must be decided by the analyzer, once it can depend on the intentions of the study. Normally, this frequency is fixed between 20 and 450 Hz, because normally 80% of the muscular energy is concentrated [12-13]. But, as said before, it is a free choice for the user, once that this frequency can differ from muscle to muscle, so, it's important for the user to know exactly the band of the muscle that is been assessed to make sure that the pass-band will cut off only the signal that doesn`t belong to that muscle, and at the same time guarantee as precisely as it can that it won't let noises get inside the signal. Basically, it limits the signal inside a previous decided range to maintain it inside the muscle activation site.

The visual difference between the raw and the filtrated signal can be really hard to notice especially when the collected process is well cared, however, if we take a rigorous look to both of them, the difference will appear to our eyes, but remembering that the main reason of using those treatments is to obtain the quantitative values of the signal.

2.3.2. Signal rectification

This procedure has the purpose to turn all the signal values integrative, submitting them to the cut of all negative values, that means, to delete the values that are under the baseline, or to turn all this negative values to positive adding the values, making them integrative. The second option is more recommended if the intention is to achieve the total muscle signal, if you cut off the negative part, half of the signal will be lost, so turning all of them positive is a more used and more interesting when it comes to final results. This procedure doesn't affect the signal noises like the filtration and the smoothing, which will be explained in sequence. However it is still recommended and made part of the studies involving this chapter, so it's important for the reader to know how we used and what it means.

This procedure is simple, and it can be easily understood by the figure above. Note that until the filtration moment the signal had both positive and negative side in the burst moments, taking the baseline as a zero mark, and once that the signal was rectified it became not only positive, but also increased the positive side size, that mean that we didn't exclude the negative part, we added it to the positive side. If the reader wants to know how the same signal without the adding of the negative values would be, you just have to take the filtrated signal and cut the down part, always considering the baseline as a zero mark. Look at the figure 3 under and try to make a qualitative analyze of the two methods.

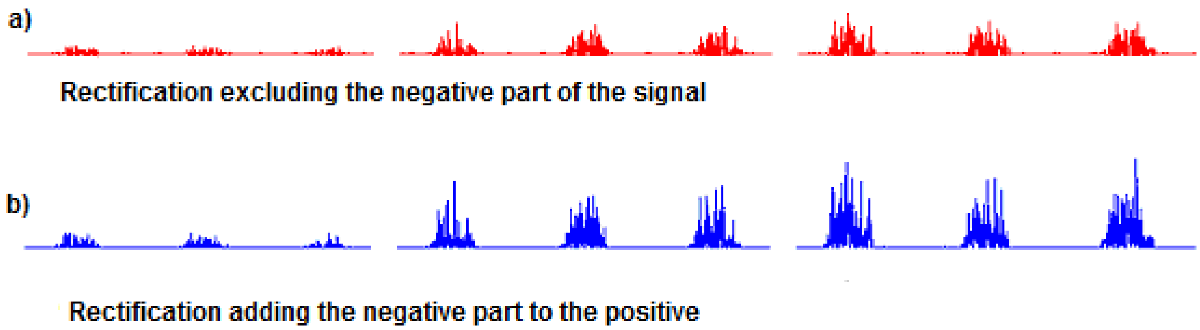

Figure 3. **a**) Half-wave rectification: rectification excluding the negative part of signal amplitude; **b**) Full-wave rectification: aggregating the negative part (reducing the ripple) of EMG signal.

Notice that for a visual analysis excluding the negative parte can bring an error, it's hard to say that the three last bursts of the red signal are different from the three before it, but in the blue signal is much easier to assume that. Thus in the first one I could say that the muscle had reached his maximal power, while in the second I could not make the same affirmation.

2.3.3. Signal smoothing

The Smoothing and the filtration have some similar parameters, mostly because both have the intention of taking out the extremes, the parts that are considering noises. Smoothing creates a linear envelope in the signal, leaving only a center part of the signal. The mainly difference between the smoothing and the filtration, is that filtration take in account the muscle activation range, and the smoothing the signal obtained itself. If the filter is strong enough or considered really good, it can even make the smoothing unnecessary. However, it's recommended to use both, especially in cyclic dynamic contractions, that as we already saw, have a bigger chance to have noises interferences. Looking at the Figure again, the smoothed signal is also really easy to realize, it creates visually a much cleaner signal, creating almost a line, which means, it excludes the extremes, leaving only the signal that is considered the muscle activation signal.

2.4. Burst and silence

During the obtainment of the EMG signal we can separate two parts of it, the Silence and the Burst, as showed in the figure 4.

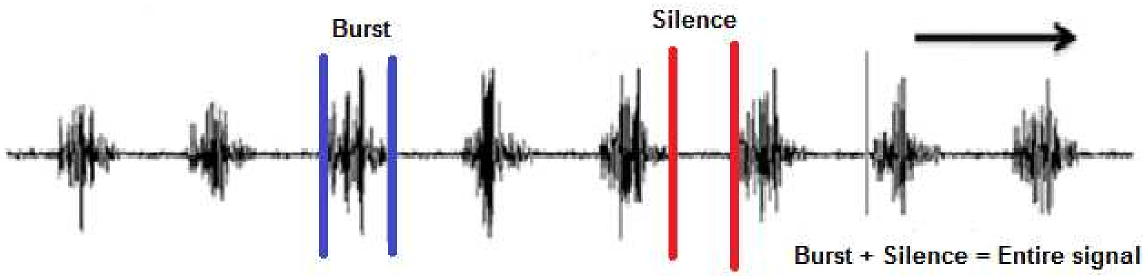

Figure 4. Burst and silence moments in an electromyography signal during a Wingate test in a cicloergometer. The break between the blue lines show a burst moment and the break between the red lines is the silence moment. Unification of Burst and Silence generates the full signal.

The Burst moment is the muscle contraction moment, easily noticed by the sudden break in the baseline, and so, the Silence moment is when no contraction is occurring, so the signal stays at zero, or at least should stay, as said before in the treatment discussions. That's another important reason to maintain a baseline close to zero; it is easier to separate the onset and the end of the Burst from the Silence moment. When a signal is collected it's normal to treat it as an Entire signal, which means that it takes to account both Burst and Silence moments of the signal. The figure showed above is from the recto femoral muscle in a cyclic exercise in a cicloergometer during a Wingate test. As expected in this kind of exercise, it is found a lot of Burst and Silence moments, differing from isometric exercises for example, that would appear only a Burst moment, which would lose strength as time goes by for the fatigue process.

The problem is the use of the entire signal, or only the Burst moments, taking into account that if the intention is to read only the muscle activity it can be assumed that should be used only the Burst moment once that a cyclic exercise will have a lot of Silence moments, and this could make the final results to become smaller, to decrease the meaning. Thus, to know if the Silence moment affects the final results in time and frequency domains variables is of great importance for the researchers that works especially with cyclic exercises. That is one of the problems that will be further discussed on this chapter.

2.5. Time windows

The term "time windows" is used to determine the size of the cuts that will be made in the EMG signal for further analyzes. The most normal is to use the 1 second window, and in case of short tasks it can easily be done once that the signal is short and it is easy to separate the total task time in 1 second parts. However, for longer tasks it can be really difficult for the researcher to separate a signal of 10 minutes in 600 windows of 1 second each for example. Thus, a study from [14] brought that to use a 5 second window and a 1 second in a cyclic exercise can provide the same result of muscle activity for further analyzes, providing for the EMG researchers an excitement about using the method in long tasks. To bring a better example, the figure 5 under shows us a signal and how it would be analyzed if it was cut in one second windows.

Figure 5. An EMG signal divided in 1 second time windows.

In the same signal, the next image has the cuts made in five seconds windows (Figure 6). The biggest importance about using a bigger window is not just because it would be hard for the researcher to divide the signal, but also because some routines that treat the signal don`t accept too much windows to process.

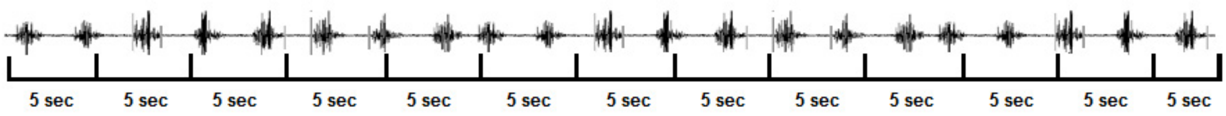

Figure 6. The same EMG signal of Figure 5, now divided in 5 seconds windows.

3. Methodology

3.1. Influence of the treatments (First study)

The Signal processing in EMG is a complex matter to adopt in determined studies, in several times the signal process used is based on the mainly recommendations and the needs of researcher, but sometimes the instructions are not so clear and are not based in studies that contemplate the new tendencies in contemporary researches. However, the main objective of this chapter is to show the great possibility of using the different treatments to find the same outcome of an EMG signal, using many combinations of process (filtration, rectification and smoothing) in a variable of time domain (RMS) and discover if bursts are capable to interfere in the final result of a dynamic exercise in high intensity that is more capable to induce great noises. In that way, we keep our efforts in test these intriguing questions about the signal processing in EMG with a considerable method to involve the main exercise capable of producing the high amount of noises in the signal and test in this sequence the differences in use several proceedings in dynamic exercise (cycling). To introduce this perspective we assessed in a first period 20 men (27,5 ± 4,1 years old; 83,1 ± 8,2 kg; 184,5 ± 4,5 cm), healthy and active physically.

Briefly the subjects passed for a session of familiarization in the protocols and the instruments of the test, basically to know the cycle simulator and find/keep adjusts in bench and foot pedals. In the next step the men did a maximal incremental test (MIT) until exhaustion to determine the maximal work load (MWL). The information obtained in MIT was used to find the intensity of effort in constant load tests (CLT) in three different intensities in severe domain: 80% MWL, 100% MWL and 110% MWL, see figure 7 for better understanding. The different intensities in severe domain were chosen with the intention to allow us to make affirmations including all domains. Each subject was tested in the same hour of day to minimize the effects of the circadian variations.

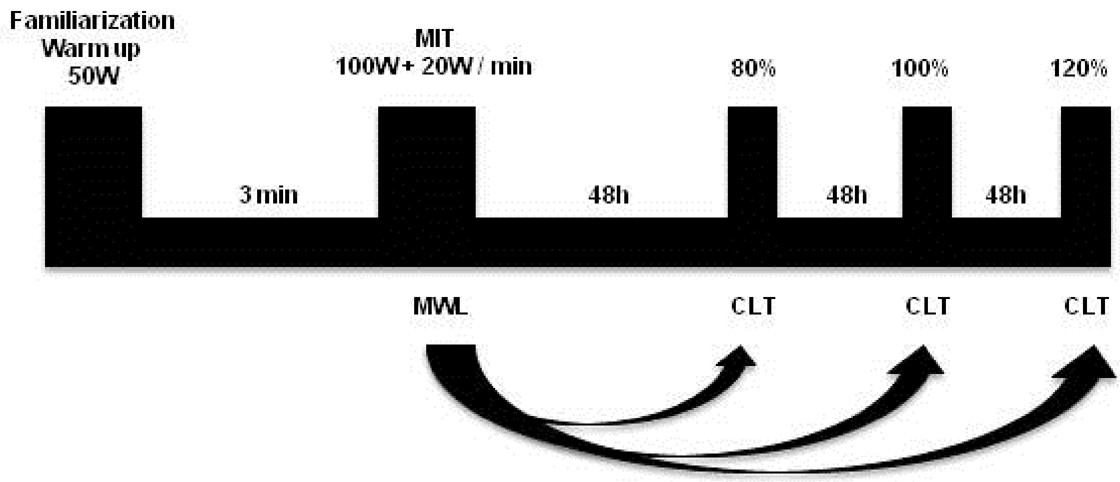

Figure 7. Illustrative representation of the first study, involving signal treatments for RMS obtainment.

Initially it was realized the MWL with initial load in 100W and 20W of increments each minute until voluntary exhaustion, remain a cadence of 70 revolutions per minute (rpm). The MWL was preceded of a warm-up with a load of 50W, with a period of three minutes, follow by three minutes in rest. The MWL was defined as a higher work load maintained for 30 seconds at least, this was assumed so we could make sure to achieve the MWL and not the peak load.

From the information obtained in the MWL, the subjects were oriented to realize three constant load tests (CLT) in different intensities, these being: submaximal (80%MWL), maximal (100%) and supramaximal (110%). Every test was realized in a cyclesimulator (Computrainer™, Racer Mate®, USA). The tests occur with at least 48 hours between then. The CLT was preceded of three minutes of warm-up with 50W, followed by three minutes of rest. After that the tests occur until exhaustion. The subjects were instructed to keep their cadence in 90 rpm, could not pedal less than that, and the test was interrupted when the subjects reported voluntary exhaustion or showed inability to keep the cadence stipulated on the test. The verbal encouragement was used.

The EMG signal was obtained during all period of realization in CLT using an electromyography with 16 channels, model MP150™ (Biopac System®, USA) with a sampling rate of 2000 samples/second, in agreement with ISEK [15]. Before the beginning of each CLT, the subjects were submitted to asepsis and curettage. The electrodes used were active and bipolar, model TSD 150™ (BIOPAC Systems®, USA), with distance among electrodes fixed in two centimeters, putted above superficial muscles of quadriceps femoral of right leg: vastus lateralis (VL), vastus medialis (VM) and rectus femoris (RF), following the standard of SENIAM [12], as showed by the white circles on the figure 8.

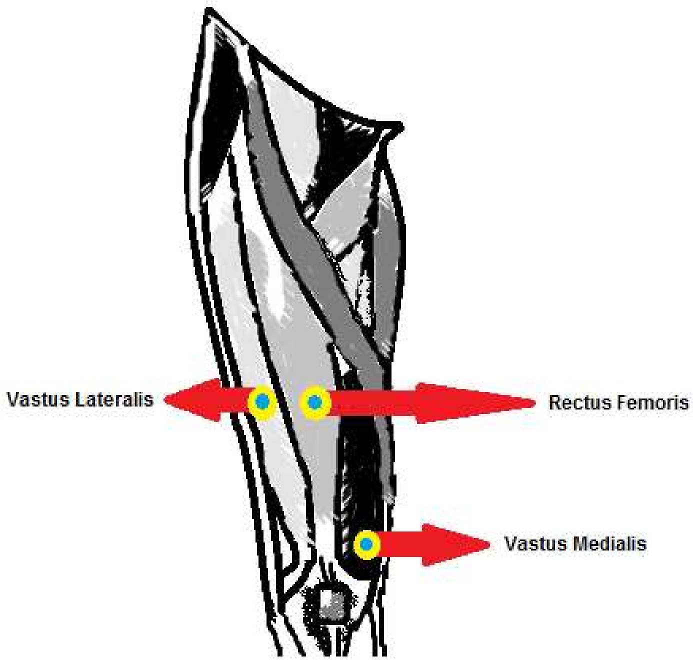

Figure 8. Electrode position used; SENIAM recommendations [12].

The relation of rejection common mode was >95dB and the limits of entrance of established signal in ± 5 mV. The reference electrode was positioned in the right elbow (lateral epicondyle). To capture and process the signal was used the software AcqKnowledge 3.8.1™ (BIOPAC Systems®, USA) and the software MatLab 7.0 (Mathworks®, South Natick, MA, USA).

The EMG signal was treated to obtain the RMS (root mean square) values in time windows with five seconds in the first minute of the test in different intensities. The first twenty seconds of each signal were discarded with the intention to avoid possible inertial influences. After that, it was used proceedings recommended to exclude artifacts and noises from EMG signal, divided in conditions: raw (R), Filtration (F), Filtration + smoothing (FS), filtration + smoothing + rectification (FSR). The filtration was done using a pass-band digital filter Butterworth with frequencies of 20 and 500 Hz. The smoothing process was done through a mobile mean with three points. The process of rectification was done considering all signals, without discards of negative part. The table 1 present the mean values of the load used in the constant load test in 80, 100 and 110% of MWL and the respective times to exhaustion.

Condition	**Load (W)**	**Time (s)**
CLT 80%	212.6 ± 23.5^a	1070.0 ± 250.5^a
CLT 100%	268.5 ± 33.6^b	282.3 ± 75.5^b
CLT 110%	301.5 ± 31.7^c	110.3 ± 22.3^c

Note: different letters show significant differences between loads and times to exhaustion, ($P<0.05$).

Table 1. Loads and times to exhaustion (mean and standard deviation) on constant load tests in 80, 100 and 110% of MWL.

3.2. Influence of the burst and silence in treatment of EMG signal (Second Study)

To test the possibility of bursts get in the way of an EMG signal and change the final outcome, we used a similar method, assessing 27 healthy students (14 men, age = 28,2 ± 2,7 years and 13 women, age = 23,2 ± 2,7 years). The test proposed was the Wingate supramaximal test (WST) used with a purpose to reach a higher intensity in exercise matched with a short duration. The index of performance was defined in a software (WINGATE TEST®, CEFISE, BRASIL) to determine the power by each second during the test, beyond the relative peak power (RPP) ($W.kg^{-1}$), relative mean power (RMP) ($W.kg^{-1}$), fatigue index (FI) (%) and the peak power instant (PPI). The figure 9 represents the second study protocol.

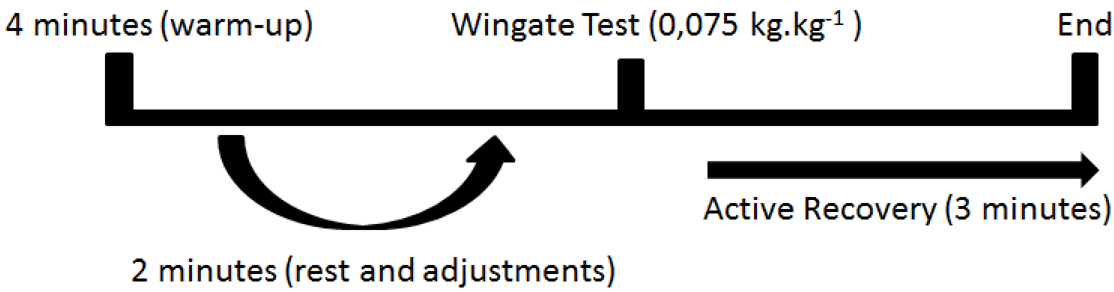

Figure 9. Illustrative representation of second study protocol, involving burst analyze.

The protocol consisted of 4 minutes warm-up in a mechanic cycle ergometer to lower limbs (MONARK 324E, SWEDEN) with 50 W load, with a pedal cadence in 70 rpm and the beginning of each minute the subjects realized a sprint during 6 seconds. After warm-up, the subjects rest for two minutes and they began the test, with a 0,075 $kg.kg^{-1}$ load until finish the test in 30 seconds. The same muscles were analyzed with the same EMG protocol and the same equipment's and procedures in the previous study. However, for this study in addition to the RMS also analyzed spectral parameters. To spectral analyses or frequency domain, was obtained the parameters from median frequency (MF), variance and slope, those values were determined using Wavelet Daubechies db4 (DWT) [6,8]. Was considered the analyses of EMG signal in the contraction phase (bursts) and during all signal (bursts + silence).

The table 2 present a descriptive analyze referent of subject performance.

Variables	**Men n=14**	**Women n=13**
RPP ($W.kg^{-1}$)	10.0 ± 0.9	7.7 ± 0,9
RMP ($W.kg^{-1}$)	7.3 ± 0.5	5.6 ± 0.6
FI (%)	52.9 ± 9,0	51.1 ± 11.9

Note: relative peak power (RPP), relative mean power (RMP), and fatigue index (FI).

Table 2. Mean values ± standard deviation of subject performance.

4. Results

4.1. Influence of the treatments (First study)

The figure 10 shows a comparative analyses of the RMS mean values from quadriceps integrated, obtained in submaximal intensity. We can see that no differences were found among different kinds of EMG treatment (p>0.05), although it shows a tendency to decrease the values encountered in the measure that the procedure of analyses are added to treatment.

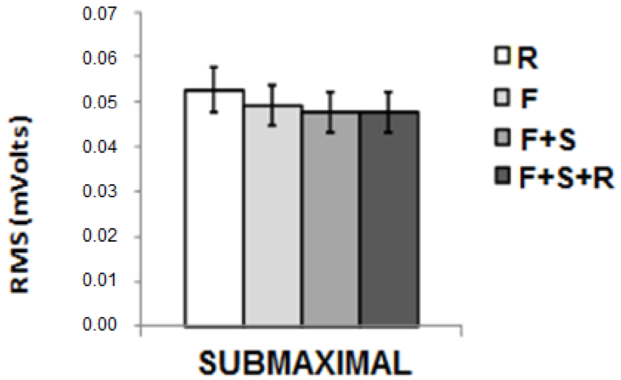

Figure 10. RMS values (mean and standard deviation) from quadriceps integrated muscles ([VL + VM+ RF] ÷ 3) in the different kinds of treatments to submaximal intensity exercise. R = Raw, F = Filtered, S = Smoothing. No differences were found (p>0.05).

The figure 11 shows a comparative analyses of the RMS mean values from quadriceps integrated, obtained in maximal intensity. We can see that no differences were found among different kinds of EMG treatment (p>0.05), although, like the submaximal intensity, it shows a tendency to decrease the values encountered in the measure that the procedure of analyses are added to treatment.

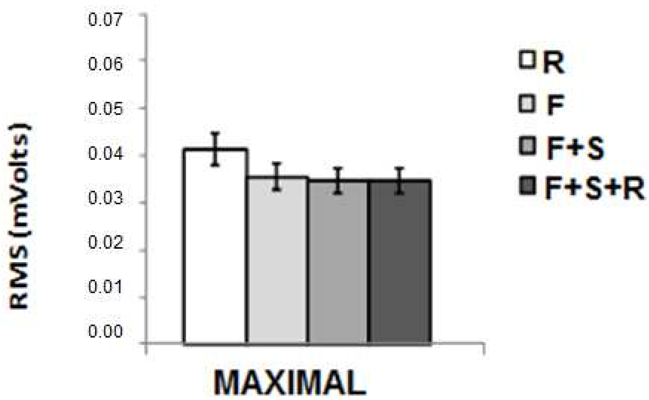

Figure 11. RMS values (mean and standard deviation) from quadriceps integrated muscles ([VL + VM+ RF] ÷ 3) in the different kinds of treatments to maximal intensity exercise. R = Raw, F = Filtered, S = Smoothing. No differences were found (p>0.05).

The figure 12 shows a comparative analyses of the RMS mean values from quadriceps integrated, obtained in supramaximal intensity. Once again we can see that no differences were found among different kinds of EMG treatment (p>0.05), although, like the other two intensities, it shows a tendency to decrease the values encountered in the measure that the procedure of analyses are added to treatment.

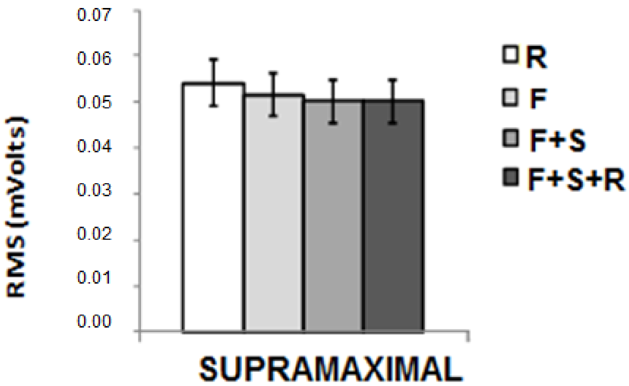

Figure 12. RMS values (mean and standard deviation) from quadriceps integrated muscles ([VL + VM+ RF] ÷ 3) in the different kinds of treatments to supramaximal intensity exercise. R = Raw, F = Filtered, S = Smoothing. No differences were found (p>0.05).

This last one is the one that most called our attention, once that an exercise in this intensity should cause a lot of noises, coming from the exercise (Cross-talk, muscular and skin movement, changes in the conductor tissues) and from the devices (electrode, wire movement, quickly distance change from the devices that capture and record the signal).

The Bland-Altman test shows good concordance between different methods of treatment in the neuromuscular activity to obtain the RMS in all muscles. In submaximal, maximal or supramaximal intensity differences among data weren`t found using as reference always the FSR method.

In trying to find possible influences of the EMG treatments procedures for the RMS value, the results allow us through the comparison and concordance tested to affirm a similar achievement in mVolts, for the muscles in any intensity. Those results shall bring us some perspective about the protocol imposed, where the principal recommendations are the filtering, rectification and smoothing [11]. The final results founded for the treatment of the muscular activity has a identification with a specific baseline achievement always close to zero [15]. Thus, the EMG is a very detailed and disturbed situation because of the sequence of noises, often caused by different reasons of difficulty control. It is worth to say the cross-talk influence, defined by the capitation of electric signal from synergic muscles. This interference normally doesn't surpass 15% of the total signal, but make it very clear the importance of a good location for the electrode. Also, a lot of different reasons can bring those noises, like the pressure, the environment and even the evaluator experience [16,18-20]. Thus, it's clear the necessities of procedures that can eliminate those noises, and give us a signal that really represents the muscular activity.

SUBMAXIMAL (n=20)			BLAND and ALTMAN TEST(µVolt)			
TREATMENTS			ICC	BIAS	LD	UD
RF FRS	and	RF R	0.927	-0.0030	-0.0120	0.0060
RF FRS	and	RF F	1.000	-0.0002	-0.0010	0.0006
RF FRS	and	RF FS	1.000	0.0000	0.0000	0.0000
TREATMENTS RF			0.980	--------	--------	--------
VM_FRS	and	VM_R	0.958	-0.0058	-0.0275	0.0154
VM FRS	and	VM F	1.000	-0.0008	-0.0023	0.0008
VM FRS	and	VM FS	1.000	0.0000	0.0000	0.0000
TREATMENTS VM			0.989	--------	--------	--------
VL FRS	and	VL R	0.830	-0.0050	-0.0247	0.0143
VL FRS	and	VL F	0.999	-0.0008	-0.0023	0.0008
VL FRS	and	VL FS	1.000	0.0000	0.0000	0.0000
TREATMENTS VL			0.959	--------	--------	--------
MAXIMAL (n=20)			BLAND and ALTMAN TEST (µVolt)			
TREATMENTS			ICC	BIAS	LD	UD
RF FRS	and	RF R	0.950	-0.0038	-0.0151	0.0074
RF FRS	and	RF F	1.000	-0.0006	-0.0018	0.0006
RF FRS	and	RF FS	1.000	0.0000	0.0000	0.0000
TREATMENTS RF			0.987	--------	--------	--------
VM FRS	and	VM R	0.994	-0.0039	-0.0075	-0.0004
VM FRS	and	VM F	0.998	-0.0022	-0.0047	0.0003
VM FRS	and	VM FS	1.000	0.0000	0.0000	0.0000
TREATMENTS VM			0,999	--------	--------	--------
VL FRS	and	VL R	0.969	-0.0070	-0.0209	0.0067
VL FRS	and	VL F	0.999	-0.0015	-0.0032	0.0003
VL FRS	and	VL FS	1.000	0.0000	0.0000	0.0000
TREATMENTS VL			0.992	--------	--------	--------
SUPRAMAXIMAL (n=20)			BLAND and ALTMAN TEST (µVolt)			
TREATMENTS			ICC	BIAS	LD	UD
RF FRS	and	RF R	0.970	-0.0022	-0.0063	0.0019
RF FRS	and	RF F	0.999	-0.0004	-0.0016	0.0008
RF FRS	and	RF FS	1.000	0.0000	0.0000	0.0000
TREATMENTS RF			0.993	--------	--------	--------
VM FRS	and	VM R	0.992	-0.0048	-0.0114	0.0016
VM FRS	and	VM F	0.999	-0.0020	-0.0042	0.0003
VM FRS	and	VM FS	1.000	0.0000	0.0000	0.0000
TREATMENTS VM			0.998	--------	--------	--------
VL FRS	and	VL R	0.992	-0.0039	-0.0087	0.0009
VL FRS	and	VL F	0.999	-0.0018	-0.0040	0.0004
VL FRS	and	VL FS	1.000	0.0000	0.0000	0.0000
TREATMENTS VL			0.998	--------	--------	--------

RF: Rectu Femoris; VM: Vastus Medialis; VL: Vastus Lateralis; FRS: Filtered, Rectified, Smooth; R: Raw; F: Filtered; FS: Filtered, Smooth.

Table 3. Intraclass Correlation Coefficient (ICC), Bias Level of treatment (BIAS) and Lower Dispersion (LD) Upper Dispersion (UD) from BIAS in submaximal, maximal and supramaximal exercise.

4.2. Influence of the burst and silence in treatment of EMG signal (Second Study)

The figure 13 present us the RMS comparison between different kinds of analyze (all signal phase and contraction phase) respectively, among muscles: RF, VM and VL in the Wingate Test, no differences were found between methods (p>0.05).

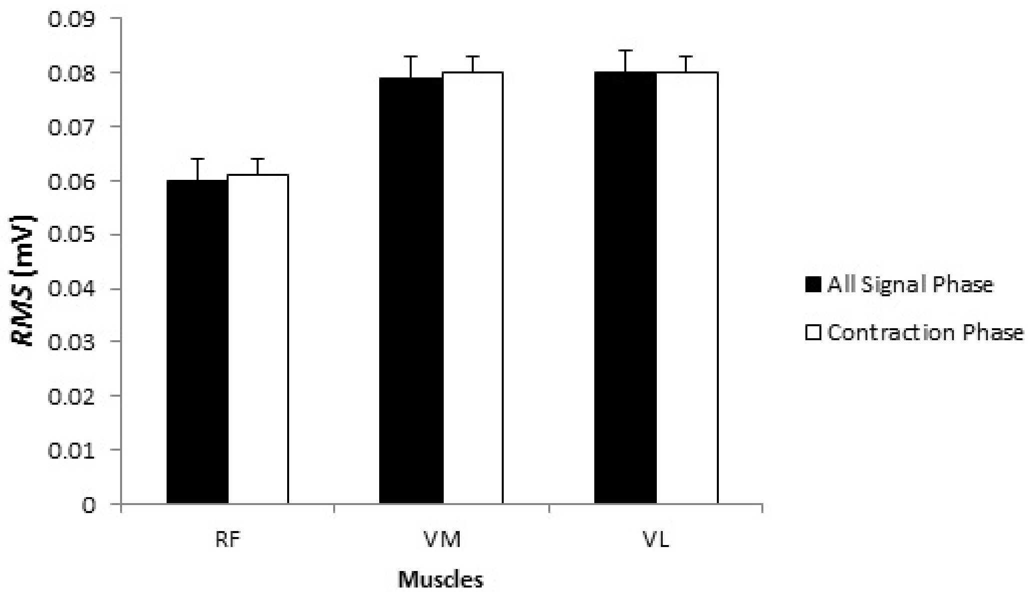

Figure 13. Comparison of root mean square (RMS) between three different muscles from quadriceps femoris (RF = rectus femoris, VM = vastus lateralis, VL = vastus lateralis) in a Wingate Test (p>0.05).

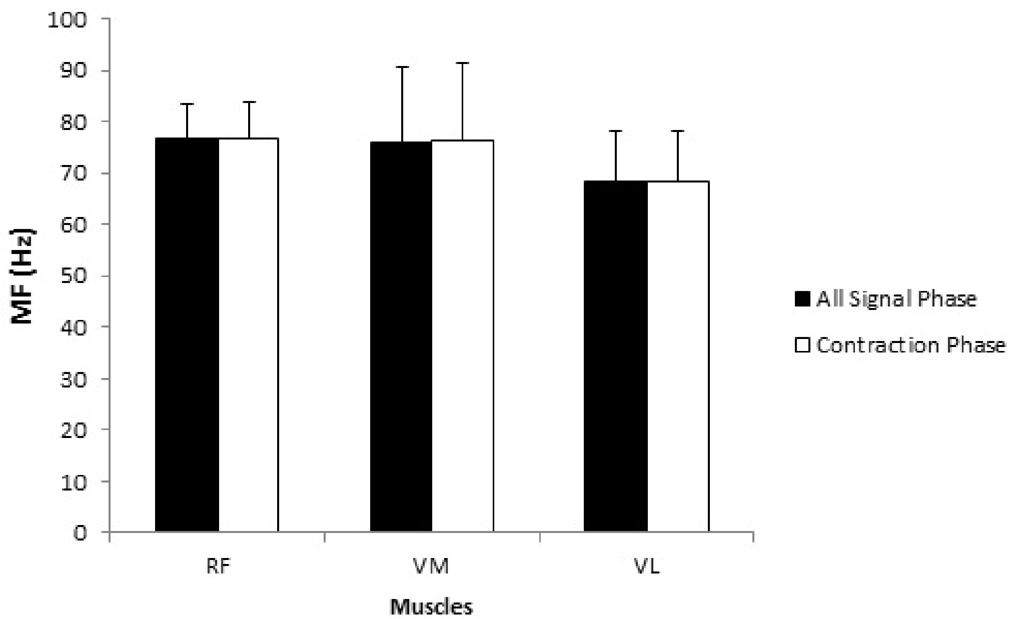

Figure 14. Comparison of Median Frequency (MF) between three different muscles from quadriceps femoris (RF = rectus femoris, VM = vastus lateralis, VL = vastus lateralis) in a Wingate Test (p>0.05).

The figure 14 present us the MF comparison between different kinds of analyze (all signal phase and contraction phase) respectively, among muscles: RF, VM and VL in the Wingate test, no differences were found between methods ($p>0.05$).

The results presented above show us that there were no significant difference between the two analyzes. Probably, these results were found because despite the silence moment has power gradient, the amount of lost energy is not enough to change the EMG signal parameters when the whole signal is analyzed. This result should not be transferred to others activity like the golf or to a martial art kick or punch for example due to the different characteristics, where in this sports the motor activity should be analyzed per complete, because during the whole time there is a contraction, so there is a signal amplitude [21-22].

5. Conclusions

We concluded that, although exist many orientations and recommendations to use and apply the electromyography method, sometimes these components can be a path too complex to understand and to respect with closed eyes. In a considerable perspective of study we were able to show with a model of exercise in high intensity, which was capable to produce a lot of noises and variations on the signal, that different methods of process to achieve the muscular activity do not change the final result if used the complete signal or just the burst parts, or still using all sequence of treatment with filtration, rectification and smoothing in many combinations of analyses. Moreover, should be noted that only filtration was sufficient to improve the quality of EMG signal, making us think in keeping the use at least the filtration in electromyography analyses, still this procedure is used to at least maintain the signal inside the muscle activity range, so, it should not be took out just because no significant differences were founded, we have to consider all the process, as said before, like the devices used and the investigator experience. These outcomes show us that we have remained with a critical knowledge to many things and test the main recommendations to use some techniques. In order to make those results clearer and give us more confidence when use the treatments in EMG analyzes. Some studies creating different noises in computer should be made. This way we can be more secure about the removing of noises, securing that the absence of difference is not because a good pre-acquisition was made, securing not enough noises to be cut.

These results and conclusion takes in consideration only cyclic exercise with the intensity used in the studies. Exercises such as isometric or acyclic have different signal waves and so, could have different results to the same treatments. Also, exercises with lower load could change mainly the results in the Burst + Silence (Second Study) results, once that a task such as 10 km in low intensity, would be realized with less intense movements, creating not only different power signals but also different silence and burst time duration.

Still, a more accuracy statistic method could be used, such as The Smallest Worthwhile Change [23], capable to find minimal and almost invisible differences between different methods, that can contribute with good perspective to sports domain when obscure changes exist among several techniques to data process in EMG analysis and if we use a classical statistic we may not identify with probabilities these modulations.

6. Future directions

Although, we should now take the conclusions and think in considerable applicability with our outcomes, we should remain our critical thinking about the theme, about our limitations and keep our considerations related just to our results in this study with these methods and these subjects. We expect that our findings encourage new experiences inside a positive vision in his complete trend to refute ours dogmas and explain in a better way how we should use and respect the recommendations and orientations to electromyography application in human studies, involving different kind of exercise in several intensities and oscillating between isometric and isotonic conditions, testing many aspects that stays around electromyography process and show to the scientific world a great amount of specificities to use this technique taking into account these variables capable to confuse and change the signal with noises, underestimating or overestimating the final value.

Such design, as showed on this chapter should be applied to others tasks with the same characteristics, like running or any other cyclic exercises that has different muscles involved with different activation ranges and other kinds of possible noises, and silence and burst times. Also, different data process should be tested for spectral analyses, like Wavelet families and Fast Fourier Transform (FFT) for different exercises modalities, until it comes to conclusion about the correct use of this technique involving the correct results achievement, signal process and interpretation.

7. Nomenclature

EMG – Electromyography
RMS – Root Mean Square
MIT – Maximal Incremental Test
MWL – Maximal Work Load
CLT – Constant Load Test
Rpm – Revolution per Minute
ISEK - International Society of Electrophysiology and Kinesiology
SENIAM – Surface Electromyography for Non-Invasive Assessment of Muscles
R- Raw signal
F – Filtrated Signal
FS – Filtrated and Smoothed signal
FSR – Signal Filtrated, Smoothed and Rectified
RF – Rectus Femoris
VM – Vastus Medialis
VL – Vastus Lateralis
ICC – Interclass Correlation Coefficient
BIAS – Bias Level of Treatment

LD – Lower Dispersion from BIAS
UD – Upper Dispersion from BIAS
FI – Fatigue Index
PPI – Peak Power Instant
MF – Median
RPP – Relative Peak Power
RMP – Relative Mean Power

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