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Development and pilot testing of a new electromyography device – EMG Lavita

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Abstract: The mechanisms involved in muscle adaptations from different resistance training protocols are still not completely understood. The aim of this study is to develop an EMG device with a supervisory system that records intensity and time duration of concentric and eccentric phases of a muscular contraction. An electronic circuit was developed with an instrumentation amplifier INA118P, a bandpass filter 30 a 150 Hz, and a rectifier. The analog signal was converted to a digital signal using a 10-bit A/D converter that is part of the Arduino NANO (Atmega328p) microcontroller, which sends data via serial communication to a supervisory system that processes and displays data in graphs and tables. A usability system test was performed by four experts using the SUS scale. Also, the system validation test was performed by the researcher who developed the device by recording simultaneously EMG signals from his muscle fibers using two different electromyography devices – EMG Comercial and EMG Lavita. For this test, the researcher performed five data collections of ten repetitions of the elbow flexion movement with a 1-minute interval for each collection. A Pearson's correlation coefficient analysis was performed with the RMS values previously collected from the devices (r=0.86), which indicated a good to excellent correlation. The device developed in this study had a similar behavior than the commercial and validated tool; besides, all experts evaluated the system as satisfactory.

Keywords: Electromyography, EMG, Device.

I. INTRODUCTION

Resistance training is a key component for physical preparation not only for high-performance athletes but also for recreational activities because it leads to increased muscle strength and endurance of these individuals [1, 2].

Regardless of the competitive level, athletes and trainers are always searching for a better outcome [3]. Thus, several training techniques were developed for aiming at sports performance optimization, e.g. eccentric training [4] and vascular occlusion training [5]; however, there are some controversies about the effectiveness of these techniques because the mechanisms that are involved in their muscle adaptations are still not completely understood [4,5].

Electromyography (EMG) has been used by clinicians and researchers to help them to understand muscular behavior regarding physical activity [6,7], but available EMG devices still show some limitations on individual analyzes on concentric and eccentric phases of a muscular contraction.

The development of an EMG device with a supervisory system able to individually analyze muscular adaptations in each phase of a muscular contraction, i.e., identification of activation level and time duration for both concentric and eccentric muscular contraction, within a training protocol, will give a better comprehension about the physiological mechanisms in different resistance training techniques.

Therefore, the aim of this study is to develop an EMG device with a supervisory system that records intensity and time duration of the concentric and eccentric phases of a muscular contraction – data is shown in tables and graphs.

II. METHODOLOGY

2.1 Device development

2.1.1 Virtual prototype

The virtual prototyping technique was used to model the device. The device structure was developed using Autodesk® Inventor 2019 (Figure 1).

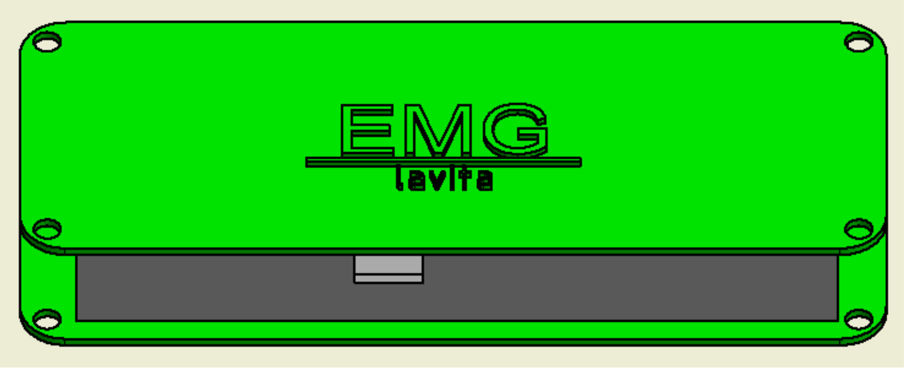

Figure 1:Three-dimensional modeling of the device.

2.2 Device functionality

The diagram below shows the steps of the device functionality (Figure 2).

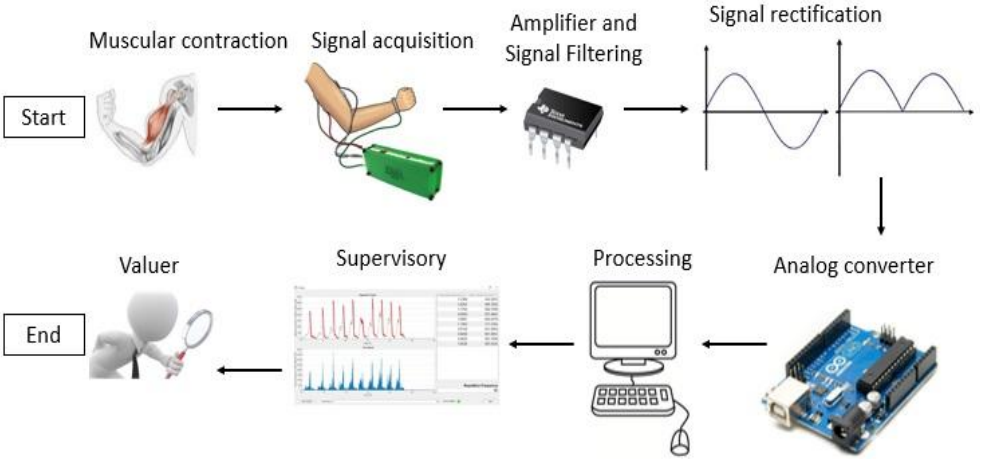

Figure 2: EMG device implementation diagram.

2.3 Power supply

Two alkaline batteries were used for supplying electric power to the electric circuit. They were connected to provide +9v and -9v to avoid noise coming from the electrical network and to make the device portable.

2.4 Signal acquisition

Two silicon self-adhesive electrodes were used for detecting the myoelectric signal. A shielded cable connecting the electrodes with the electrical circuit input was also developed to reduce possible external noise (Figure 3).

Figure 3: Developed cable.

2.5 Amplifier and Filtration

An instrumentation amplifier INA118P was used to collect and amplify the electrode signal. This signal was filtered by a bandpass filter 30 to 150 Hz Butterworth first-order. Then, it was amplified and generated a final gain of 400 times more than the original signal. These parameters are also present in the literature [8].

2.6 Rectification / Microcontroller

After filtering, the signal was rectified and negative signals became positive, so that the A/D converter fromArduino NANO (Atmega328p) could capture, convert, and send all the signal variations by a serial communication.

2.7 Supervisory system

The supervisory system was developed using MatLab®. Unlike pre-existing EMG devices, the supervisory from this study enables the evaluator to segment a muscular contraction in concentric and eccentric phases and to have access to all data related to muscular activation intensity and time duration from each phaseindividually (Figure 4).

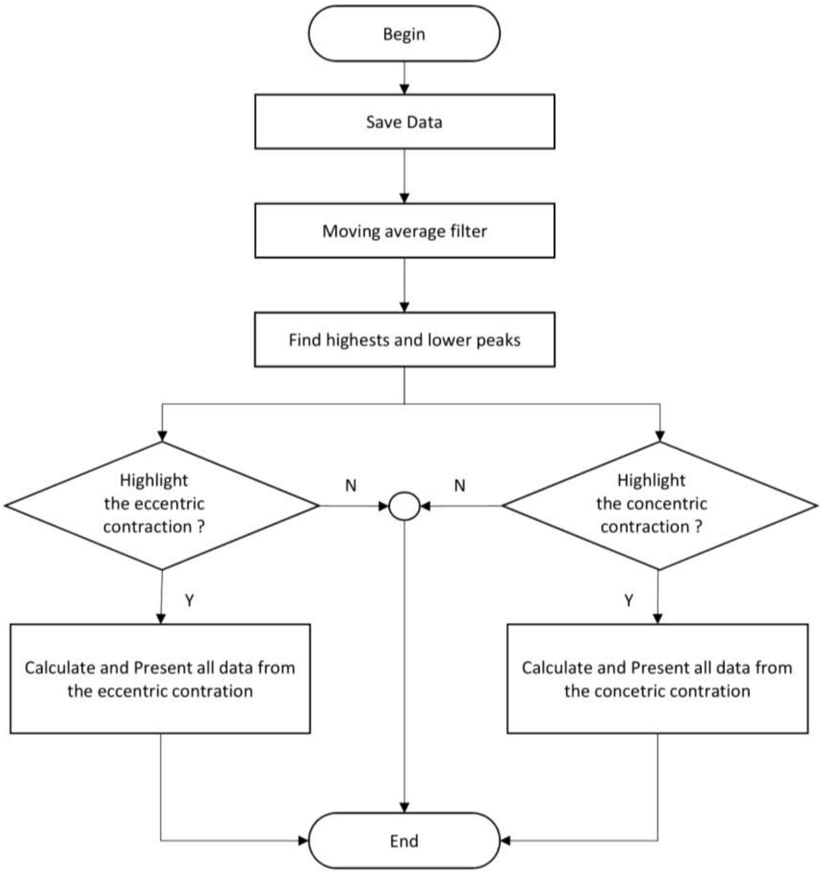

Figure 4: Supervisory system operating flowchart.

2.8 Digital processing of collected data

After receiving collected data, the supervisory system used an average moving filter to filter the signal. Thus, the system found superior and inferior peak positions from the concentric and eccentric phases of the muscular contraction; also, it calculated time (given in seconds) for each peak.

2.9 System usability test

Aiming to evaluate the developed system, four experts have participated in this study (two physiotherapists and two electrical engineers). For measuring the system usability, each expert evaluated the EMG and answered the System Usability Scale (SUS). This is a fast and trustable scale composed of a 10-item test, with five answer options that varies from strongly agree to strongly disagree.

2.10 System validation

A system validationpilot test was performed by the researcher who developed the device and the EMG signal was recorded simultaneously using two different electromyography devices – EMG Comercial (EMG System do Brasil, SAS2000V12-WF) and EMG Lavita (developed in this study). For this test, two pairs of surface electrodes were connected in parallel to the muscle fibers at 2.0 cm between them (Figure. 5). Both devices were adjusted to a sampling rate of 2000 Hz. The electrode positioning procedure and skin preparation have followed SENIAM recommendations [9]. Five data collections were performed, with a 1-minute interval among them. These collections were also made by the researcher who developed the device.

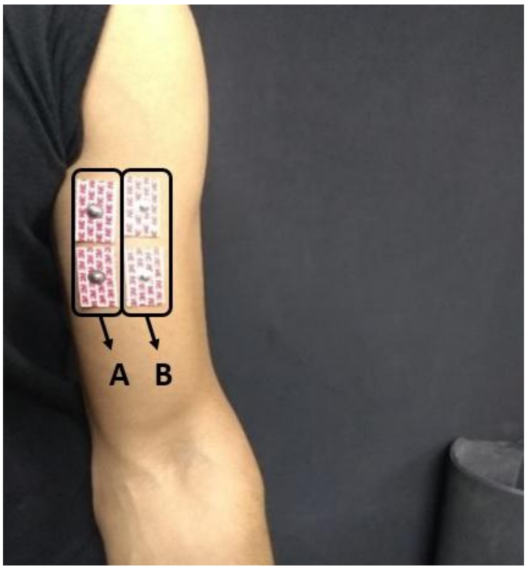

Figure 5: Positioning of the electrodes on the biceps brachii muscle: A) EMG System; B) EMG Lavita.

For each collection, the researcher sat comfortably on a chair and performed ten repetitions of the elbow flexion movement with a 2-kg dumbbell in his hands (Figure6).

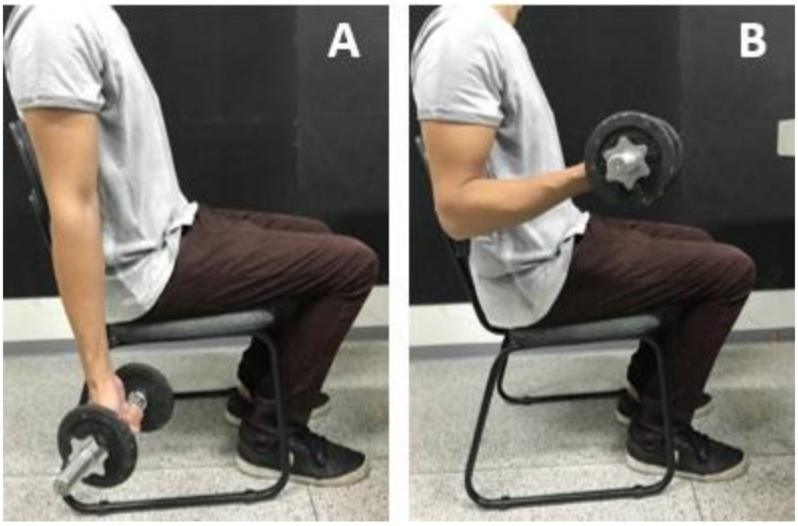

Figure 6: Exercise performed for data collection: A) Initial position; B) Final position.

2.11 Data Analysis

For analyzing possible correlations among root mean square (RMS) values from the devices, Pearson's correlation coefficient analysis was performed with the RMS variables from EMG System and EMG Lavita, following the recommendations from Jang et al. [8]. Based on square root calculation, RMS reflects average signal strength and it is the best parameter to reflect motor unit activity during muscle contraction [10].

III. RESULTS

3.1 Developed device

Figure 7 shows the final version of the EMG device developed in this study.

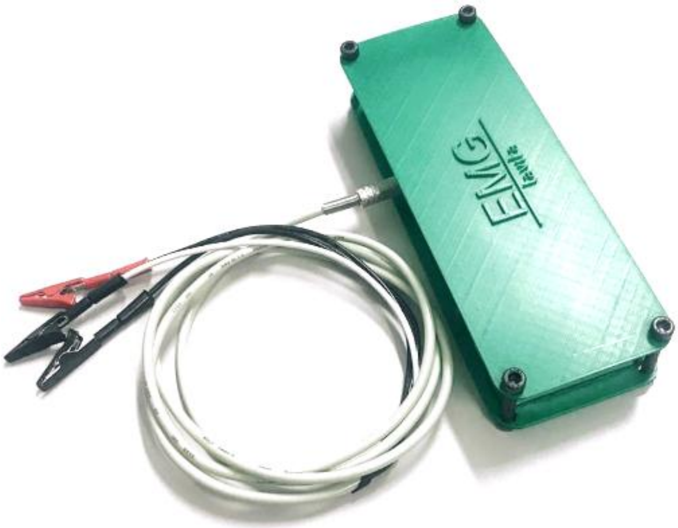

Figure 7: EMG Lavita device.

3.2 Supervisory system

The supervisory system developed in this study enables the evaluator to segment a muscular contraction in concentric and eccentric phases and to have access to all data related to muscular activation intensity and time duration from each phase individually. On the screen of the supervisory there are the following options: (i) analyze only concentric phase, (ii) analyze only eccentric phase, and (iii) analyze both concentric and eccentric phases simultaneously.

Figure 8 shows the supervisory displaying the concentric phase of muscle contractions, highlighting them in blue.

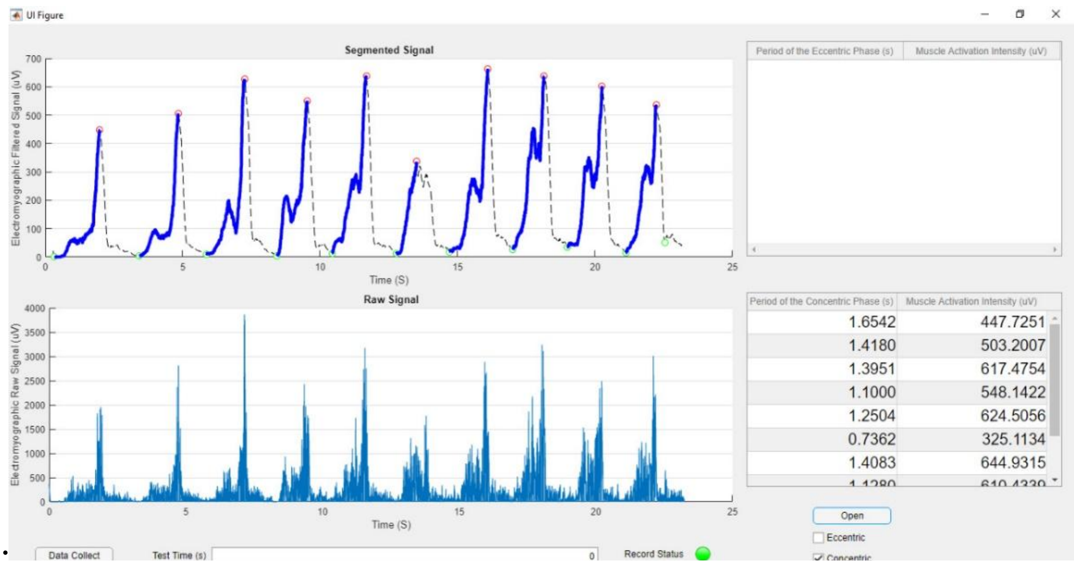

Figure 8: Supervisory presenting the concentric phase.

Figure 9 shows the supervisory displaying the eccentric phase of muscle contractions, highlighting them in red.

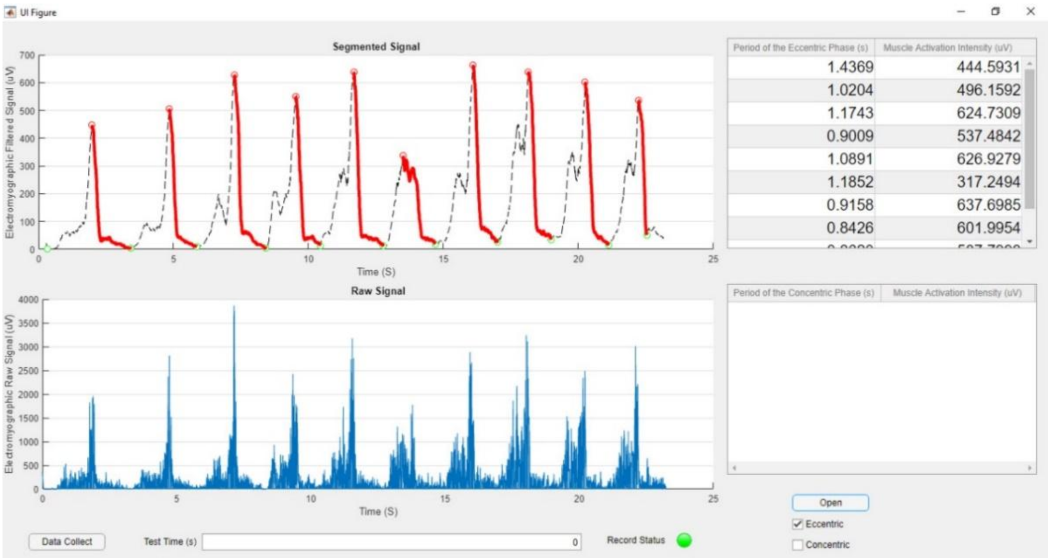

Figure 9: Supervisory presenting the eccentric phase.

Figure 10 shows the supervisorydisplaying the concentric and eccentric phases of muscle contractions simultaneously, highlighting them in blue and red, respectively.

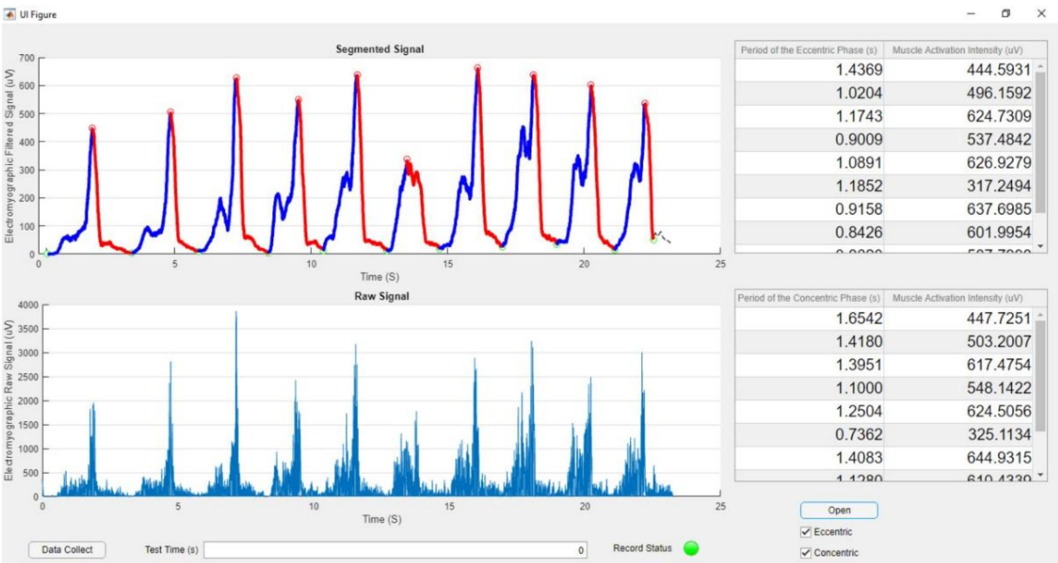

Figure 10: Supervisory presenting the concentric and eccentric phase.

3.3 System usability test

Four experts evaluated the EMG and the supervisory system using the System Usability Scale (SUS). For Nielsen [11], this number of participants enables the identification of 80% of system usability issues, which satisfies our purposes. Table 1 shows the results of each expert assessment.

Table 1: Evaluation of experts by SUS scale.

VOLUNTARY	SCORE
1	80,0
2	95,0
3	90,0
4	82,5
AVERAGE	86,8

In the System Usability Scale (SUS), scores below 60 show systems with relatively poor experiences and userdissatisfaction. Scores above 80 show very good experiences, with a high level of satisfaction [11]. Thus, we see that the EMG and supervisory developed in this study were evaluated by all experts as a very satisfactory system, being able to create very good experiences for the final user. These results point that the system does not show significant flaws and it was very accepted by all users.

3.4 System validation

For system validation, EMG System and EMG Lavita data were compared. EMG System is an already validated tool and it is largely used; EMG Lavita is the device from our study. Table 2 shows the RMS values from the five different data collections done by the researcher.

Table 2: Device RMS values.

Coleta	EMG Lavita	EMG System
1	377,64	396,09
2	296,43	326,99
3	341,05	378,19
4	385,35	402,55
5	344,28	332,85

A Pearson's correlation coefficient analysis was performed with the RMS values collected previously (r=0.86), which indicated a good to excellent correlation [8, 12]. We can see that the device developed in this study had a similar behavior when compared to the commercial and validated[13].

3.5 Device cost

The final version of the EMG Lavita device had a total cost of less than $500, which allows that a larger group of people have access to this technology. It is important to notice that this is the lowest EMG cost found during our literature research.

IV. DISCUSSION

The EMG device developed in this study shows promising results, with similar RMS values when compared to the EMG System – a validated tool as well as largely cited in the literature [13]. These results encourage the development of new studies to validate our device with a larger sample.

The supervisory system developed in our study for EMG Lavita has unique features that are not present yet in already existing electromyography tools – it can segment a muscular contraction in concentric and eccentric phases and give access to all data related to muscular activation intensity and time duration individually from each phase, which is not possible to be done by commercial EMG.

With our system, it is possible that the evaluator has access to a large amount of data related to physiological mechanisms and muscular adaptations, from different resistance training protocols, and comes to conclusions about the effectiveness of some training techniques that are still not elucidated such as eccentric training [4] and vascular occlusion training [5].

An example of this issue is shown by Paulsen et al. [14] and Flann [15], which discuss if the muscular damage induced by eccentric training is beneficial or not to the health of individuals who practice these activities; therefore, the development of a device able to perform a specific analysis on muscular behavior during the eccentric phase of contraction could elucidate the physiological mechanisms involved in this type of training, filling the gaps that exist in the literature about it.

Another important aspect of our device is its lower price when compared to already existing EMG devices. A lower price would be crucial for more people to have access to an innovative technology with a more accessible cost than already existing EMG devices.

V. CONCLUSION

This study had developed and tested an EMG device with a supervisory system able to show data about intensity and time duration of concentric and eccentric phases of a muscular contraction; also, it had similar results when compared to a commercial EMG device as well as a more accessible cost. This new technology could lead clinicians and researchers to a better understanding of physiological answers in different protocols of resistance training.

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