EMG BIOANALYZER^{BR} FOR ANALYZING ELECTROMYOGRAPHIC SIGNALS WHEN SWALLOWING

EMG Bioanalyzer^{BR} para a análise de sinais eletromiográficos na deglutição

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ABSTRACT

Purpose: to describe the construction phases of EMG BioanalyzerBR (version 1.0) and demonstrate its applicability in analyzing parameters provided by surface electromyography (EMG). **Method:** it is a descriptive analysis software developed in order to analyze the parameters obtained in surface electromyography of muscles involved in swallowing. This software was written in a development environment used by worldwide researchers, with easy accessibility and programming: **Scilab**. **Results:** this tool has proved effective for analyzing transferring short data records, having on average 10 seconds duration, but for with longest periods above 20s there were some failures that did not harm the calculation after a few tries. **Conclusion:** despite the difficulties, EMG BioanalyzerBR fostered the development of channel-by-channel markings and how many marks were needed simultaneously, and thus the tabulation of data became faster and with reduced margin as for human error, but needing improvements for version 2.0.

KEYWORDS: Software; Deglutition; Electromyography

INTRODUCTION

Swallowing is the process by which food is transported from the mouth to the stomach[1], and comprises a complex, bilateral coordination of muscle contraction and inhibition of the lips, tongue, larynx, pharynx and esophagus[2].

Swallowing is usually divided into three phases: oral, pharyngeal and esophageal. The oral phase is conscious and voluntary, the pharyngeal phase conscious and involuntary, and both are controlled by the central nervous system, while the esophageal phase is unconsciously and involuntarily controlled by the parasympathetic automonic nervous system[3-5].

Understanding how muscles act during swallowing is decisive for diagnosis and therapeutic management. Because the clinical myofunctional evaluation is subjective, the electromyographic examination can be used to quantify and demonstrate the functioning of these muscles during swallowing[6].

The EMG record is less expensive, simpler, involves less discomfort for the patient, is noninvasive and provides information to suggest electrophysiological dysfunction in swallowing (dysphagia)[7].

Clinical electromyography involves the detection and recording of electrical potentials of skeletal muscle fibers. This record requires a system of three phases: an entry phase, which includes electrodes for recording of electrical potentials of contracting muscle; a processing phase, during which the small electrical signal is amplified; and an output phase, in which the electrical signal is converted to visual

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and/or auditory signals, so that they can be viewed and analyzed using the EMG signal acquisition software[8, 9].

The acquisition and analysis software usually comes with EMG equipment, but the analysis performed by these instruments does not provide detailed information necessary for the work of researchers. Often the technical specifications of the equipment are not suitable for research, therefore adjustment is required.

Thus, the objective of this study was to describe the stages of construction of the EMG Bioanalyzer[BR] (version 1.0) and demonstrate its applicability in the analysis of parameters provided by surface electromyography (EMG), which is important for the study of electrical activity of muscles activated during swallowing.

METHOD

This is a descriptive study that consisted of a graphical interface for use by health professionals, who use EMGs in scientific research for the study of swallowing.

The EMG Bioanalyzer[BR] was written in Scilab, which is a development environment of easy accessibility and programming. It was used for analysis of EMG data obtained at the Electroneuromyography Laboratory of the Hospital das Clinicas, Federal University of Pernambuco.

The equipment used has four channels, with preamplifiers and a Butterworth type bandpass filter of 20 to 500Hz, amplified 2000 times (common mode rejection > 120 dB) and digitized with a sampling frequency of 2 KHz per channel.

After analog processing, the signal is digitized and displayed on a computer screen by means of the data acquisition software of EMG System do Brasil and converted to the format (.txt) to be read by EMG BioanalyzerBR.

The EMG parameters related to swallowing function were: onset, duration, maximum RMS, average RMS, duration of interswallowing, average RMS of the pre- and post-swallowing baseline and signal-to-noise ratio.

To calculate the root mean square (RMS) signal, we used a moving window of 100 ms, without overlapping by means of the following formula[10]:

$$x_{\mathrm{rms}} = \sqrt{\frac{1}{n}\sum_{i=1}^{n} x_i^2} = \sqrt{\frac{x_1^2 + x_2^2 + \cdots + x_n^2}{n}}$$

Where: X_1, X_2 ,..., X_n are the values of the captured signal, n is the number of points obtained.

The **onset** is the parameter that indicates the beginning of swallowing and is indicated with an odd-numbered mark, i.e., the moment of the first mark is the beginning of swallowing (Figure 1A).

The **duration** of swallowing is the relative time from the even-numbered mark subtracting the time of the odd-numbered mark immediately preceding, i.e., the time of the second mark subtracting the time of the first mark. If more than one swallow occurs, then the time of the second swallow is obtained by subtracting the time of the fourth mark by the time of the third, and so on [Figure 1A].

The **Maximum RMS** (**RMS MAX**) is the maximum RMS amplitude in one swallow, considered the highest point of the electromyogram [Figure 1B].

The **average RMS** of a swallow corresponds to the amplitude of average RMS, of the voltage picked up by EMGs, calculated in the interval between the onset and end of the same swallow (Formula 2)[8,9,11,12].

$$AM = \frac{1}{n}\sum_{i=1}^{n} a_i.$$

Where: *AM* means *arithmetic mean*; a_i, with i = 1, 2, ..., n, represents the RMS values of the captured signal, n is the number of points obtained.

The **interswallowing duration** (**ISD**) is obtained when there are additional swallows to consume a certain amount offered. It is calculated by subtracting the onset (odd-numbered mark) of the second swallowing minus the end (even-numbered mark) of the first swallow [Figure 1C].

The **average RMS of the pre-swallowing baseline** is the parameter consisting of the amplitude of the average RMS of the baseline that corresponded to the 100 ms interval considered the **moment of onset** of swallowing.

The **average RMS of the post-swallowing baseline** is the parameter consisting of the amplitude of the average RMS of the baseline corresponding to the 100 ms interval considered **final moment** of the last swallow.

If the participants perform more than one swallow, the average RMS interswallow baselines are also calculated, which correspond to the onset of subsequent swallows.

The signal-to-noise ratio (SNR) is the factor that reflects the ability of the amplifier to limit noise, with respect to the amplified signal. At the same time, it also refers to the desired/undesired signal ratio (noise). This noise is usually produced by the internal electronics of the amplifier (resistors, transistors and integrated circuits)[8,9].

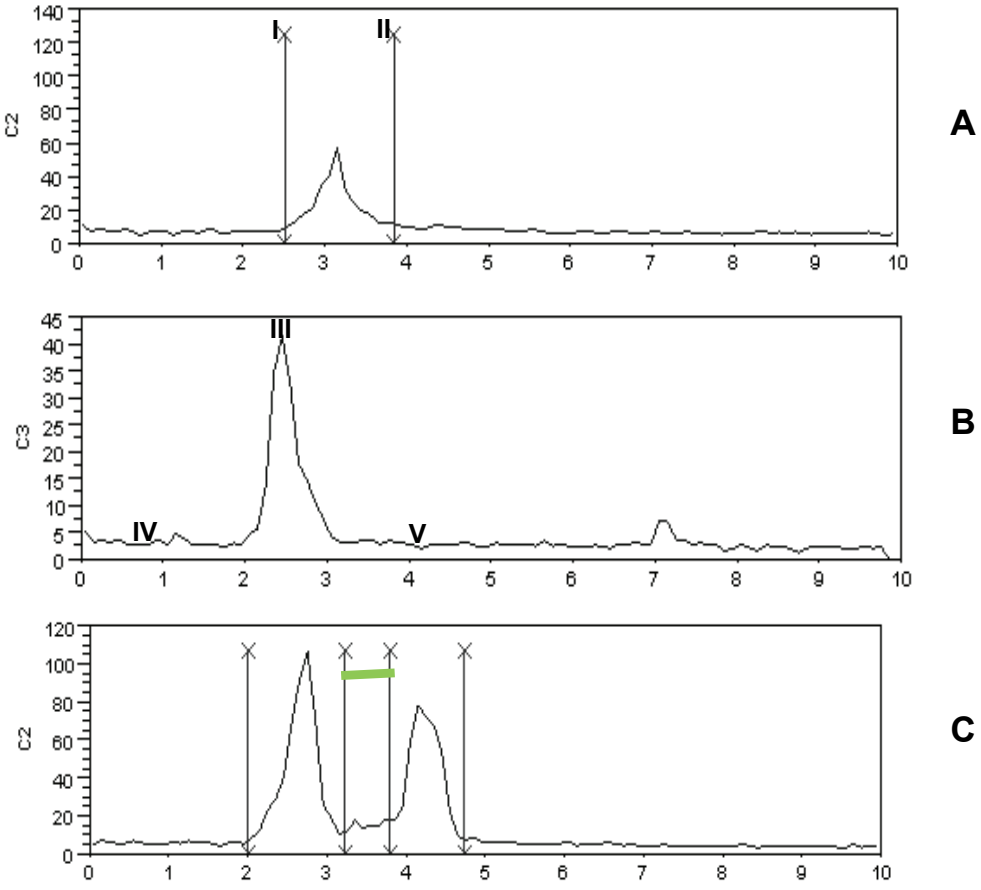


Figure 1 – 1A: onset (I) end of the swallowing (II). 1B: RMS MAX (III), pre-swallowing baseline (IV), post-swallowing baseline (V). 1C: interswallowing duration (green line-VI)

This parameter is calculated by dividing the average RMS of the signal by the average RMS of the immediately preceding baseline. The result of this division is raised to the second power[13].

RESULTS

To properly use the EMG Bioanalyzer[BR], it is necessary to follow a sequential routine of commands shown in Figures 1 and 2.

Figure 2A shows the initial screen of the software. The *menu* has three items for accessing the EMG signal, "File", where you can open the raw EMG signal in .txt format or exit the software; "Edit", where the functions for processing the EMG signal can be found, among them: remove the offset, obtain the absolute value and mobile RMS; "Settings", where you can define preferences, filters, functional parameters and parameters that you wish to study.

Clicking on File Open, which is the first time the .txt signal is accessed, the "Preferences" screen opens [Figure 2B], in which you can choose the format to copy the parameters for Microsoft Office Excel or Br Office.Org.Calc. You can also define the number of channels of the file and the maximum number of swallows that were made.

The following must be decided if the signal is to be digitally filtered. In Figure 2C, a Finite Impulse Response (FIR) type filter was used and a filter in which the signal passes through the Teager-Kaiser operation. In this case the operator must choose the FIR filter.

After choosing the file to be opened in .txt format, the EMG Bioanalyzer[BR] builds a new window with the raw data of the EMG signal [Figure 2D]. Then, the raw signal must be processed by means of the "Edit" *menu* in the main window of the software.

In the edit window [Figure 2E], the functions in the time domain, frequency, and other less commonly used functions in the analysis of EMG signals can be found. However, only the RMS function was used, calculated by Formula 1.

With editing finished, a new window opens containing the processed signal, with the channels

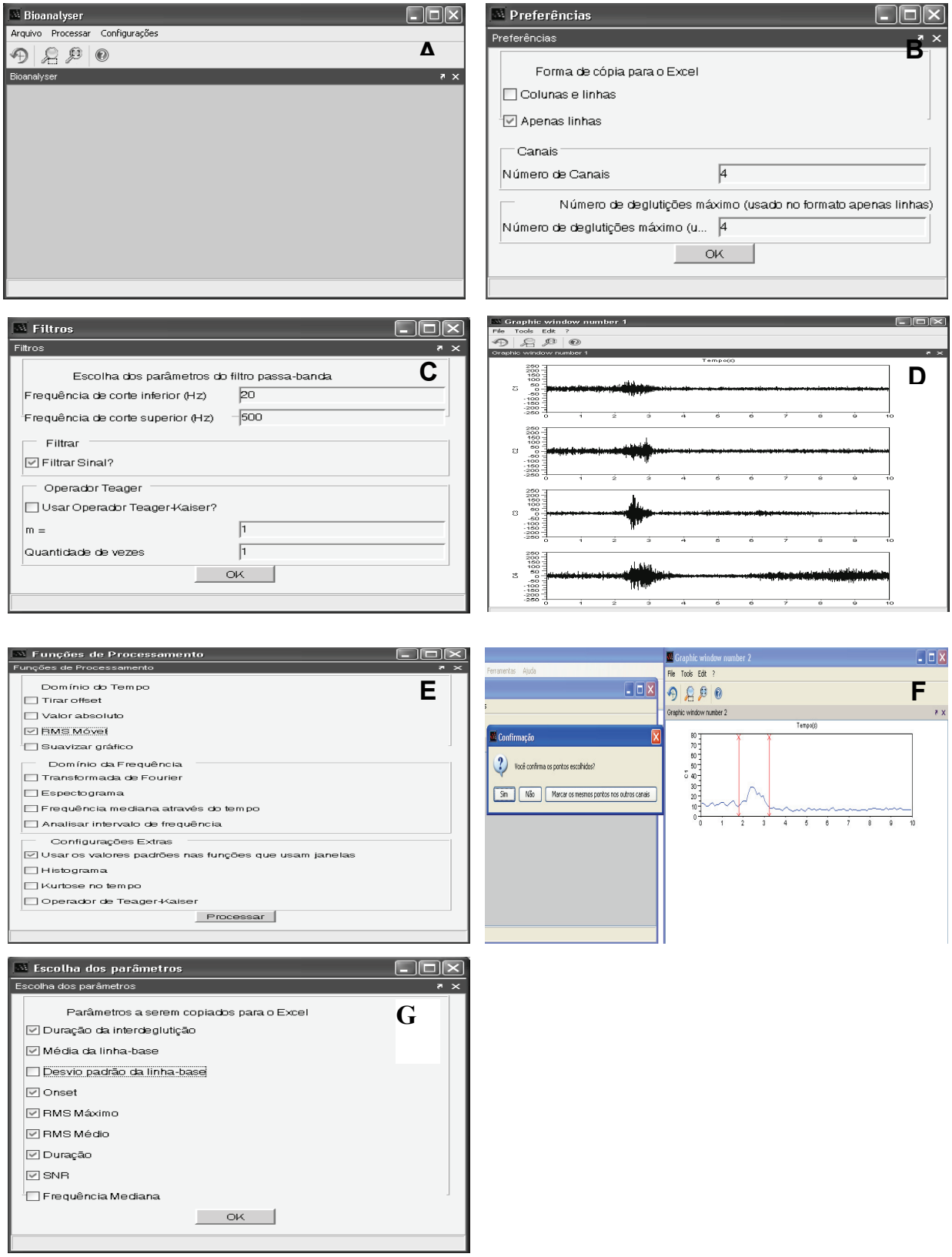


Figure 2 – 2A: Initial screen of EMG Bioanalyzer[BR]; 2B: Preferences window of the EMG Bioanalyzer[BR]; 2C: Window for the setting of parameters of the filters to be used; 2D: Display window of raw records of the four channels; 2E: Processing functions of the electromyographic signal; 2F: Window to perform the setting of of onset and end of swallowing marks; 2G: Window to choose the parameters to be analyzed.

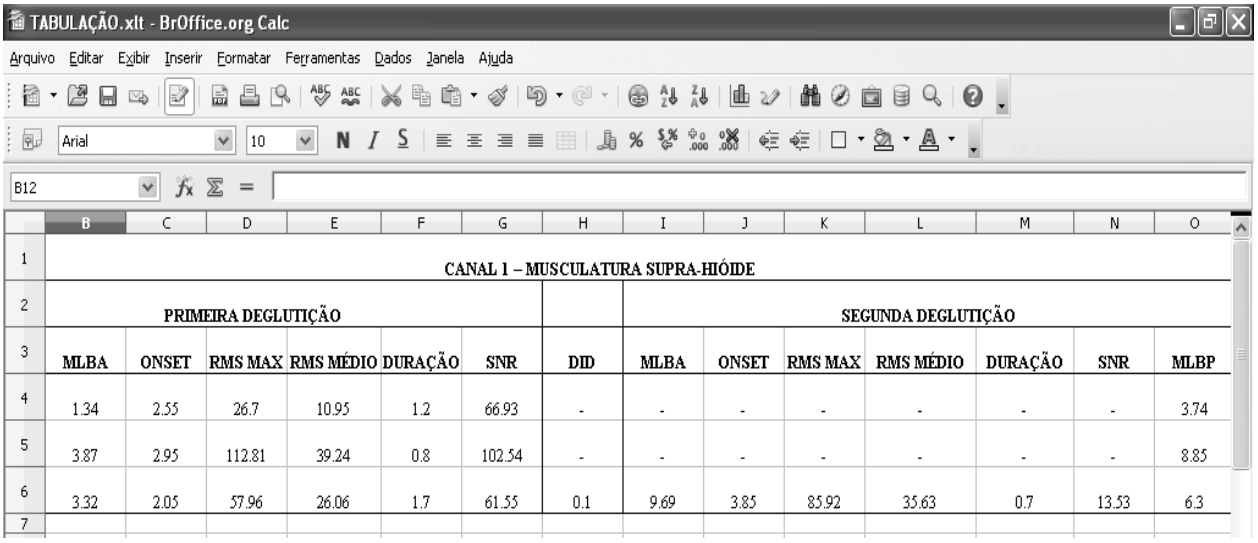
in sequence. At this point, the marks where each swallow begins and ends should be made [Figure 2F]. Then, the examiner will be asked if he wants to confirm the points (Yes or No) or if he wants to mark the same points in the other channels [Figure 2G].

If the chosen points are wrong, the researcher has the option of clicking on "No" in the "Confirmation" window, which will allow a new marking. The first channel is free to make as many marks as needed, while the other channels allow the same number of marks made in the first channel.

After setting the marks of swallows in all channels and then confirming the marks, the software will open a new window for selection of parameters to be analyzed and copied to the clipboard [Figure 2G]: onset, duration, maximum RMS, average RMS, interswallowing duration, average RMS of the pre- and post-swallow baseline and signal-to-noise ratio.

Thus, all the parameters of the EMG channels (separated by commas by Scilab) are transferred simultaneously to the program chosen by the researcher, as shown in Table 1.

Table 1 – Spreadsheet of the Data Table containing the parameters of the EMGs related to the function of swallowing (BrOffice.org.Calc)



	B	C	D	E	F	G	H	I	J	K	L	M	N	O
1	CANAL 1 – MUSCULATURA SUPRA-HIÓIDE													
2	PRIMEIRA DEGLUTIÇÃO							SEGUNDA DEGLUTIÇÃO						
3	MLBA	ONSET	RMS MAX	RMS MÉDIO	DURAÇÃO	SNR	DID	MLBA	ONSET	RMS MAX	RMS MÉDIO	DURAÇÃO	SNR	MLBP
4	1.34	2.55	26.7	10.95	1.2	66.93	-	-	-	-	-	-	-	3.74
5	3.87	2.95	112.81	39.24	0.8	102.54	-	-	-	-	-	-	-	8.85
6	3.32	2.05	57.96	26.06	1.7	61.55	0.1	9.69	3.85	85.92	35.63	0.7	13.53	6.3
7														

DISCUSSION

The EMG Bioanalyzer[BR] was developed by Feodrippe, a member of the Clinical and Experimental Neurophysiology research group. It was developed due to the need to analyze parameters that were not provided by the surface electromyography software that is part of the collection of the Electroneuromyography Laboratory of the Hospital das Clínicas, Federal University of Pernambuco, as well as to make the tabulation (transfer of data for each parameter) faster, with less margin for error and standardized to achieve the necessary statistical tests.

As performed by Ruark et al, 2002[14] and Green et al, 1997[15], the analysis of EMG data is performed after processing the raw signal in a rectified and filtered wave (Botterworth = 8 and low-pass cutoff = 30Hz), then the setting of marks is done manually from visual analysis by the researcher, with the onset defined as the instant when the signal activity begins to exceed the baseline and the end corresponds to when this activity return to baseline or its reduction[14,16-19].

The parameters provided by the software include information about the duration, amplitude and morphology of the electromyograms of the muscles of interest obtained at intervals before, during and after swallowing. These parameters were: onset, duration, maximum RMS, average RMS, interswallowing interval, average RMS pre- and post-swallow baseline and signal-to-noise ratio.

The **marking of the "on" (onset) and the "off" intervals** enables the analysis of activation time and duration of the contraction of muscles to perform a specific motor activity. The literature recommends that the electromyographic signal be investigated to see if it is contaminated by the activity of neighboring muscles ("crosstalk") and if the amplitude of the noise surpasses the amplitude level of muscle activity, which would invalidate the analysis of this parameter, generating false positives[20].

The study of duration allows the researcher to evaluate whether the period of contraction of the muscles studied in swallowing is very long in relation to electromyographic activity in subjects without swallowing difficulties, suggesting lack of coordination and/or slow reaction to the realization of pharyngeal swallowing (swallowing itself), whether as a normal consequence of aging[18], due to the presence of neurological disease such as Parkinsons[7,12,21,22] or other types of dysphagia.

The **baseline** corresponds to a period of electromyographic silence, when the muscles are at rest. The **rest period** can provide important information, such as the presence of noise and interference in the EMG signal by involuntary contractions of the studied muscles performed before or after swallowing[11,17,18].

The analysis of noise in the baseline is extremely important to identify the amount of effective electromyographic signal in the recording[22].

It is important to note that muscle tone is not evaluated by EMG, because tone is not a function of the motor unit, but is the tension in a resting muscle. Thus, as with a normal relaxed muscle, a spastic muscle will also feature a electromyographic silence[9].

The **average RMS** and **maximum RMS** are important to quantify the electrical activity of the muscles studied. These values are commonly used to compare the electrical activity between rehabilitation sessions, muscles and individuals, but the great variability of the captured signal due to anatomical differences and differences in the execution of movements can lead to erroneous interpretations[8,9,11,12].

It is recommended in the evaluation of muscle activity, such as in the swallowing of different volumes or of different consistencies, that normalization of the signal is done by means of calculating the percentage of these values from peak to peak or calculating the percentage from the baseline[11,14].

We found no references to studies that had analyzed the **interswallow duration** (**ISD**). From the work of Belo (2009)[21], Coriolano (2010)[12] and Vaiman (2005)[23], the need is clear for studies to assess the interswallow duration, especially in the analysis of free swallowing of 100 ml of water. Analysis of this parameter can indicate the status of muscle coordination in sequential action of each swallow and its variation with time.

The signal-to-noise ratio is an important parameter to improve the reliability of EMG recordings in order that from their analysis electromyograms can be included or excluded that present a very low STN value, suggesting contamination of the electromyographic signal by noise that is so intense as to prejudice the data obtained in research[13].

The EMG Bioanalyzer^{BR}, in the shortest recordings of approximately 20,000 points, proved effective for the processing and transfer of data for the chosen parameters. However, longer electromyographic recordings, with nearly twice as many points (40000), led to overload in the program memory with system freezes and crashes, though it was possible to complete the calculation after a few tries. Despite these occurrences the software achieved its goals.

CONCLUSION

The EMG Bioanalyzer^{BR}, despite failures in the system, proved effective for the processing and transfer of parameters chosen for the spreadsheet and later statistical analysis, especially due to the possibility of carrying out channel-by-channel markings and simultaneously setting as many marks are required per swallow. Thus, the data tabulation was faster and with reduced margin of human error. Yet, there is a need for improvements in the next edition.

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RESUMO

Objetivo: descrever as etapas de construção do EMG Bioanalyzer[BR] (versão 1.0) e demonstrar a sua aplicabilidade na análise de parâmetros fornecidos pela eletromiografia de superfície (EMGs). **Método**: trata-se de um estudo descritivo do software de análise desenvolvido para analisar parâmetros obtidos na eletromiografia de superfície de músculos envolvidos na deglutição. Este software foi escrito em um ambiente de desenvolvimento utilizado por pesquisadores do mundo todo, de fácil acessibilidade e programação: o SCILAB. **Resultados:** esta ferramenta se mostrou eficaz para a análise e transferência de dados nos registros curtos, contendo em média 10s de duração, porém para registros mais longos com duração maior que 20s apresentou falhas que não prejudicaram o cálculo após algumas tentativas. **Conclusão**: apesar das dificuldades, O EMG Bioanalyzer[BR] possibilitou a realização das marcações canal por canal e quantas marcações fossem necessárias de forma simultânea,e desta forma a tabulação dos dados ficou mais rápida e com margem de falhas humanas reduzidas, porém com necessidade de aprimoramentos para a versão 2.0.

DESCRITORES: Software; Deglutição; Eletromiografia

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