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Narrative Review

Modeling the Electromyogram Signal of Stimulated Biceps Brachii Muscle

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Abstract

Introduction: The usage of modeling methods has been proposed to achieve a better understanding of biological systems, so that some ambiguities about their function could be resolved. Accordingly, the present review was performed to model the electromyogram signal of stimulated biceps brachii muscle.
Methods: In this review study, a search was performed in databases of Emerald, Cochrane Library, MEEDLINE, EMBASE, Wiley, Scopus, and Magiran on papers published over the past 20 years. Papers that fulfilled all inclusion criteria were critically appraised in order to assess their quality. Out of the 66 papers extracted, eight original papers were included. The findings obtained from the papers were noted, and then underwent content analysis and categorization.
Results: Findings indicated that most of the performed studies had been modeled using cybernetic, robotic, regression, and neural network modeling methods. These physiological mathematical models model the physiological structure of the muscle based on a direct description of biomechanical, biological, and physiological characteristics of the system individually, which is difficult for obtaining many parameters.
Conclusion: Most of the models presented so far do not match reality and have errors. Thus, studies are required to design a model similar to a biological system with the properties of biological systems in order to reduce the modeling error.

Keywords: Modeling, Signal, Electromyogram, Biceps Brachii Muscle

Introduction

The human has always sought to replace any of his lost organs. In some people, congenital disability or disability acquired by war, trauma, accidents, etc. cause amputation of upper or lower limbs, which is psychologically and aesthetically significant, in terms of practical applications, and resolving dependence on others.[1]

In many cases of amputation of limbs especially the upper limbs such as the arm, parts of the muscles close to the amputated limb remain, whose electromyogram signals can be measured and then used as a control signal.[2]

Electromyogram consists of three Greek words of electron meaning amber, mys meaning muscle, and gramma signifying recording and electrical signal associated with muscle contraction. The characteristics of electromyogram signals of a muscle are used for clinical treatments, and provide important information about physiological behaviors.[3]

When recording superficial electromyogram signals, noises often affect the signal of interest from different sources including intrinsic noise in the electronic components of detection and recording equipment, environmental noise, motion artifacts, intrinsic instability of the signal, as well as other biological signals including the electrocardiogram (ECG) signal.[4]

The ECG signal controls artificial- cybernetic limbs, which are called myoelectric prostheses.[5] These prostheses allow automatic control, detect the superficial electromyogram signal from the skin surface noninvasively, whereby the muscle needs relatively low activity in order to provide the control signals.[6]

Various methods have been proposed for classifying the motion classes in terms of the electromyogram signal features. Nevertheless, the overlaps between motion classes in the feature space are the major problem. In other words, some motion classes are close to each other or even overlap with each other, resulting in wrong detection of the motion command.[7]

With great advances in recent decades, modeling of biological systems composed of numerous elements interconnected with each other have resulted in complete understanding of the behavior of these systems. Therefore, understanding diseases and finding effective therapeutic methods for them have been accelerated, but inadequate knowledge about biological systems has hindered achieving this goal.[8]

The nonlinear and complex behaviors of biological systems heavily complicate their behavior prediction. Therefore, modeling biological systems with conventional methods did not lead to proper results and required its own special mathematics.[9]

The most important and principal application of biological models is evident in employing various smart limbs. In order to reduce the modeling error, a model similar to biological systems is required with the features of biological systems. Indeed, there is no output for these models based on every allowable stimulation; thus, one cannot introduce the desired stimulation frequency to the model and expect a proper.

response. Furthermore, there is no model in line with continuous stimulation capable of predicting the joint angle in horizontal plane and responding to any type of stimulation.[10]

In the present case study, the EMG signal modeling of biceps brachii muscle was investigated. The biceps brachii and brachialis are among the muscles in charge of bending the arm, while the triceps and the Anconeus muscle are among the muscles that are responsible for opening the forearm.[11] Since during the forearm bending, the major role is played by the biceps brachii muscles as a major muscle, while during opening the forearm, in addition to the triceps muscle, the biceps brachii muscle and its EMG signal are also affected, thus the biceps brachii muscle is considered as the black box of the hand, on which all stimulations and recordings are done.[12]

Based on the mentioned points and since it is possible to consolidate the body of human knowledge and understanding about the treatment of biological systems and improve the quality of life for people with amputated organs through modeling the body members, this study intended to deal with extracting different types of modeling performed on the bicep brachii based on investigating various studies.

Methods

Search Strategy

In this review study, the search was performed in the databases of Scopus, Emerald, Cochrane Library, MEDLINE, EMBASE, PubMed, ISI Web of Knowledge, Science Direct, and Google scholar, Wiley and Magiran on the papers published over the past 20 years (2000-2020). The search strategy for papers was mostly based on Persian and English keywords and with possible combination of key and sensitive words. The search was done by benefiting from the Persian and English keywords of “modeling”, “signal”, “electromyogram”, and “biceps brachii” alongside AND and OR operators.

After removing the absolutely relevant papers, the full text of all the relevant papers was prepared. Next, the text of all papers was examined based on predetermined inclusion criteria, whereby again some irrelevant papers were excluded. The bibliographical details of articles that were identified through the searches were exported into Endnote. The details included the title, keywords and abstract, where available. Appropriateness for inclusion was judged by the criteria listed above.

Inclusion and Exclusion Criteria

The inclusion criteria were as follows: the paper titles should have been in line with the study objective, language of the paper should have been English or Persian, the tables should have been reported clearly, the site of the research and sample size should have been mentioned, the paper should have been original and published in one of the credible internal or foreign journals, and the paper should have been full text.

The exclusion criteria included the studies published in languages other than Persian and English, cases published before 2000, review studies and books, theses, and studies conducted as qualitative. For data extraction, a data extraction form design based on the research objective was used. This form included sections including authors’ name and position, year of publication, place of the study, name of journal, study objective, and sample size.

Generally, 66 papers were extracted based on the expressed keywords. Initially, the title of papers was assessed and then screened based on the inclusion and exclusion criteria. Out of this number, 32 papers were excluded because of not meeting the inclusion criteria, lack of access to the full text of the paper, lack of precise thematic relationship, as well as duplicate papers. Accurate investigation of the original version of the extracted papers led to the removal of 26 papers because of inaccurate thematic relationship and the paper being not an original paper (review studies). Eight papers were examined in terms of type of study. Eventually, eight original papers that had dealt with extracting different types of modeling performed on biceps brachii were included. Diagram 1 displays the process of search results.

The title and abstract of papers obtained through search in databases were investigated by the author based on exclusion and inclusion criteria, in order to achieve a list of papers employed in this study. The original version of the papers detected based on this initial assessment was also prepared. The recovery rate of the identified papers was 100%.

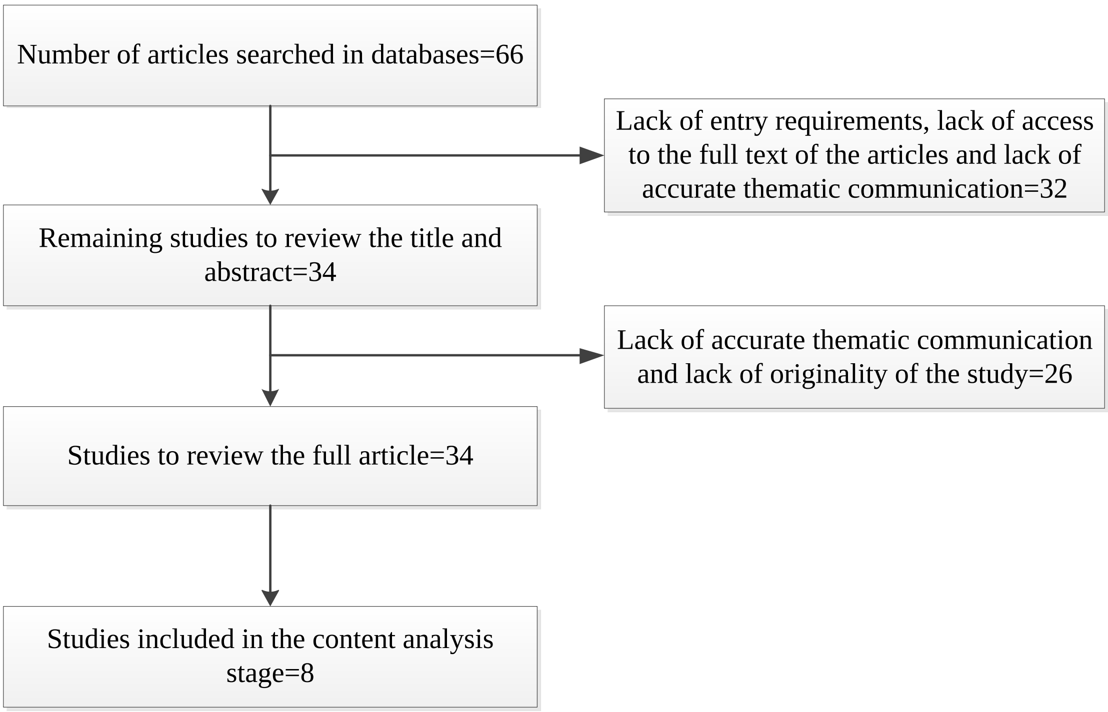

Diagram 1. The procedure of investigating the databases and finding papers

Quality Assessment and Data Extraction

In order to quality assessment to identify the weaknesses and strengths of the papers, Aveyard[13] and the CRD guidelines[14,15] were used. The assessment criteria of the quality of papers examined in the assessment protocol. The quality of the papers also needed to be taken into account during the literature synthesis. No articles were rejected as a result of this process. Investigations and extractions of information were performed by the researchers who had completed mastery over the subject. The important findings obtained from the papers were noted and then underwent content analysis and categorization.

Results

Out of the description and review papers published on modeling, signal, electromyogram, and biceps brachii over the past 20 years (2000-2020), only eight papers had examined the goal of this study. Regarding content analysis, the findings of these papers can be summarized in Table 1.

All of the papers revolved around modeling, in which data collection had been performed in real settings and on both healthy and diseased people. The only study which was modeling and simulated in a computer environment was the study by Rahnejat and Pishbin.[16] In all studies, EMG signals were used to predict the behavior of muscles. The limbs examined in the studies included the arm, hand, elbow, and the tested muscle was biceps brachii.

The mentioned studies have been modeled using cybernetic, robotic, regression, and neural network modeling methods. One of the key issues in achieving successful control for functional electrical stimulation is the use of a proper and suitable model which adequately represents the behavior of a biological system.

Table 1. Modeling with EMG signal

Name of Authors	Year	Title	Type of Model	The Investigated Limb	Final Finding
Rahneja[16]	2014	Designing and controlling a cybernetic hand via EMG signal processing and neural network	Cybernetic and neural network	Arm and hand	In this study, an artificial hand prosthesis is synthesized, which receives control commands from the human and then process them by receiving the command from the muscle of the disabled person's arm as EMG signal. Then, it extracts the intended command and applies the necessary command electronically to the artificial hand.
Namdar Qalaati[17]	2009	Modeling, controlling the position and arm force of a pneumatic flexible robot	Robotic	Arm	The results obtained from this research indicate that the behavior of pneumatic arms can be equalized to the behavior of rigid arms with an acceptable approximation. The difference is that pneumatic arms have a far lower weight and do not have the destructive effects of traditional robots in human interaction. Pneumatic robots, as a subset of soft robots, have a high level of safety in their interaction with humans. Also, due to their structural characteristics, they have suitable portability, thus enhancing their attractivity.
Farago[18]	2019	Developing an EMG-based muscle model for patients with elbow trauma	wearable robotics	Arm and elbow	The model results indicated that assessment and optimization can improve the consistency and accuracy of classification models. This in its own right can be useful for identifying EMG criteria in muscle health assessment by wearable rehabilitation devices.
Guo[19]	2019	Joint angle prediction based on EMG for upper limb elbow using neural network	Neural network	Elbow joint and upper limb	In this study, the predicted angle and real angle were compared with each other. The experimental results indicated that the proposed method can predict the elbow angle across the sagittal plane with the maximum level of error of more than 5%.
Kuthe[20]	2018	A method based on superficial EMG for calculating the muscular power and fatigue of biceps brachii muscle and its clinical function	Regression	Biceps brachii muscle	The muscular performance is usually measured in terms of power or ability of force generation during contraction. Accordingly, the force generated by skeletal muscle during isometric contraction is measured for trained individuals. In previous studies, it was not possible to measure the muscular power of the person. However, in the present study, the power was measured using non-invasive S-EMG method.
Mordhorst[21]	2015	Predicting the EMG signals under realistic conditions	Chemical-electromechanical	Upper limb	Unlike previous models, EMG phenomenology, which describes the shape and AP propagation speed as part of the model development, is based on transient diffusion equation in relation to Biofikin-Hodgkin-Hoxely. The model of membrane -sipers electrophysiology type forms membrane fatigue causing change in the amplitude and diffusion speed of AP during stable contractions. Thus, using the presented multiscale model, their effect on EMG signal can be analyzed, which may improve their interpretation and result in better understanding of recorded signals.

Name of Authors	Year	Title	Type of Model	The Investigated Limb	Final Finding
Tao[22]	2014	An EMG-based neuromuscular interface for elbow	-	Arm and elbow	The neuromuscular interface is used to record and process EMG signals during arm bending as well as tests for confirming the feasibility of the entire interface system. In this study, some advances have been made to achieve precise control, real-time processing, and wireless transmission.
Blemker[23]	2005	A 3D muscular model for biceps brachii muscle	Biomechanical	Biceps brachii muscle	The model indicated that the changes in the bone length in the muscle and curvature of bones are the major factors contributing to heterogeneous types. Also, the method of complex geometric arrangement of muscle fibers on the contraction mechanics of muscles is required.

The models used in these studies were physiological mathematical models modeling the physiological structure of the muscle based on direct description of the biomechanical, biological, and physiological features of the system individually, which is difficult for obtaining many parameters.

As it can be seen, the models used in these studies were not nonlinear, unpredictable, or even complex. Accordingly, the extent of their correspondence with features of biological systems is questioned.

Discussion

Around 3% of accidents lead to amputation of upper limbs, amputation from the arm section. An upper limb with adequate sensation to prevent damage, which can also somehow encompass an object, is preferred to prosthesis. Meanwhile, EMG signals of the arm muscles can provide important information about the physiological behaviors of that muscle. In this study, the most important types of the upper limb modeling were identified as review of papers along with their content analysis. Based on these studies, it can be stated that today with the advances in the medical engineering sciences, usage of modeling has gained great popularity and offers promising results for treating disability especially in individuals with amputated limbs or brain stroke.

Various models have been presented for biological purposes, each having their own limitations. The most important applications of biological models are found in employing various smart limbs, which are controlled nonlinearly by the primary signals of the body. In a cybernetic hand, biological models based on the arm EMG signals are used. Therefore, presenting a hand-based nonlinear biological model that has resolved the problems of previous models is important.

Accordingly, when modeling, a proper model is the one in which all states of biceps brachii muscle stimulation respond to the various frequencies and amplitudes of stimulation. The output of this model can predict the extent of change in the joint angle in relation to its initial state and the EMG signal in proportion to the stimulation. In addition, a model should be developed which is absolutely congruent with the biological system features; it should also establish a significant relationship between stimulation and output of the EMG signal, as well as a significant relationship between stimulation and changes in the joint angle, whereby the model generalizability is also possible.

Conclusion

Based on what has been stated, the models presented in this regard have had deficiencies such as lack of generalizability. Indeed, they are trained with special states and are problematic in generalizability to other states. In such models, only mathematical relations and neural networks have been used, most of which have found errors in the outputs. Furthermore, many models are not practical because of not using the features and systems similar to biological systems.

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