A COMPUTATIONAL APPROACH FOR EARLY STAGE IDENTIFICATION OF LOWER LIMB MUSCLE ABNORMALITIES IN HUMANS

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ABSTRACT

The human skeletal musclehas a complex hierarchical organization comprising ofseveral force producing muscle fibres arranged within a connective tissue network, whichcan contract and relax to cause motion or movement of the limbs [1]. This contraction and relaxation of skeletal muscles fibresresults in walking or conduct of locomotion activities in the lower limbs. Due to frequent travelling in the tough hilly areas, with age may cause the hampering of activities of daily living (ADL) tasks and restriction of movement of people living in these regions resulting from severe pain in the lower limbs. Hence, there is intensive potent need to develop an interactive GUI which will be helpful to doctor(s) and as well as to scientist(s) working in the field of biomechanics and rehabilitation. In this paper, an attempt has been made to develop an interactive GUI by employingmyoelectric signals from significant lower limb muscles corresponding to the specific activity or task performance in an individual. The data is procured from freely available online sources such as University of California Irvine (UCI), department laboratories for the different population age groups for both the genders. This data would comprise of standard and abnormal patterns of activity while performing ADL tasks, which could be further analysed employing signal processing tools post conditioning with the help of MATLAB in the GUI software.These processed bioelectric signals are sent to an Artificial Neural Network (ANN) to train the software for detection of abnormalities in EMG signals of the lower extremity muscles. Post-processing, information from the ANN would be available in the GUI for the diagnosis or clinical interpretation by the physicians about the type, frequency and level of abnormality in selected muscles. This would help remove stress on the medical fraternity for performing routine diagnosis due to high patient load in the hospitals of our country.

KEYWORDS

Artificial Neural Network, myoelectric, GUI, rehabilitation.

I. INTRODUCTION

Movement and locomotion in humans is basically done by the contraction and relaxation of related muscles fibres in the lower limbs. The movement and locomotion in humans is developed by the tendons and muscles fibres by transmitting and developing skeleton force [1]. The human skeletal muscle has a complex hierarchical organization comprising of several muscle fibres arranged within a connective tissue network that causes contraction and relaxation of these muscles leading to onset of lower limb movements. The properties of the three elements namely serial, parallel and contractile in the Hill muscle model [9,10] are responsible for the generation of force and velocity that are defined in terms of force-length and force-velocity properties. The isometric contraction of the muscles which is based on the force-length property where the force is generated within the muscles, but the muscle length remains constant. During an isometric contraction of muscles, the contractile element shortens while the series element enlarge The total muscle length remains constant as the lengthening of the serial element is equal to the shortening of the contractile element. because of enlargement of the serial element, the parallel element no longer remains slack and develops non-linear tension. The total force that isgenerated within the muscle is calculated as the sum of the forces in both the passive and active muscle tissues [9].

The electrical activity of the muscles fibres is recorded with the help of electromyogram and the study of the electrical currents generated during a muscle contraction, provides data describing both neuromuscular activity as well asmuscular morphology. To understand the amount of neuromuscular activity in a muscle, the EMG signal is employed as a biological tool measuring voltages associated with the electrical currents produced during relaxation and contraction of the muscle fibres [2,3]. The surface electromyogram measured by employing surface electrodes provides a non-invasive method of measuring muscle activity, and has been extensively investigated over the years as a means of controlling prosthetic devices. Figure 1 shows the raw EMG signal obtained from the lower limb muscle. These myoelectric signals are generated due to physiological variations in the membranes of the muscle fibers.

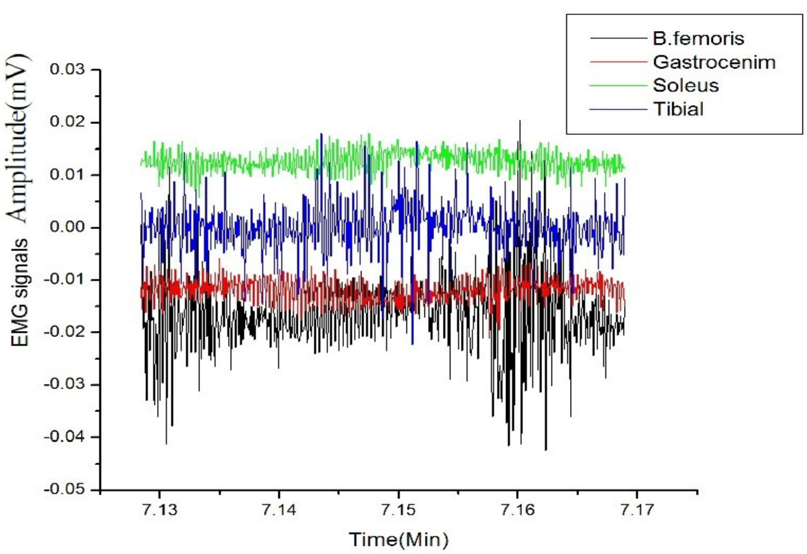

Figure 1. EMG signal from UCI data-base

A. Artificial Neural Network

The method of recognizing EMG patterns could be performed by an intelligent advanced signal processing technique, known as Artificial Neural Network (ANN). The ANN has been proposed as a potential method for reliable data characterization and classification [4,5]. A typical pattern recognition algorithm can extract features from the data set beyond signal magnitude to characterize and classify the acquired EMG signals. This classification may be employed by the user for the intended movement by an external device control.

It has been found that most researchers and scientists apply Artificial Neural Network (ANN) technique for the processing and utilizing the various biological signals to meet task performance or functional outcomes [6]. ANNs cells can simulate low-level functions of human neurons and are particularly beneficial for complex pattern classification and recognition tasks which are widely employed by the humans. The ANN can be trained to reproduce arbitrary non-linear functions of input data. The highly parallel and regularstructure of ANN along with accuracy makes them suitable and perfect choice for pattern classification tasks [7]. It has been found that different types of ANN structure have been utilized by several researchers because of its ability to adapt and learn from arbitrary data provided to classify EMG signals into different categories. For making ANN more interactive, informative and user-friendly, a Graphical user Interface (GUI) is proposed to be designed with the help of Matlab toolbox. The back-propagation of neural network has been designed and optimized in this research work to classify the pre-processed EMG signals which are obtained for different limb motions which may include lower or the upper limb. Seven statistical time and time-frequency based features for EMG signal data analysis namely Slope Sign Change (SSC), Moving Average (MAV), Waveform Length (WL), Root Mean Square (RMS), Variance (VAR) , Standard Deviation (SD) and Zero Crossing (ZC) have been employed as inputs for designing the neural network [8].

B. Graphical User Interface (GUI)

The chances of having abnormality in the lower limbs increases with age often leading to health related problems or issues causing shorter life-span of population inthe hilly areas. As the age passes and after the surgery of the knees or injury to the lower limb(s), it may cause the weakening of muscles of lower limbs and hampering movement of the individual thereby quantitatively degrading the muscle strength by affecting activities of daily living (ADL) and restricting movement due to development of abnormal gait patterns of humans resulting from severe pain/ discomfort in the lower limbs. This may lead to other direct or indirect related problems (due to lack of regular activities) affecting the cardiovascular, respiratory, neurological processes of the human body thereby affecting overall human health of population residing in the hilly region/ areas and mostly cut-off from mainstream areas of the country due to less awareness and lack of proper medical facilities.

To overcome this problem, a Graphical user interface (GUI) has been proposed to be developed using Matlab which would be made compatible with other available software(s) such as android, windows to study the abnormalities arising due to changes in lifestyle and movement patterns in individual (s) affected with lower limb problems. Graphical user interface (GUI) is the communication platform between a computer and its user. All programs of this GUI use a consistent set of graphical elements so that once the end user learns how to use a particular interface; he or she can use all programs. This GUI would be interactive interface that would provide know-how to physicians treating such patients with the help of available medicines, yoga and physiotherapy techniques to access the level of improvement made over a period of time. As of now, no such interactive tools for accessing the level of improvement post-treatment exist. Hence, there is an intensive need to develop an interactive GUI which will be helpful to doctor(s) and as well as to scientist(s) working in the field of biomechanics and rehabilitation.

II. MATERIALS AND METHODS

Figure 1 shows myographic signal in form of electrode potentials corresponding to the activity of specific muscles under investigation. In our study, the EMG signals were obtained from the UCI database for healthy subjects between the age group of 20 to 60 years for both the genders. This data has been collected with the help of physiological acquisition from different department laboratories or hospitals for the various population age groups for both genders and stored in the database. This interactive interface is further trained to provide feedback for reassessment to observe the level of improvement in patients thereby assisting physicians.

The EMG data from identified lower limb muscles (Femoris,Gastrocnemius, Soleus and Tibialis Anterior) of normal healthy controls (with no symptoms of discomfort or pain in the lower limbs) and abnormal subjects (suffering from disability or abnormality of lower limbs) while performing flexion and extension of lower limb muscles during gait, from online databank between the age groups 20-60 years. EMG data of subjects with age group <20yrs and >60yrs is not included in the study population, as the muscles below 20 years are not well developed and for above 60 years the signals are not significant and not considered. Similarly, the database of a lower limb amputee or those found to be medically unfit or with any co-morbid condition was nonconsidered for the study.

III. RESULTS

The activity of above mentioned four muscles were taken in consideration during flexion and extension of lower limb as shown in figure 3 and incorporated in the GUI software. Figure 1 shows the normal data set from UCI data. The results are shown in figure 3 which provide the working of software in GUI module to predict the deviation or variation in the EMG signals with the help of trained ANN to show outcome for determining whether the muscles are functioning normally or abnormally. The graph in Figure 2 shows the normal pattern of EMG signal during flexion and extension with respect to time. Table 1 shows the normal activity of muscles during flexion and extension with respect to time and Table 2 shows the abnormal activity of muscles during flexion and extension with respect to time. In GUI with help of ANN, EMG signal are compared with standard EMG signal. If the input signal matches with the standard EMG signal then no abnormality is reported by the GUI.

If there is some deviation in input EMG signal to the standard EMG signal then abnormality is reported by GUI. In case of abnormality the resultant EMG signal graph with respect to time does not match with the standard EMG signal graph with respect to time. In case of abnormality GUI provide the solution in terms of Standardized yoga exercise, which helps instrengthening of the lower limb muscles.

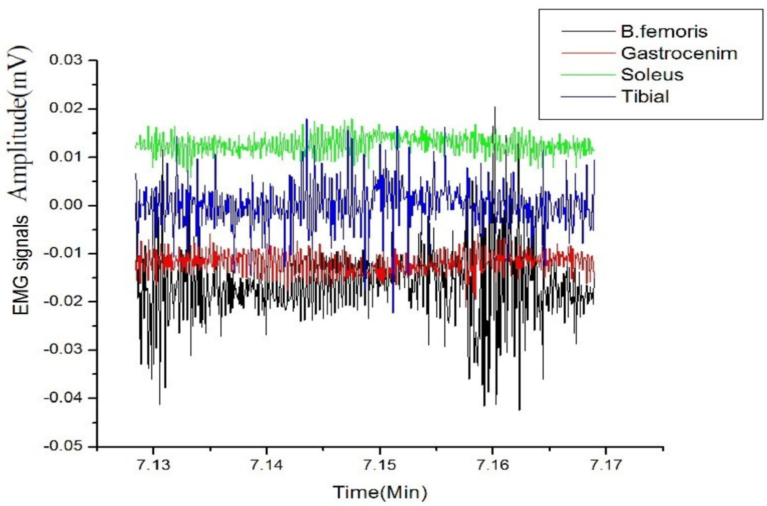

Figure2.Normal muscle activity during walking

Table 1 Normal activity of muscles during flexion and extension with respect to time

1.Time(sec)	**Muscles Length(mm)** 2.GASTRONEMIUS	3.FEMORIS	4.SOLEUS	5.TIBIALIS ANTERIOR
0	394.3293	267.3235657	318.3863	272.5042
0.011	392.6201	266.8819	318.6532	271.9064
0.0247	395.0324	266.3409	318.8557	269.4904
0.0368	395.3232	265.4611	318.9104	268.8406
0.0418	395.5431	265.1397	318.968	268.4305
0.0506	395.9967	264.4207	319.0512	268.0481
0.0606	396.5072	263.4892	319.0216	268.1451
0.0749	397.5499	261.9248	319.0628	267.4212
0.0854	398.4963	260.4321	319.1208	266.5034
0.0954	399.4207	258.9812	319.1133	265.6597
0.1005	399.9976	258.1151	319.1148	265.4373
0.1106	401.2117	256.3248	319.1377	264.6394
0.1208	402.4431	254.4128	319.1123	263.4963

Table 2.Abnormal activity of muscles during flexion and extension with respect to time

	Muscles Length(mm)			
1.Time(sec)	2.GASTRONEMIUS	3.FEMORIS	4.SOLEUS	5.TIBIALIS ANTERIOR
0	234.3254	356.3864	313.3233	242.5322
0.011	392.62012	236.8221	318.6532	222.9064
0.0247	335.03455	266.3409	318.8557	234.4904
0.0368	372.3221	265.4611	348.310	268.8406
0.0418	3775.5431	265.1397663	318.968	268.4305
0.0506	365.9667	244.42076	314.0523	268.0481
0.0606	356.5072	263.48926	322.0216	268.1451
0.0749	378.54932	261.92483	311.0623	267.4212
0.0854	396.4963	260.4322	321.1132	231.5034
0.0954	389.42073	258.9812	319.1133	265.6597
0.1005	399.9976	245.1152	319.1148	265.4373
0.1106	411.2117	256.32485	319.1377	264.6394
0.1208	400.44315	254.41286	319.1123	263.4963

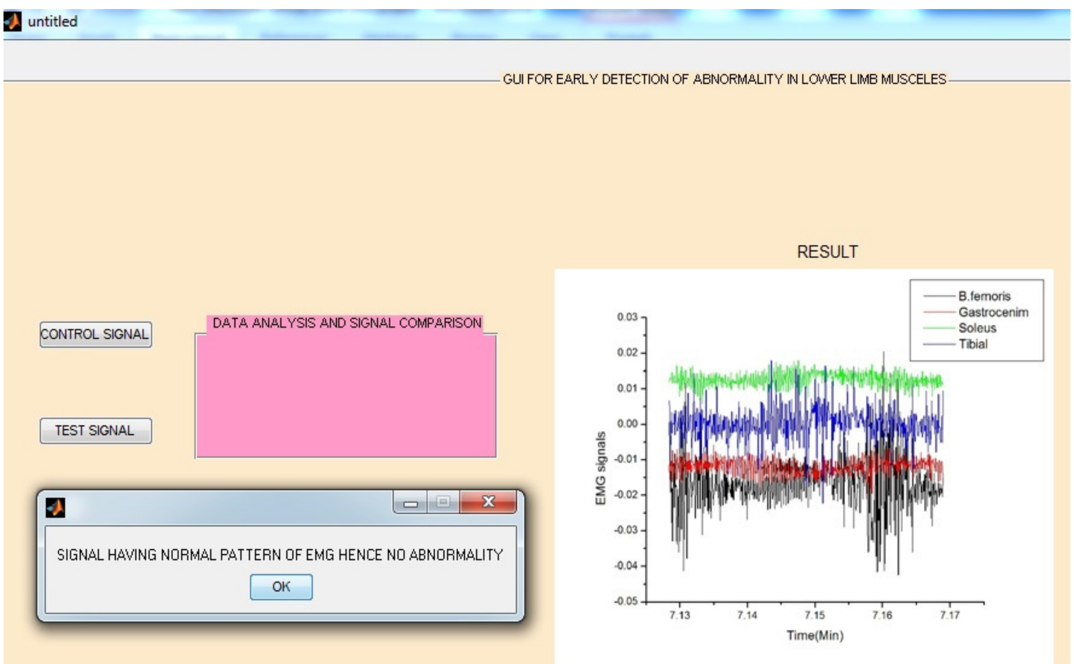

Figure.3GUI of software for prediction of EMG signals

IV. CONCLUSION AND FUTURE PROSPECTS

GUI is an important interactive tool through which a person having limited knowledge is able to better explore information outside his domain area. Moreover, when it is applied to health care, the outcome is beneficial to both the patients as well as for the doctors. Physician can use this GUI software to provide much needed rehabilitation at nominal costs to the local population residing in hills and in rural areas of North Eastern States. Moreover, it has been proved in available literature that different muscle abnormalities and muscle pain arising in the lower limbs can be improved with the help of yoga exercises. This GUI would provide an interactive interface, which will help the doctors to provide requisite rehabilitation at nominal costs to the population in the hilly areas for detecting muscles abnormalities and provide the information of success of various treatment regimens by employing YOGA or physical therapy modes so that abnormalities can be rectified by improving muscle strengthening to provide better lifestyle and reduce related health disorders.

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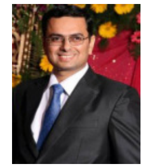

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