NEURO-MUSCULAS FATIGUE PREDICTION USING sEMG SIGNALS

Pavansimha. K[1], Kiran. N.B[2], Chaitra. K.N[3], Dr. L. Swarna Jyothi[4]

[1-3]*Dept. of Electronics and Communication, Rajarajeswari College of Engineering, Bangalore-74*
[4]*HOD, Dept. of Electronics and Communication, Rajarajeswari College of Engineering, Bangalore-74*

ABSTRACT

Physical activity is a necessity for the present lifestyle. Over burdening the body can be dangerous causing fatigue. Detection of such a phenomenon had been the main area of research in the bioengineering fields. To predict such muscle activity, electromyography with sophisticated machinery is being method used by medical practitioners which is not economical. The main problem associated with surface EMG signals is lower quality of the sEMG signals due to lot of noise associated with the signals. This work aims at developing a simple and cost effective hardware module that detects the muscle fatigue in human body using the surface EMG signals. The main aspect of this project is the assessment of the muscular liveliness and thus the fatigue related to it.

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1. INTRODUCTION

Electromyography (EMG) is an electrodiagnostic medicine technique for evaluating and recording the electrical activity produced by muscles. EMG is performed using an instrument called an electromyography to produce a record called an electromyogram. An electromyography detects the electric potential generated by muscle cells when these cells are electrically or neurologically activated. The signals can be analyzed to detect medical abnormalities, activation level, or to analyze the biomechanics of human movement.

Human body generates signals that can be measured and monitored. Such signals are referred to as bio signals. The bio signals can be of electrical in nature. The variations in the bio signals can be due to different parameters like time and genetic code. Bio signals describe the physiological phenomenon of a human body and the description can be irrespective of its nature. The possibility of a bio signal is unlimited. It is present everywhere in a specimen and every bio signal has a description related to it. The bio signals can be observed through variety of techniques. Some bio signals can be visually inspected in the patient and some can be recorded using sensors like electrocardiography and electromyography.

2. LITERATURE SURVEY

[1] “Consequences of lower extremity and trunk muscle fatigue on balance and functional tasks in older people: a systematic literature review”. JL Helbostad, DL Sturnieks, J Menant BMC 2010. This paper provides Muscle fatigue reduces muscle strength and balance control in young people. It is not clear whether fatigue resistance seen in older persons leads to different effects. In order to understand whether muscle fatigue may increase risk in older persons, a systematic literature review aimed to summarize knowledge on the effects of lower extremity and trunk muscle fatigue on balance and functional tasks in older people was performed.

[2] “Muscle fatigue: what, why and how it influences muscle function”, RM Enoka, J Duchateau - The Journal of physiology, 2008 - Wiley Online Library. This paper provides the four examples underscore to specificity of the impairments that contribute to the development of muscle fatigue and thereby make it impossible to identify a single causal mechanism for muscle fatigue.

[3] “Research on fatigue in facial and jaw muscles: review of the literature”. Angela Ruviaro Busanello-Stella, Ana Maria Toniolo da Silva, Eliane Correa. Rev. CEFAC vol.16 no.5 São Paulo Sept./Oct. 2014. This paper provides the purpose of this study was to deepen the knowledge about muscle fatigue of masticatory and facial muscles through analysis of scientific literature. The search strategy was based on the statements of the Cochrane Library. Articles were selected through the PubMed database, using the descriptor “muscle fatigue” in conjunction with the following descriptors: “speech therapy”, “facial muscles”, “jaw muscles”, “mastication”, “chewing”, “lip” and “clenching”. Articles from the last ten years were included, regardless of the language. The texts were analyzed, at first, in its abstract and those that did not fit the study`s objective was excluded.

[4] Finkelman, M., “A large database study of the factors associated with work-induced fatigue, “The Journal of the Human Factors and Ergonomics Society. This paper provides a computer survey was conducted using the records of 3705 temporary employees who reported job fatigue during their assignments; 10000 additional employees, who did not report fatigue, were also surveyed in order to establish base rates. Low job challenge, poor-quality supervision, low job control, poor job performance, and low pay rates were associated with employees' experiencing job fatigue.

[5] Bosch, T., De Looze, M.P., and Van Dieen J.H. “Development of fatigue and discomfort in the upper trapezius muscle during manual work,” The Journal of the Human Factors and Ergonomics Society. This paper provides Optimization of the temporal aspects of task design requires a better understanding of the development of muscle fatigue in the neck and shoulder region over time. The objective of the study was to investigate this in two production companies and to determine the relationship between objective and subjective estimates of fatigue. Indicators of fatigue were obtained through electromyography (EMG) during test contractions and ratings of perceived discomfort. EMG amplitude increased during the day in both case studies while mean power frequency decreased only in one case. In both cases, a more detailed frequency analysis of the EMG signals showed an increase in lower frequency power accompanied by a decrease in higher frequency power.

[6] J. Oksa, M.B. Ducharme, and H. Rintamaki, “combined effect of repetitive work and cold on muscle functions and fatigue, “Journal of Applied Physiology. This paper provides a study compared with the effect of repetitive work in thermoneutral and cold conditions on forearm muscle electromyogram (EMG) and fatigue. We hypothesize that cold and repetitive work together cause higher EMG activity and fatigue than repetitive work only, thus creating a higher risk for overuse injuries.

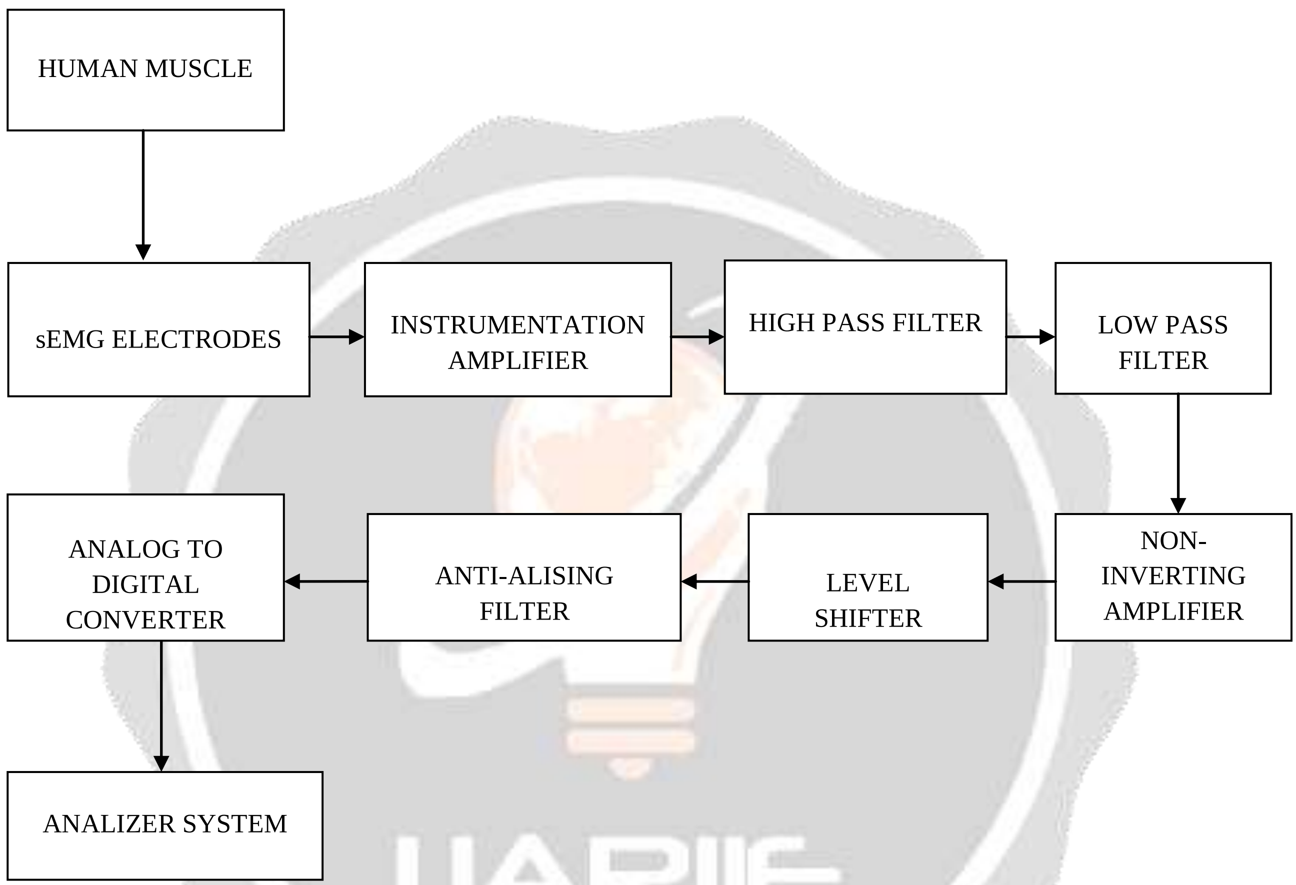
[7] Hashemi J, Morin E, Mousavi P, Hashtrudi-Zaad K, "Estimation and application of EMG amplitude during dynamic contractions," IEEE Transactions on Neural Systems and Rehabilitation Engineering, vol. 23, no. 1, pp. 41-50, 21 May,2014. This paper provides Numerous studies have investigated the relationship between surface EMG and torque exerted about a joint. Most studies have used conventional EMG amplitude (EMGamp) processing, such as rectification followed by low pass filtering, to pre-process the EMG before relating it to torque. Recently, advanced EMGamp processors that incorporate signal whitening and multiple-channel combination have been shown to significantly improve EMGamp processing. In this study, we compared the performance of EMGamp-torque estimators with and without these advanced EMGamp processors.

[8] Solnik S., Devita P., Rider P., Long B., Hortobagyi T. "Teager—Kaiser Operator improves the accuracy of EMG onset detection independent of signal-to-noise ratio," Journal of Bioengineering and Biomechanics, vol. 10, no. 2, pp. 154-160, 2008. This paper provides A temporal analysis of electromyographic (EMG) activity has widely been used for non-invasive study of muscle activation patterns. Such an analysis requires robust methods to accurately detect EMG onset. We examined whether data conditioning, supplemented with Teager–Kaiser Energy Operator (TKEO), would improve accuracy of the EMG burst onset detection.

3. METHODOLOGY

Muscle fatigue detector developed through this project, uses surface EMG electrodes which are placed on the relevant muscle after cleaning the skin surface. The signals from these electrodes are then fed to the differential amplifier for amplification and elimination of noise. These signals are then passed through filters where signals with frequencies below 8Hz and above 500Hz are eliminated, thus providing the signal in the required frequency range. This filtered output is given to a second stage of amplification, followed by a level shifter. The level shifter makes sure that the signal lies in 0-5V range so it can be given as an input to the ADC present in the Arduino Uno. The anti-aliasing filter prevents interference of high frequency components. The ADC coverts the analog signal to digital form. The digital data is processed on MATLAB to check for any deviation of the median frequency and amplitude from the power spectrum. The artificial neutral network is predicting muscle fatigue.

3.1 Block Diagram Reprensentation of Neuro-Musculas Fatigue Prediction System



4. sEMG SIGNAL ACQUISITION

The hardware for sEMG signal acquisition is based on collecting the surface electromyography signals using the surface EMG electrodes. These signals are then filtered and amplified to remove noise and then sent to the ADC. This data is used to predict the fatigue in muscle.

4.1 SURFACE EMG ELECTRODES

It is a non-invasive technique for EMG signal detection. This electrode forms equilibrium between skin of the body and detecting surface through electrolytic conduction, so that current can flow into the electrode. Disposable type Silver-Silver chloride (Ag-AgC1) electrodes are used which provide accurate and clear transmission of surface bio potentials. They are cheap and easy to handle as compared to the reusable ones, which need specific electrolytic gel and they need to be cleaned every time they are used. Disposable electrodes contain an Ag-AgC1 flat pellet spread with a thin coating of a saline base conductive gel and embedded into a fabric style backing. For connecting the electrodes to the hardware circuit, special coaxial cables are used. (DIN EKG/EMG/EEG Snap Leads - 24 inch).

The EMG leads contain Med Safe 1.5mm (.060) DIN connectors with snap style receptacles. To obtain good quality of EMG signal, impedance of the skin must be considerably low. Hence, we must completely remove the dead cells on the skin, hair and dust, where sEMG electrodes have to be placed. There should be no moisture content on the skin and to eliminate this, the skin must be cleaned with alcohol. Electrode design is important for better quality of EMG signals. Electrodes can be invasive or non-invasive. Passive type surface electrode has a conductive detection surface which touches the skin. Active type surface electrode has a differential amplifier along with the passive electrode.

4.2 SKIN PREPARATION

Some of the methods of skin preparation include:
i. Special abrasive and conductive cleaning pastes are available which remove dead skin cells (they produce high impedance) and clean the skin from dirt and sweat.
ii. Fine sand paper rubbed softly and with controlled pressure for 3 or 4 times is enough to get good results.
iii. The pure alcohol may be another alternative if used with a textile towel (that allows soft rubbing). The latter method may be sufficient for static muscle function tests in easy conditions.

Whichever skin preparation method and electrode application technique is used, when done properly, the skin typically receives a light red color. This indicates good skin impedance condition.

4.3 SEMG ELECTRODE PLACEMENT

To obtain best possible signal, proper placement and orientation of sEMG electrodes across the muscle is important.
i. Location and orientation of the electrode: The electrode should be placed between a motor point and the tendon insertion or between two motor points. It must also lie along the muscle's longitudinal midline. The muscle fibers must be parallel to the longitudinal axis of the electrode.

ii. Not on or near the tendon of the muscle: The amplitude of sEMG signal reduces when the muscle fibers approach the tendons. It is difficult to properly locate the electrode position as the muscle's physical dimension is reduced and thus makes the signal susceptible to crosstalk due to the proximity of agonistic muscles.

iii. Not on the motor point: Introduction of minimal electrical current at the motor point will cause a perceptible switch of the surface muscle fibers. It corresponds to the innervation zone in the muscle having the greatest neural density which depends on the anisotropy of the muscle. The action potentials travel caudally and rostrally along the muscle fibers in this region and hence the positive and negative phases of the action potentials (detected by the differential configuration). The result would be addition and subtraction of phase differences which causes the EMG signal to have higher frequency components. The signal appears more jagged and with more sharp peaks in time domain.

iv. Not at the outside edges of the muscle: Here the electrode is susceptible to detecting crosstalk signals from adjacent muscles.

The electrodes must not be spaced too far away as the volume of the tissue increases and thus data becomes non-specific and less localized which is required for detection of fatigue in a muscle. To ensure less noise is present due to equipment, the electrode must be cleaned after each application, the ionic conductivity of the electrolyte must be good, electrode position must be maintained and the quality of the adhesive tape must be good. The electrodes must be placed parallel to the dominant muscle fibers to minimize the signal cancelling and maximize the system's sensitivity. Figure.4.3 represents electrode placement.

5. HARDWARE AND SOFTWARE TESTING AND RESULTS

The electrodes with electrolyte Ag/AgC1 collects the EMG signals from the surface of the skin where the muscle is present. The data processing unit which consists of instrumentation amplifier, high pass filter, low pass filter, second stage of amplification and level shifter circuits. The ADC and the USB 2.0 which is the conversion unit.

Fig-5.1: The sEMG electrodes connected to snap cables placed on bicep brachii

The output from the ADC is given as input to the PC serially through the USB 2.0. The data in digital form taken from the Arduino Uno through the communication port COM6 is used for analysis in MATLAB. The output of the MATLAB program displays the signal after the analog to digital conversion.

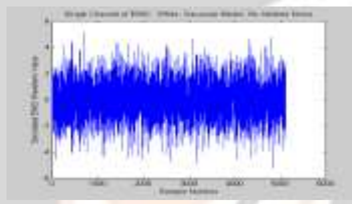


Fig-5.2: Output from the sEMG electrodes

The output from the sEMG electrodes is shown in Fig. 5.1.1 It is the raw sEMG signal before sending it to the conditioning circuit. The raw sEMG data has a lot of noise associated with it such as power line noise and noise due to motion artifacts. Due to noise, the signal appears highly distorted and random in nature.

6. CONCLUSIONS

Muscle is a soft tissue which helps to produce force and motion. Its main function is maintaining and changing posture, locomotion and movement of internal organs. Fatigue in muscles can be a result of vigorous exercise caused due to the reduced ability of the muscle fiber to contract known as metabolic fatigue. Fatigue plays a major role in limiting performance in individuals in sports. Surface EMG is a research technique which is used to look at muscle recruitment in various conditions. It quantifies the electrical signals sent to muscle fibers through motor neurons. Median power frequency is used to determine fatigue using EMG. The raw EMG data is amplified, filtered to reduce noise, Fourier transformation is applied and the median power frequency is found. The median power frequency decreases over time, demonstrating fatigue. This is cost effective research work which was prepared with the available resources in an economical way and is ready to detect muscle fatigue among patients.

7. REFERENCES

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