IJITLS

International Journal of Information Technology and Language Studies (IJITLS)

The Real-time monitoring of muscle fatigue using Surface Electromyography (sEMG)

Imran Qayyum Mundial[1], Muhammad Shahzad Alam Khan[1], Muhammad Asif[1], Faiqa Saheen[2], Yasir Ali[3], Imad Ali[1], Akhtar Hussain Phul[4], Shakir Sultan[5], Faisal Rehman[1]

[1]Department of Mechatronics Engineering NUST College of E&ME, National University of Sciences and Technology NUST Islamabad, 44000, Pakistan.

[2]School of Chemistry, Lahore College for Women University, Lahore 54000, Pakistan.

[3]Department of Computer Science Sir Syed CASE Institue Islamand, Islamabad, 44000, Pakistan.

[4]Khairpur Medical Colleges and University KMC Khairpur Mirs, Sindh, Pakistan.

[5]Department of Electronics and Information Engineering, Xi'an Jiaotong University, Xi'an, China.

iqmundil@gmail.com, m.shahzad.alamkhan@gmail.com, m.asif@uettaxila.edu.pk, shafaika28@gmail.com, yasiriazi74@gmail.com, its.imadkhan@gmail.com, radiology205@gmail.com, shakir635@gmail.com, faisal.rehman.be13@iba-suk.edu.pk

Article Information

Article type: Article

Article history:

Received: January 01, 2022
Revised: July 17, 2022
Accepted: July 17, 2022

Keywords:

Surface Electromyography,
Muscular Fatigue,
Vital Signals,
Electromyography Signal.

Abstract

Muscle fatigue is the decline in muscle performance after undertaking any physical activity. Muscle fatigue can adversely affect the efficiency, productivity, and safety of athletic persons. Monitoring muscle performance during training to avoid any injury and achieve optimum results is a demanding task for current sportsmen. This research discusses the methods of fatiguing muscle and their use in assessing the fatigue of athletes. However, these methods have also been subject to high biases and interrupt athletes' training. Therefore, this paper aims to monitor real-time muscle fatigue by using electromyogram graphical (EMG) signals to address these concerns. These electrical (signals) impulses vary with fatigue levels, and these EMG signals were acquired from an athlete while lifting different weights (from the forearm muscle). For this research work, we consider a few cases first, the acquired initial signal is amplified, and filtration is applied to reduce signal artifacts. Later, rectification was done before monitoring EMG signals in the time domain. The Muscle exertion scale (BorCR-10 scale) was used for measuring muscle fatigue levels. The number of repartitions with different sizes of weightlifting shows dissimilar results in the development of muscle fatigue. It has been observed that when weight is overloaded compared to human capacity, the precision is quite good compared to accurately and verse visa.

I. INTRODUCTION

Nowadays, humans are surrounded by a lot of diseases, and to diagnose these diseases number of biomedical devices are designed. These muscles are the major's sources of the human so the muscle in the body has some potential that is more suitable to monitor the heath activities as we can detect the behavior by this signal with the help of electrodes [1]. EMG signals acquired from body muscles require the latest methods for detection, decomposition, processing, and further classification. Automatic decomposition of surface electromyography (sEMG) signals into constituent motor unit action potential trains (MUAPTs) is been carried out naturally. Variations in the sEMG signal due to fatigue have an imperative effect both in time and frequency domains [2, 3]. EMG signal is a biomedical signal that measures electrical current generated in muscles during its relaxation/contraction representing neuromuscular activities [4]. The biomedical signal (vital signals) means electrical signal collectively acquired from any organ ort human body that can be represents a physical value of interest for further investigation. EMG signal is precisely a complicated signal, duly controlled by the nervous system and depends on the anatomical and physiological properties of body muscles. At times EMG is referred to as a myoelectric activity. Muscle tissues conduct electrical potentials similarly as nerves do [5], these electrical signals are also known as the muscle action potential. Every muscle is composed of packets of special cells capable enough to contract and relax as required [6, 7].

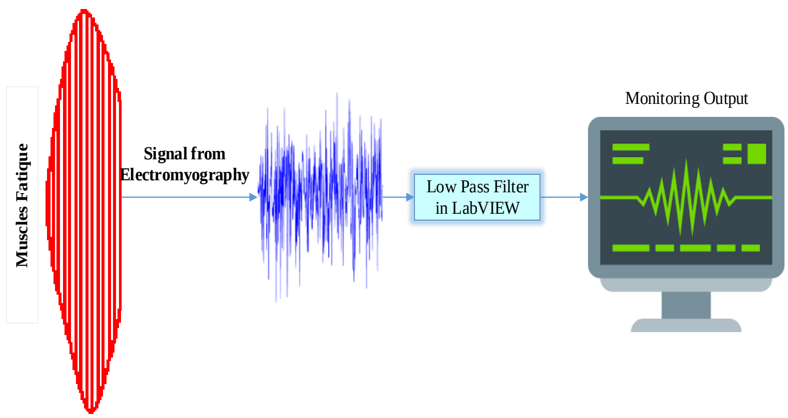

Figure 1. The basic concept of detection of EMG signal.

Figure 1 shows the basic concept of detection of EMG signal, its further decomposition, processing, and classification. The foremost function of said specialized cells is to generate forces, movements as desired, and the ability to communicate such as speech, writing, or any other mode of expression. The contraction of skeletal muscles is initiated by required impulses in the neurons to the said muscle, and it is mostly under voluntary control. Skeletal muscle fibers are well supplied with neurons for their relaxation or contraction. This particular type of neuron is known as "motor neuron" [8] and it approaches close to muscle tissue but is not connected to it. Usually, one motor neuron supplies stimulation to several muscle fibers.

The development of muscle fatigue is characteristically quantified as a decline in the maximal force or power capacity of muscle, which usually means that submaximal contractions may be sustained after the occurrence of muscle fatigue [9]. However, it ultimately affects the performance of the subject individual and excessive fatigue may cause extreme damage to the muscle. The variation in the strength of the biceps brachii muscle is because large numbers of motor units (MUs) are recruited to take part in contraction for more force, and the number of MUs recruited depends upon the muscle's physiological status. Therefore, the trained muscle recruits more MUs during increased weight [10,11]. In the literature review, abnormal movement at the endpoint during post-fatigue with rapid elbow extension is associated with a decrease in mutual muscle contraction [12], and the variability induced by neuromuscular noise limits the accuracy due to a high degree of fatigue within the triceps [13]. This research aims to analyze sEMG signals in time domain features for fatigue and muscle disorder. The programming and selected software have been employed for checking muscle fatigue level continuously, and in real-time; otherwise, it is possible to lose data during signal processing. The complete circuitry consists of an EMG sensor AD8232 module, electromyography electrodes, Arduino Mega 2560 module, and laptop (for data logging). Software LabVIEW has been used for real-time results displays and further application of fatigue algorithm.

The Paper is divided into the following categories: Basic System Model is discussed in Section II. The algorithm is discussed in Section III. Experimental results are shown in Section IV. The discussion part is in Section V. Finally, the paper is concluded in Section VI.

2. Related Research Work

The EMG sensor results are classified into multiple sections for fatigue, and researcher varied their research level from base to expertise. As discussed earlier, EMG signal is generated by the nervous system consist of a large number of exciting cells communicate with the body to generate an electrical signal. So, this signal is very noisy and passed from multiple processes are classified into feature extraction, muscle fatigue measurement, the efficiency of EMG sensor, signal processing, and effect of the body after high loading for measuring fatigue on body muscles. Feature extraction of EMG signal is proposed into three domains such as time domain, frequency domain, and complex network domain. The Signal processing is a widely studied topic in EMG for increasing the efficiency of the sensor, even the quality of EMG sensor, feature extraction, and methods are a factor that affects the signal processing method for the sEMG. Regardless of the process of analysis the relative movement of the electrodes concerning the measured muscle during this EMG signal measurement in dynamic conditions makes such estimates questionable and may lead to incorrect conclusions [16]. Recently, non-linear methods such as recurrence quantification analysis RQA have been proposed for behaviors of sEMG signals, mainly in fatigue assessment [17]. The Surface electromyography (sEMG) is a non-invasive measure of muscle activity that is widely used in research and medical field for the hospitals and other activities and under-utilized as a clinical tool in rehabilitative medicine applications. Many scholars have used different kinds of advanced methodologies and fabrication process, including wavelet transform, Wigner-Ville Distribution, Independent component analysis, Empirical mode decomposition, and higher-order statistics for analyzing the EMG signal appropriately and their physiological activities. The second section of this paper contains EMG signal classification methods and its details [18]. A common method of initially processing surface-detected EMG signals activity was to differentially amplify, rectify, and then smooth with the help of the a low-pass filter to rectified activity of these signals. The SNR depends upon the contraction level, type of smoothing filter, and the amount of smoothing for the particular filter. The SNR ratio of signals are very important in signal communication problems of both a design and a theoretical nature. In 1975. The mentioned an approach technique to overcome the recognition problems using autoregressive moving average parameters as well using the kalman filter parameters of the EMG time series applying on prosthesis control purpose [21]. The theme of prosthesis using surface EMG gradually began from the year of 1975. The designed a system using digital signal processing techniques for generating control signals for a multifunction lower arm prosthesis using surface electromyography is the key elements now a days for the researcher [22].

3. S-EMG SIGNALS

The EMG signal is the measurement of electrical current that is generated with the help muscle fibers during their movement period which will represents the neuromuscular activities. These signals are very complicated and non-stationary which is controlled by the nervous system because the nervous system is always responsible for muscle activities. The amplitude of these EMG signals is very low in terms of microvolts (50µv to 1mv) with frequencies varying from 10Hz to 3000Hz [19]. The EMG Signal analysis is based on different slandered parameters. There are three types of parameters which is normally used to evaluate the performance of signals.

1. Amplitude related parameters
2. Frequency related parameters
3. Time-related parameters

These parameters are measured from rectified EMG Signal, which is obtained after the conversion of raw EMG Signal. Amplitude-related parameters are EMG peak, mean, integrated EMG, RMS value of EMG; frequency-related parameters are mean frequency, median frequency, and total power spectrum, and time-related parameters are onset time, offset time [20].

4. METHODOLOGY OF RESEARCH WORK

These Several issues affect the conformity of EMG signals. However, two are dominating and the first one is the signal-to-noise ratio, mainly it is the ratio of the energy present in the EMG signals to the energy in the noise signal. It is desired that signal-to-noise ratio should contain the highest amount of information from available EMG signals as possible and must have a minimum amount of noise contamination. The second issue is the distortion of the signal, which means that the relative contribution of any frequency component in the EMG signal should not be altered. The distortion in the EMG signal must be as minimum as possible. To address both issues a biomedical instrumentation system has been designed to incorporate an Arduino-based controller with a real-time LabVIEW interface. The basic system model used in this research is in Figure 2.

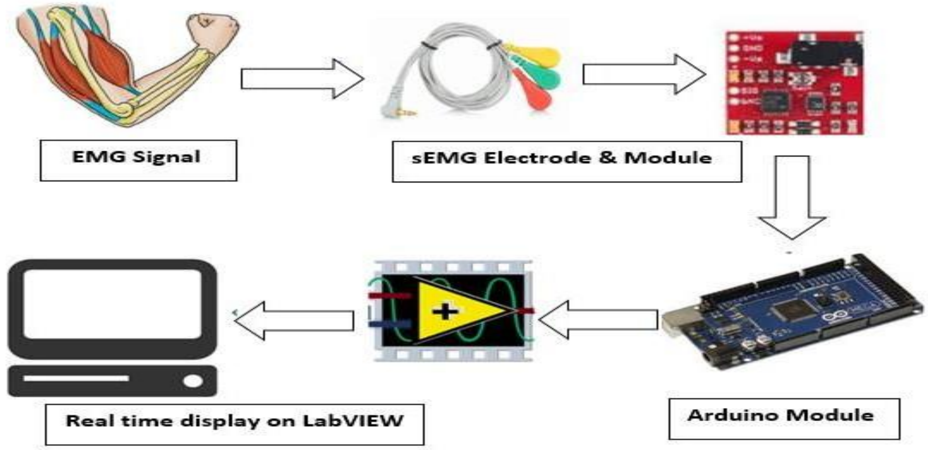

Figure 2. Biomedical instrumentation system incorporating basic electronics components.

The EMG sensor AD8232 module is connected with the electromyography electrodes and receives a physical signal from the muscles. AD8232 is an integrated signal conditioning block for ECG and other biomedical signal measurement applications. It is designed to pull out bio-potential signals in the presence of noisy conditions, such as those created by movement or remote electrodeposition. Arduino Mega 2560 module receives the said noisy signal and forms a link between hardware i.e., EMG sensor AD8232, and software LabVIEW. A transducer (sEMG) attached to the forearm limb requires certain optimization steps before useful output could be extracted from it.

Output values from an EMG electrode require considerable amplification since resistance and voltage variations are very nominal and the presence of noise also hinders the evaluation. After that filtration of the amplified signal is carried out to remove maximum noise. Rectification of said signal is done to avoid complications in the application of algorithms on the real-time received data and to ensure that signal does not reduce to zero (while signal averaging). Amplification, filtration, and rectification are also done in the LabVIEW domain shown in Figure 3. LabVIEW displays result in real-time as the subject undergoes a different set of weight lifting exercises. Certain values are fixed depending upon the muscular strength and it affects the repetitions and further fatigue levels are obtained.

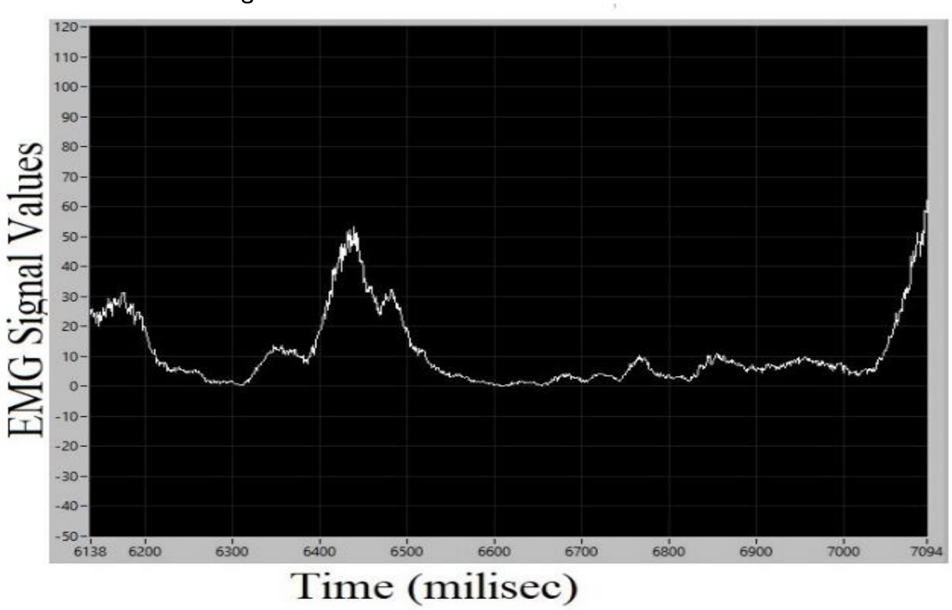

Figure 3. The received signal in LabVIEW after necessary amplification, filtration, and rectification.

Acquisition of physical signal, amplification, filtration, and rectification play a vital role until the signal is finally displayed in graphical form for analysis. Therefore, it purely replicates a comprehensive data acquisition and control system since it involves the signal acquisition, signal processing and signal analysis in detail shown in Figure 4.

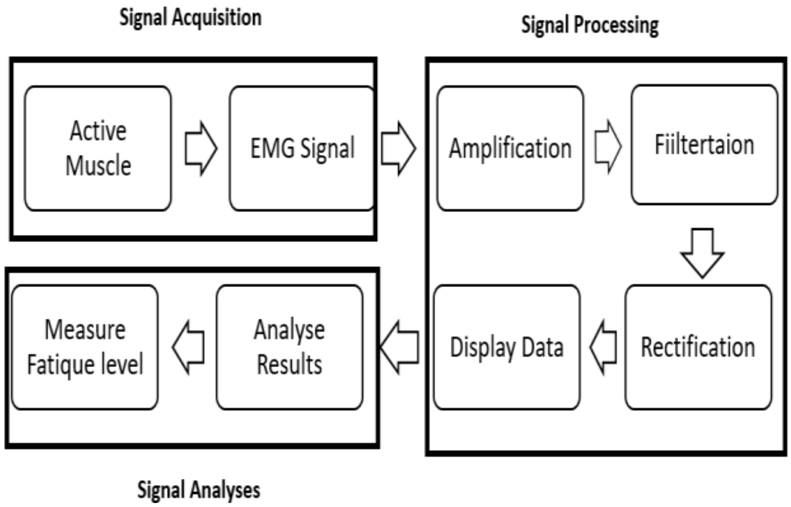

Figure 4. Application of basic instrumentation model incorporating simple signal acquisition and control system concepts.

5. ALGORITHM

1) Get values from EMG sensor AD8232 module and store them at variable.
2) Signal amplifies up to 500. The flow chart of the algorithm is in Fig. 5.
3) The amplified signal passes through a low-pass filter (average filter).
4) Rectification to be carried out (in case signal is negative it has to be phase-shifted).
5) A comparator compares the last 25 values to ensure proper increment after a certain fixed value.
6) Fixed value to be changed in LabVIEW domain depending upon the muscular response.
7) The increment is done if the received value exceeds said fixed value and later on intimate total increment figure at fatigue algorithm.
8) Increment value represents certain muscular activity.
9) After how much increment fatigue level occurs, a certain threshold value is defined.
10) On crossing threshold value indication displays and intimate no of muscular activity have been carried out.

6. EVALUATION RESULTS

A physical signal is received from the EMG sensor AD8232 module and has to be sent to LabVIEW via Arduino Mega 2560 module. Necessary signal conditioning processing carried out as required and displayed as per applied algorithm for muscular fatigue in software LabVIEW in a real-time environment. In LabVIEW, GUI requires few inputs i.e., two variables to be defined, the first one is to count the number of repetitions and the second is the level at which fatigue has occurred. In this case, the first variable is defined as 30 and the second variable is 60. Values of these are both variable dependent upon the muscular strength and it varies from man to man. Under steady-state without exercise EMG signal value is normal however on the application of increasing weight EMG signal value tends to increase and subsequently reaches fatigue value. Firstly, the EMG signal in relaxed conditions is measured. Then the subject is provided with resistance to the weight of the dumbbell of 4 kg and 7 kg and a measured number of counts as the muscle got fatigued. In lifting 4 kg of dumbbell weight, the subject manages to complete 6 repetitions and got fatigued shown in fig 6. Therefore, muscular activity reached its defined upper limit for fatigue. Fig 7 shows the graphical representation of this signal along with the repetitions count.

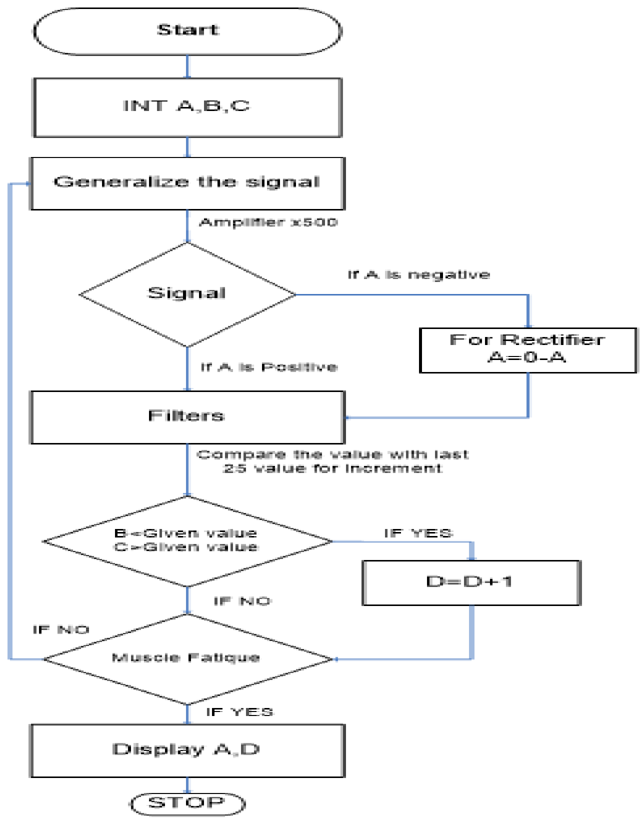

Figure 5. Flow chart of the defined algorithm used in a system with IF-ELSE statements.

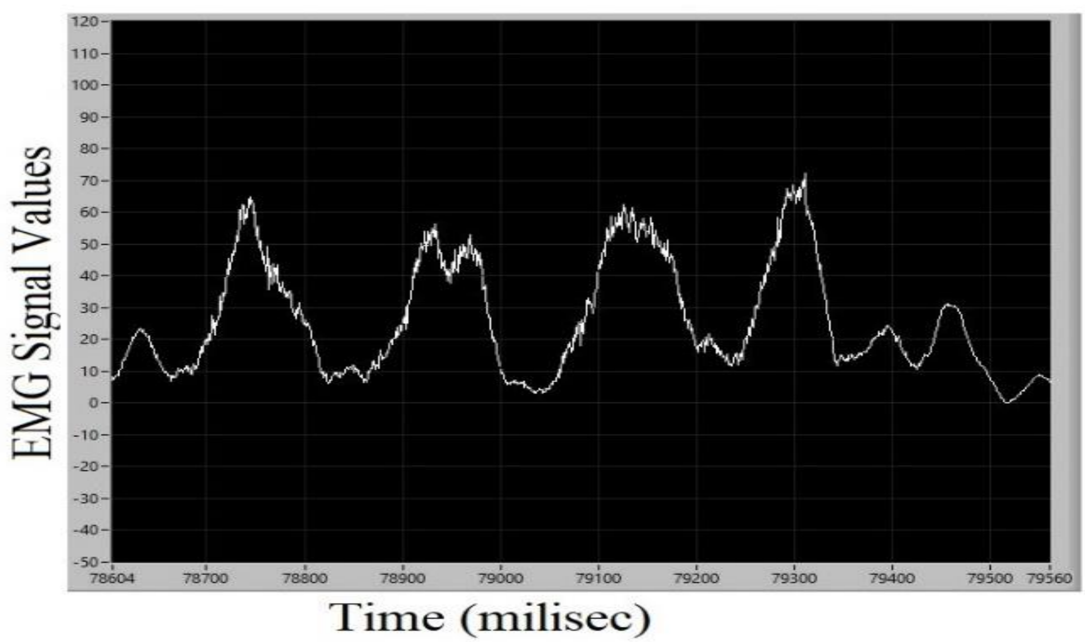

Figure 6. Muscle fatigued after 6 repetitions of 4 Kg weight and reaches its defined value.

With increased weight muscle has to be fatigued in earlier time domain along with a smaller number of repetitions. Therefore, the same has been confirmed here, as, in the case of the lifting of 7 kg of dumbbell weight, it has completed only 3 repetitions and reaches its fatigued value shown in Figure 7.

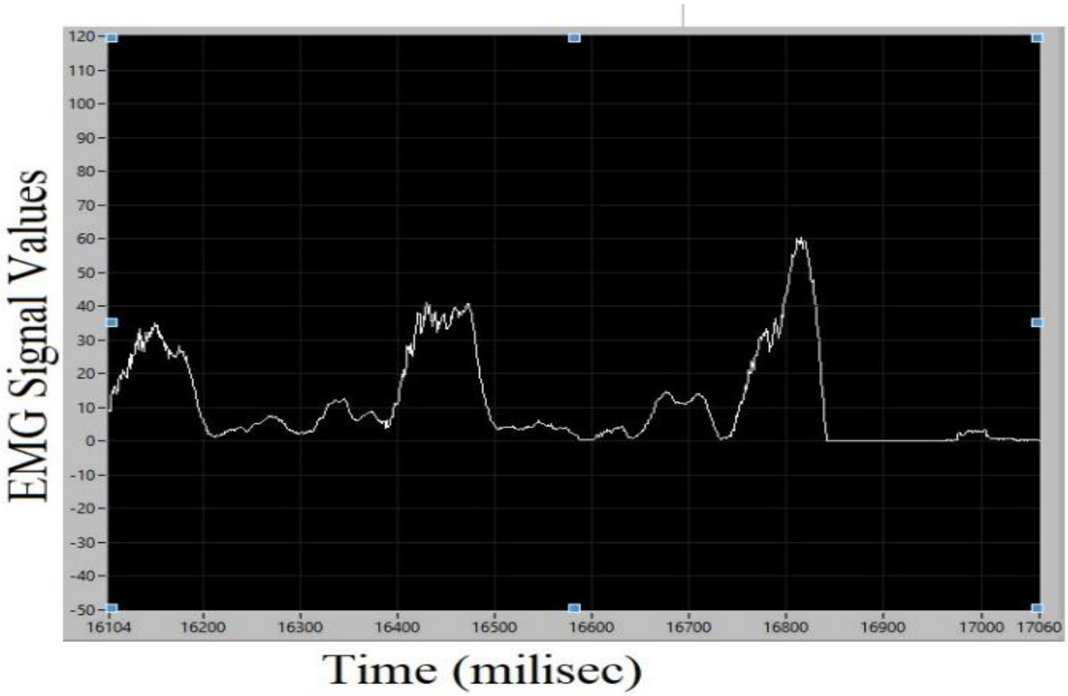

Figure 7. Muscle fatigued after 3 repetitions of 7 Kg weight and reaches its defined value.

At the time of normal weight lifting, the precision of the result is quite good but the accuracy of the result is slightly low at the time fatigue level due to tiredness of the upper limb. After extraordinary weight lifting the precision of the result is quite strange and varies due to high fatigue at initial, but the good accuracy of the result has been achieved earlier as compare to low weight lifting 4 kg.

7. DISCUSSION

This research work is performed to analysis of vital signals and shows the efficacy of modern-day transducers in biomedical science. This study focused on the use of an sEMG sensor and its further interpretation in respect to varying weight exercises for fatigue analysis. In comparison to the model suggested by A. Kumar et al [14] EMG sensor receives the physical signal and further passes it to the Arduino module for processing and it parses the received data, displays the EMG signal, and performs analysis using MATLAB. In the model suggested by Z. Taha et al [15] accelerometer with a gyro sensor is applied to the dumbbell in addition to the EMG sensor applied on muscles. The zero-crossing recorded from sEMG data is not as consistent as desired and as compared to the accelerometer data. This is feasibly due to the disadvantage of the post-processing of the sEMG data. Moreover, there is surrounding interference towards the EMG, it is hard to justify the initial point and endpoint of the EMG burst. Although we can apply a filter in EMG data, some critical data might have filtered away, together with interference during the said process. These seriously affect the accuracy of the data collection and have an impact on the results of the muscle fatigue analysis. However, in this paper is a complete analysis and carried out on real-time filtered signal received in the LabVIEW module to observe the signal activities.

8. CONCLUSIONS

This research work and study is focused on real-time monitoring and analysis of fatigue in the upper limb. The approach used and that is consists of measuring the amplitude of motors unit action potential (MUAP) appearing in the surface electromyogram (EMG) signal, which offers potentially valuable information during exercise and subsequently initiates fatigue. The Micro Controller is used for the digital processing and interface between the hardware and software tools as the Signal conditioning and application of simple algorithms on real-time signals for analyses in LabVIEW dominates the major part of the research work and intimate the subject about the initiation of fatigue before severe damage. While this research work shows that this kind of act is more efficient to monitor the health of sports men's and humans.

ACKNOWLEDGEMENT

This work has been supported by the Pakistan Science Foundation National University of sciences and technology NUST Pakistan.

References

Chakrabarti, B., Maity, S., Barui, S. Palbhowmik, S., Das, S., & Neogi, B. (2015). Overview on Literature Survey towards EMG Interpretations Technique in Addition to Several Interdisciplinary Work Related to EMG Interpretations. *International Journal of Scientific & Engineering Research*, *6*(5).

Chowdhury, R. H., Reaz, M. B., Ali, M. A. B. M., Bakar, A. A., Chellappan, K., & Chang, T. G. (2013). Surface electromyography signal processing and classification techniques. *Sensors*, *13*(9), 12431-12466.

de Freitas, M. R., Orsini, M., Prufer de Queiroz Campos Araújo, A., Abraão Jr, L. J., Barbosa, G. M., França, M. C., . . . Trajano, E. (2018). Allgrove syndrome and motor neuron disease. *Neurology international, 10*(2), 65-68.

De Luca, C. J. (1997). The use of surface electromyography in biomechanics. *Journal of applied biomechanics*, *13*(2), 135-163.

Doerschuk, P. C., Gustafon, D. E., & Willsky, A. S. (1983). Upper extremity limb function discrimination using EMG signal analysis. *IEEE Transactions on Biomedical Engineering*, (1), 18.

Enoka, R. M., & Duchateau, J. (2008). Muscle fatigue: what, why and how it influences muscle function. *The Journal of physiology, 586*(1), 11-23.

Farina, D., Merletti, R., Nazzaro, M., & Caruso, I. (2001). Effect of joint angle on EMG variables in leg and thigh muscles. *IEEE engineering in medicine and biology magazine*, *20*(6), 62-71.

Felici, F., Rosponi, A., Sbriccoli, P., Filligoi, G. C., Fattorini, L., & Marchetti, M. (2001). Linear and non-linear analysis of surface electromyograms in weightlifters. *European journal of applied physiology*, *84*(4), 337-342.

Ferrigno, B., Bordett, R., Duraisamy, N., Moskow, J., Arul, M. R., Rudraiah, S., . . . Kumbar, S. G. (2020). Bioactive polymeric materials and electrical stimulation strategies for musculoskeletal tissue repair and regeneration. *Bioactive materials, 5*(3), 468-485.

Graupe, D., & Cline, W. K. (1975). Functional separation of EMG signals via ARMA identification methods for prosthesis control purposes. *IEEE Transactions on Systems, Man, and Cybernetics*, (2), 252-259.

Hayashi, M., Tsuchimoto, S., Mizuguchi, N., Miyatake, M., Kasuga, S., & Ushiba, J. (2019). Two-stage regression of high-density scalp electroencephalograms visualizes force regulation signaling during muscle contraction. *Journal of neural engineering, 16*(5), 056020.

Kumar, A., Pahuja, S., & Singh, A. (2018). *Real time monitoring of muscle fatigue and muscle disorder of biceps brachii using Surface Electromyography (sEMG).* Paper presented at the 2018 First International Conference on Secure Cyber Computing and Communication (ICSCCC).

Kuthe, C. D., Uddanwadiker, R. V., & Ramteke, A. A. (2018). Surface electromyography-based method for computing muscle strength and fatigue of biceps brachii muscle and its clinical implementation. *Informatics in Medicine Unlocked, 12*, 34-43.

Mambrito, B., & De Luca, C. J. (1984). A technique for the detection, decomposition and analysis of the EMG signal. *Electroencephalography and clinical neurophysiology, 58*(2), 175-188.

Missenard, O., Mottet, D., & Perrey, S. (2008). The role of cocontraction in the impairment of movement accuracy with fatigue. *Experimental brain research, 185*(1), 151-156.

Mohr, M., Schön, T., Von Tscharner, V., & Nigg, B. M. (2018). Intermuscular coherence between surface EMG signals is higher for monopolar compared to bipolar electrode configurations. *Frontiers in physiology, 9*, 566.

Potvin, J. R., & Fuglevand, A. J. (2017). A motor unit-based model of muscle fatigue. *PLoS computational biology, 13*(6), e1005581.

Reaz, M. B. I., Hussain, M. S., & Mohd-Yasin, F. (2006). Techniques of EMG signal analysis: detection, processing, classification and applications. *Biological procedures online, 8*(1), 11-35.

Selen, L. P., Beek, P. J., & Van Dieën, J. H. (2005). Can co-activation reduce kinematic variability? A simulation study. *Biological cybernetics, 93*(5), 373-381.

Shair, E., Ahmad, S. A., Marhaban, M., Mohd Tamrin, S., & Abdullah, A. (2017). EMG processing-based measures of fatigue assessment during manual lifting. *BioMed research international, 2017*.

Taha, Z., Lee, C. M., Ahamed, N. U., Joseph, S., & Omar, S. F. S. (2016). Performance analysis in strength training: an innovative instrumentation. *Procedia engineering, 147*, 455-460.

Zhang, Q., Yao, Y., Sun, B., Bai, D., & Yang, J. (2018). *Fatigue Detection and Analysis of Upper Limb Muscles.* Paper presented at the 2018 IEEE International Conference on Intelligence and Safety for Robotics (ISR).