# DESIGN AND ANALYSIS OF SMART THERAPEUTIC MUSCLE STIMULATOR

[1] K.Sangeethapriya ,[2]A.Keerthana, [3]G.Srividhya, [4]4Jayarubi,[5]R.Chandrasekaran
[1]Assistant Professor, [2]Assistant Professor, [3]Assistant Professor, [4]Assistant Professor, [5]Assistant Professor
[1]Department of Biomedical Engineering,
[1]Vels Institute of Science, Technology and Advanced Studies, Chennai- 600 117, India.

***Abstract-*** A Muscle's reversible loss of its force is called its Muscle fatigue. It is often seen in sports persons and patients affected with paralysis and muscular dystrophy. In order to overcome this, an electrical stimulus can be given to the affected muscle so that it increases the distribution of oxygen, blood and nutrients in that muscle for a faster healing. The main aim of this project is to design a muscle stimulator in which the EMG signals are automatically detected in the presence of fatigue and by means of using a microcontroller , the required stimulation can be given for muscle restoration.

***IndexTerms:*** **Electromyogram, Muscle Fatigue, Functional Electrical Stimulator**

## I.INTRODUCTION

EMG is often defined as a muscle's electrical activity which is often useful for diagnosing their working ability [1]. This method of recording the electrical conduction between the motor nerves, helps in tracking the contraction and relaxation of these muscle's. Most of these EMG signals are represented graphically. Contraction of these skeletal muscles, increases the number and frequency of the motor units which in turn fires the motor neurons. As a result of this, these nerves contracts the muscle fibers, thereby the transmission of action potentials occurs through the neuromuscular junction and it passes through the muscle fibers, thus resulting in an increased electrical potential of that muscle. This can be detected using surface electromyography on the skin.
Usually an EMG is analyzed when a patient suffers from any one of these symptoms such as, Numbness, Muscle weakness, pain (or) cramping, Involuntary muscle twitching, etc. Whenever there is a loss of force-generating ability of a muscle due to tiredness, it is called as Muscle fatigue[2] Due to this, the activity of performing exercise by a sports person with a certain intensity and duration will cause harm to them due to lack of conditioning,poor fueling etc.
Therapeutic treatment can be provided through electrical stimuli to the muscles in order to treat muscle spasms and pain. It works by applying impulses to muscles for muscle contraction which increases the patient range of muscle motion. This process builds strength and keeps the muscles active after any type of injury or stroke. Mostly this type of treatment is given to the people suffering from Sprain, Arthritis, Back pain, Scoliosis etc.
Patrick et al [3] had developed a closed loop force control system in order to modulate the recruitment and temporal summation during intramuscular stimulation. It provided a useful orthoses for the subjects which in turn can be a better choice of force modulation and repeatability of the responses. Finally, it was found that the response time of the closed loop system was faster than the open loop system.
Heasman et al [4] mainly concentrated on an M - wave of EMG, which is due to depolarization of the muscle membrane for fatigue detection. In this proposed method, muscle force, RMS and second phase area versus stimulation pulse width of M-wave was plotted. Thus the M-wave parameters were detected. This in turn satisfied the definite requirement for the myoelectric parameter of isometric muscle contractions and yet it should be applied to nonisometric muscular contractions.
Mart Ergeneci et al [5] had designed a dry, active, noise cancelling, low cost, wearable 8- channel sEMG data acquisition system for adaptive contraction and noise detection. This system demonstrated a 1.1 dB more SNR and a strict band pass filtration when compared to Biometrics sx230–1000. It was finally concluded that this system can acquire a high quality sEMG successfully and it can detect the contractions successfully. Moreover, this system can also be integrated into any of the wearable device.The main drawback of this method was that it should be improved to analyze athlete's training performance in real time.
Strojnik et al [6] proposed a stimulator in order to provide gait assistance using FES. In this work,a shoe-insole heel switch was used for synchronizing the stimulation and the gait. Preliminary experience showed that the multichannel FES represented a successful approach to complex correction of the hemiplegic patient's gait. By using this,both the course of the swing phase as well as the effectiveness of the stance phase was influenced.The automated fatigue detection method was not achieved in these above methods , which will find a major role of this project.

## II.Materials and Methods

The block diagram of this proposed work is shown in the Fig.1 and its overall methodology of this work has been given in the Algorithm 1 below.

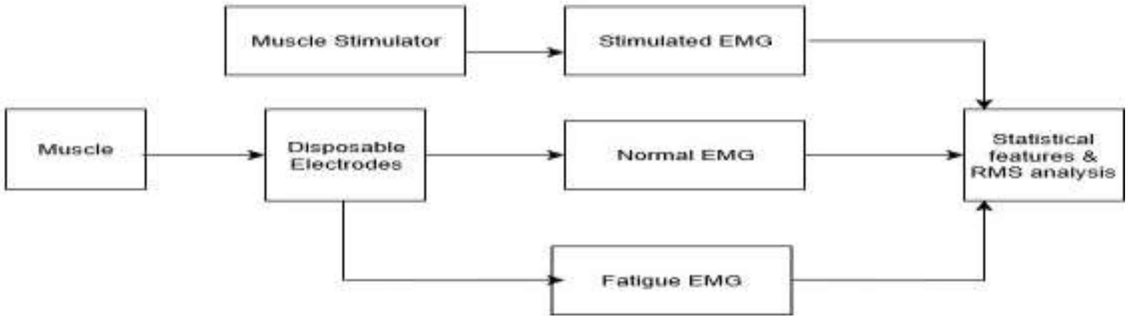


Figure 1. Block Diagram

---

Algorithm 1 Overall Methodology

---

1. Choose two kinds of target groups, namely normal subjects and fatigue subjects.
2.Select a particular subject from a corresponding target group.
3.Connect the disposable electrodes to the subject to be analyzed.
4.Record the EMG signals of the respective subjects.
5.Design a Muscle Stimulator as per the circuit diagram in the Figure 2 given below.
6.Check for its tingling sensation which will produce a stimulated EMG when connected to a subject.
7. Acquire the Stimulated EMG from the target group.
8.Analyze the Statistical features and RMS values from all these acquired signals.

---

**2.1 Muscle stimulator:**

The circuit diagram of Muscle stimulator is shown in Fig.2 Electrical impulses generated by this device are acquired through the disposable electrodes in the affected region where the muscle needs stimulation.

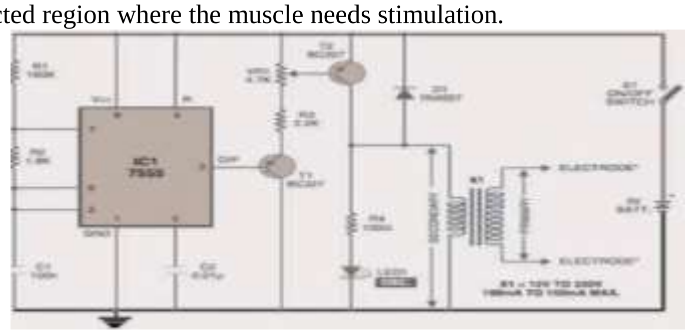

Figure 2. Muscle stimulator circuit

Electrical stimulation has been delivered to a subject giving 3V and 5V as input to the stimulator circuit . As a result,a tingling sensation has been felt by subjects . Thus the stimulated EMG signal is obtained.

**2.2 Target Group**

The target group comprises of the sports persons who often get fatigue due to hyperactivity. These persons come under the age group of 18-24yrs both male and female subjects.

**2.3 Activity**

At first EMG signal is acquired from ten healthy subjects.After their sports activity,the fatigue EMG is acquired from these subjects. Atlast, the stimulated EMG is also acquired from these subjects by giving the required amount of stimulation inorder to overcome their fatigue.

**2.4 Statistical features**

The statistical features like Mean,StandardDeviation,Medain,Correlation,Kurtosis,Frequency,Slope,Skewness are analyzed for these obtained EMG signals.

**2.5 RMS Value**

The RMS value representsthe average power of the EMG signal and its square root for a given period of time.It is denoted by the Eq.1 given below.It helps in reflecting the physiological activity of the motor unit during contraction.It is also used to quantify the EMG signal .The equation to calculate the RMS value is denoted below ,where x is the power of the signal & n is the number of samples.

.

$$RMS = \sqrt{1/n \sum_{n} x2(t)} \qquad (1)$$

This RMS value also converts the given signal into DC if any AC components are present in it.

## III.RESULTS AND DISCUSSION

The statistical features acquired from ten Healthy subjects are tabuled in the Table1. below:

Table 1. Statistical analysis of Healthy EMG signal

| Features / Signal | Mean | Standard Deviation | Skewness | Kurtosis | Median | Correlation | Frequency | Slope |
|---|---|---|---|---|---|---|---|---|
| 1 | 0.006 | 0.431 | -0.292 | 5.595 | -0.004 | 0.013 | -0.4 | 0.037 |
| 2 | 0.12 | 0.128 | -0.293 | 5.697 | 0.008 | -0.059 | 0.551 | 0.042 |
| 3 | -0.09 | 0.281 | -0.192 | 5.014 | -0.08 | -0.051 | 0.002 | 0.051 |
| 4 | -0.008 | 0.167 | -0.232 | 6.726 | -0.009 | -0.003 | 0.481 | 0.016 |
| 5 | -0.002 | 0.106 | -0.122 | 6.101 | 0.006 | -0.232 | 0.529 | 0.03 |
| 6 | -0.0006 | 0.254 | -0.125 | 5.648 | -0.009 | -0.213 | 0.456 | 0.036 |
| 7 | **-0.0008** | 0.269 | -0.165 | 6.123 | -0.007 | -0.236 | 0.548 | 0.056 |
| 8 | 0.13 | 0.169 | -0.189 | 5.314 | -0.003 | -0.041 | 0.489 | 0.026 |
| 9 | 0.003 | 0.365 | -0.164 | 6.548 | -0.008 | -0.045 | 0.478 | 0.048 |
| 10 | 0.006 | 0.498 | -0.256 | 6.389 | -0.003 | -0.064 | 0.565 | 0.065 |

The statistical features acquired from ten Fatigue subjects are tabulated in Table 2 below:

Table 2. Statistical analysis of Fatigue EMG signal

| Features / Signal | Mean | Standard Deviation | Skewness | Kurtosis | Median | Correlation | Frequency | Slope |
|---|---|---|---|---|---|---|---|---|
| 1 | 0.069 | 0.696 | -8.316 | 79.783 | 0.005 | -8.99 | 167 | 0.216 |
| 2 | 0.48 | 0.446 | -11.468 | 169.575 | 0.006 | 0.9 | 93.657 | 0.306 |
| 3 | 0.098 | 0.597 | -7.368 | 92.31 | 0.006 | 0.86 | 59.669 | 0.061 |
| 4 | 0.048 | 0.407 | -7.895 | 57.927 | 0.007 | 0.204 | 35.412 | 0.309 |
| 5 | 0.041 | 0.342 | -5.12 | 56.927 | 0.008 | 0.201 | 35.715 | 0.112 |
| 6 | 0.233 | 0.504 | -8.0334 | 91.301 | 0.0052 | 0.278 | 78.29 | 0.208 |
| 7 | 0.054 | 0.549 | -7.0930 | 59.23 | 0.0065 | 0.78 | 40.2 | 0.286 |
| 8 | 0.079 | 0.369 | -8.654 | 69.3 | 0.0056 | 0.92 | 33.5 | 0.09 |
| 9 | 0.065 | 0.589 | -7.564 | 60.23 | 0.0065 | 0.87 | 36.5 | 0.089 |
| 10 | 0.0648 | 0.698 | -8.230 | 95.6 | 0.0087 | 0.95 | 39.4 | 0.097 |

The graph plotted between the healthy and Fatigue EMG signals is shown in the Fig. 3 below:

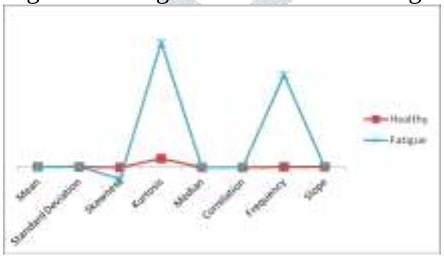


Figure 3.Statistical analysis of healthy and fatigue EMG signal

The graph plotted between the healthy Vs stimulated EMG is shown in the Fig 4. given below

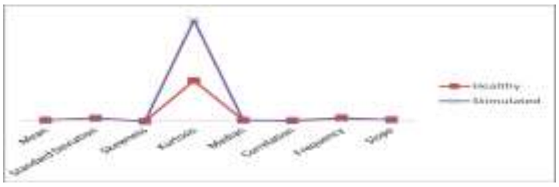

Figure 4. Statistical analysis of healthy and Stimulated EMG signal

The RMS values of healthy,fatigue and Stimulated EMG signals are tabulated in the Table 3 shown below

Table 3. RMS values of healthy,fatigue and Stimulated EMG signals.

| RMS Value / Subjects | Healthy EMG Signal( µV) | Fatigue EMG Signal( µV) | Stimulated EMG Signal( µV) |
|---|---|---|---|
| 1 | 43.5 | 120.9 | 80.25 |
| 2 | 56.7 | 328.4 | 153.26 |
| 3 | 37.9 | 580.7 | 253.21 |
| 4 | 64.8 | 848.6 | 489.35 |
| 5 | 52.2 | 259.6 | 126.58 |
| 6 | 68.32 | 108.32 | 240.25 |
| 7 | 45.36 | 369.58 | 196.45 |
| 8 | 63.24 | 598.36 | 300.45 |
| 9 | 58.36 | 794.45 | 165.32 |
| 10 | 50.32 | 365.2 | 209.65 |

These values are plotted below as follow

s

Figure 5. RMS values of healthy, fatigue and stimulated EMG signals

The graph plotted between the RMS values of normal ,Fatigue and stimulated EMG is shown in the Fig.5 above.

## IV. CONCLUSION

Thus the acquisition of EMG signals from ten healthy and fatigue persons each has been performed . A muscle stimulator circuit was also designed and stimulation was given to a subject and checked for tingling sensation.The statistical features of these signals are analyzed which showed a major difference in the average values of kurtosis and frequency from the healthy Vs fatigue EMG signals.The Kurtosis values of Stimulated signal is seen to be higher than the normal EMG signals. Then the RMS values of these signals are analyzed using which showed that the average RMS value of healthy muscle is lesser than 80µV .

## V. FUTURE WORK

In the previously described methods, many features including RMS were analyzed for different types of contractions for fatigue detection,but automatic fatigue detection was not achieved. .From the above results,it is seen that the obtained RMS values shows a better option inorder to fix an optimum threshold for automatic fatigue detection.

Further to the above discussions,yet an Arduino has to be programmed with these obtained values inorder to detect the presence of fatigue in EMG signals and also to give electrical stimulus for such conditions automatically. An additional feature can also be added to this prototype for visualising EMG in the display module.

## REFERENCES

[1]. Dr. A. A. Gurjar, Rhutuja Raut.2015.Bio-medical (EMG) Signal Analysis and Feature Extraction Using Wavelet Transform, International Journal of Engineering Research and Applications ,ISSN : 2248-9622, Vol. 5, Issue 3, ( Part -1) pp.17-19.

[2]. Shannon McCallum.2017.**Muscle fatigue, muscle recovery and how this knowledge applies to rock climbers,**The Duluth Journal of Undergraduate Biology,Vol 4.

[3]. Patrick E. Crago, J. Thomas Mortimer, And P. Hunter Peckham. 1980."Closed-Loop Control Of Force During Electrical Stimulation Of Muscle",IEEE Transactions On Biomedical Engineering, Vol.-27, No. 6.

[4].John M. Heasman, Timothy R. D. Scott,A.Vare, Ruth Y. Flynn, Claudia R. Gschwind, James W. Middleton, and Susan B. Rutkowski.2000.Detection of Fatigue in the Isometric Electrical Activation of Paralyzed Hand Muscles of Persons with Tetraplegia ", VOL. 8, NO. 3.

[5] Mert Ergeneci, Kaan Gokcesu, Erhan Ertan, and Panagiotis Kosmas.2017 An Embedded, Eight Channel, Noise Canceling, Wireless, Wearable sEMG Data Acquisition System With Adaptive Muscle Contraction Detection", IEEE Transactions On Biomedical Circuits And Systems.

[6] P. Strojnik, A. Kralj, And I. Ursic.1979. Programmed Six-Channel Electrical Stimulator for Complex Stimulation of Leg Muscles During Walking ,IEEE Transactions On Biomedical Engineering, Vol. Bme-26, No. 2.
[7] G. Robertson, G. Caldwell, J. Hamill, G. Kamen, and S. Whittlesey.2013. Research Methods in Biomechanics, 2nded.UnitedStates: Human Kinetics, Champaign, IL 61825–5076.
[8] T. Kamali, R. Boostani, and H. Parsaei.2014."A multi-classifier approach to MUAP classification for diagnosis of neuromuscular disorders," IEEE Trans. Neural Syst. Rehabil. Eng., vol. 22, no. 1, pp. 191–200.
[9] S. S. Nair, R. M. French, D. Laroche, and E. Thomas.2010.The application of machine learning algorithms to the analysis of electromyographic patterns from arthritic patients.IEEE Trans. Neural Syst. Rehabil. Eng., vol. 18, no. 2, pp. 174–184.
[10] Z. Song, S. Guo, and Y. Fu. 2011.Development of an upper extremity motor function rehabilitation system and an assessment system, Int. J. Mechatronics Autom., vol. 1, no. 1, pp. 19–28.
[11] T. Kamali, R. Boostani, and H. Parsaei.2014. A multi-classifier approach to MUAP classification for diagnosis of neuromuscular disorders," IEEE Trans. Neural Syst. Rehabil. Eng., vol. 22, no. 1, pp. 191–200.
[12] M. Nagaraju et al.2010.Circuit techniques for wireless bioelectrical interfaces, in Proc. Int. Symp. VLSI Des. Autom. Test, pp. 117–120.
[13] Y.Oonishi,S.Oh,andY.Hori.2010.A new control method for power-assisted wheelchair based on the surface myoelectric signal, IEEE Trans. Ind. Electron., vol. 57, no. 9, pp. 3191–3196.
[14] X. Zhang, X. Chen, Y. Li, V. Lantz, K. Wang, and J. Yang.2011. A framework for hand gesture recognition based on accelerometer and EMG sensors, IEEE Trans. Syst., Man, Cybern.A, Syst. Humans, vol.41,no.6,pp.1064– 1076.
[15] M. Khezri and M. Jahed.2007.Real-time intelligent pattern recognition algorithm for surface EMG signals,Biomed. Eng. Online, vol. 6, no. 1, pp. (1-12)–(3-12).
[16]S.Benattietal.2015.A versatile embedded platform for EMG acquisition and gesture recognition, IEEE Trans. Biomed. Circuits Syst., vol. 9, no. 5, pp. 620–630.
[17] O. Levin, J. Mizrahi, M. Gornish, and E. Isakov.2000.Muscle strength and geometrical changes in a paralysed muscle following FES, Hong Kong Physiother. J., vol. 18, no. 1, pp. 3–11.
[18] A. E. Scremin, L. Kurta, A. Gentili, B. Wiseman, K. Perell, C. Kunkel, and O. Scremin.1999.Increasing muscle mass in spinal cord injured persons with a functional electrical stimulation exercise program 1, Arch. Phys. Med. Rehabil., vol. 80, no. 12, pp. 1531–1536.
[19] K. W. Eric Cheng, Yan Lu, Kai-Yu Tong, A. B. Rad, Daniel H. K. Chow, And Danny Sutanto, Senior Member, IEEE.2004.Development Of A Circuit For Functional Electrical Stimulation, IEEE Transactions On Neural Systems And Rehabilitation Engineering , Vol. 12, No. 1 .
[20]. Sharique Rahman, Shahanaz Ayub.2015. Microcontroller basedMuscle Stimulator, International Journal of Advanced Research in Computer and Communication Engineering,Vol 5.