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Analysis of Difference in Electrical Activity in the Gastrocnemius Muscles of Both the Legs during Step-Up & Skipping Exercises

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Abstract: Electromyography (EMG) is a real time based experimental technique for assessment and recording a series of electrical signal that arise from body muscles and motor units. Different body exercises produce different electrical activity in body muscles. From the analysis of these electrical activities produced in different muscle, the degree of strain in concerned muscle can be interpreted and thus comparative benefit of the exercises can be commented. The purpose of this study is to determine the EMG activity of the Gastrocnemius muscle during step-up and skipping exercise. For the purposed research analysis a total of 18 participants were recruited and study was conducted using the EMG device (Trigno EMG wireless system, model: SP-W02A-1849 DELSYS, USA).
The results show that for Gastrocnemius left leg muscle there is significant difference between the RMS values calculated for the EMG activity obtained from the different exercises with p-value being 0.011. Also for Gastrocnemius right leg muscle there is no significant difference in the EMG activity for the different exercises with p-value being .092. From inferential statistics it can be concluded that more electrical activity is produced during step-up exercise in the mentioned left leg muscle.

Keywords: Biomedical Signal Processing, Electromyography, RMS values, Gastrocnemius muscle, Statistical Analysis.

I. Introduction

The Electromyography is a graphical recording of electrical activity in the skeletal muscles. Transmission of the action potentials along the fibre leads to change in the membrane potential, these change is measured by EMG. This allows for the measurement of the change in the membrane potential as the action potentials are transmitted along the fibre. The study of muscle activity during a particular exercise can provide insight into which muscles are active and when the muscles initiate and cease their activities [1].While doing exercise a movement in muscles produce tension and which movements generate more or less tension from a particular muscle or muscle group it can be easily identified by EMG. Along with the diagnosis and tracking of pathological state of the neuromuscular system EMG can also use clinically to access nerve conduction velocities and muscle response in conjunction [2].There are two ways to record the electromyogram, one is the invasive by using needle electrodes and non-invasive by applying the surface electrodes. It is the universal truth that the best way to keep our body and mind in top shape is to be physically active, for this the best this is exercising. Exercising will not only change your lifestyle however will also have some fascinating body changes and benefits. It makes the body pump more blood to the muscles. This can raise the blood flow, which is beneficial for your brain. We all know that exercise is good for us, but we tend to don't understand as much about the molecular mechanisms, the processes throughout the cells of the body, that benefits us when we exercise. Therefore in this study we selected most frequent exercises which are simple and easy to do anywhere [3].

The purpose of this experiment is to identify the biomechanical response of Gastrocnemius muscle during various exercises. We are extracting Root Mean Square (RMS) as a statistical feature for EMG analysis of this muscle and these features for step-up and skipping exercise [4]. Shapiro-Wilk test is used to check normality following which Friedman's test is conducted to check the statistical significance between the data of both the muscles obtained for each delivery. SPSS Statistics software is used for conducting both the tests.

II. METHODOLOGY

A. Participants

A total of 18 male and female participants for the purposed study work were recruited for the purposed study work**.** All the participants were given a briefing about the Exercise experiments to be conducted through their help and all of them were informed about the statistical analysis to be done after acquiring the EMG signals from the muscles of the Gastrocnemius muscle permissions every participant gave their consent. Fig 1 shows one of the sensors used on the

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muscle while figure 2 shows the Trigno EMGworks wireless system. The mean and standard deviation (mean $\pm$ SD) of the demographics of the participating as follows: n=18, age (years) = 25.18±2.43, weight (kg) = 68.94±6.18, and height (cm) = 174.05±4.14.

B. Study Design and Sensor Positioning

The experimental design for conducting the purposed study took place in the Biomedical Signal Processing Laboratory of the Madhav Institute of Technology & Science, Gwalior. The experimental study was conducted on different days within the time frame of 3-4 weeks as per the availability of the participants. To understand the details about the these exercises step-up, skipping and few other things regarding how the signals will be recorded from their muscles each participant was given an orientation session.

Fig. 1 4- channel Ag/AgCl electrodes used on the sensor

Fig. 2 Trigno EMG wireless system with model SN: SP-W02A-1849

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Fig. 3 Sensors placed on concerned Gastrocnemius muscles during step-up

Fig .4 Sensors placed on concerned Gastrocnemius muscles during skipping

C. Data Acquisition and Analysis Gastrocnemius

After each sensor was assigned a channel in the Trigno EMGworks Acquisition software gain value of 300 was given to each channel in the hardware section of the software. A 10 seconds window was selected in both the channels of afore mentioned software for the purpose of acquiring the EMG raw signals from both the sensors placed on the respective muscles of the participants. For the purposed study only the signals of left or right leg Gastrocnemius muscle during the 2 different types of exercises i.e. step up exercise and skipping exercise were acquired. Figure 3 & 4 shows the sensor placement on the concerned calf-leg muscle while performing the respective exercises. After EMG signals were acquired for each participant the raw data in the respective channel was saved for further analysis using the Trigno EMGworks Analysis software. Root Mean Square (RMS) is taken as the EMG variable for the purposed study. For marking the EMG data during each exercise in the channel window of the mentioned software, pink and yellow cursors were used. The RMS values are than easily calculated for the raw data in between these cursors.

EMG signals, for both leg concerned muscles of one of the participants during the step-up exercise are shown in figure 5a & 5b and 6a &6b.

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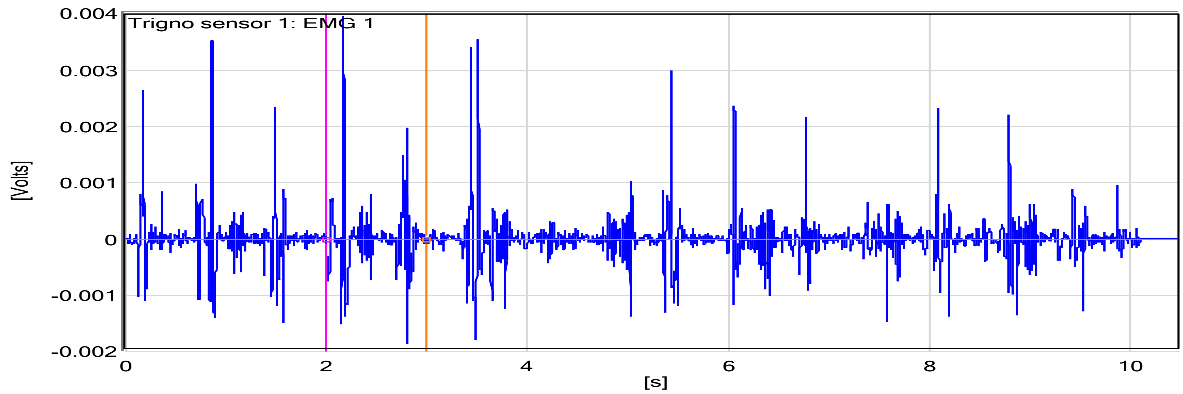

Fig. 5 (a) EMG raw-data obtained for Left Leg Gastrocnemius muscle of one of the participant during the Step-up exercise

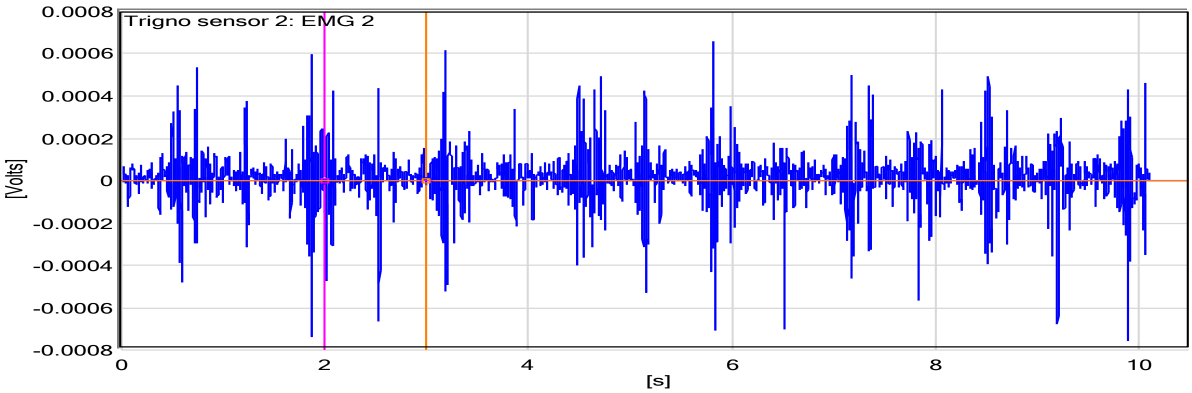

Fig. 5 (b) EMG raw-data obtained for Right Leg Gastrocnemius muscle of one of the participant during the Step-up exercise

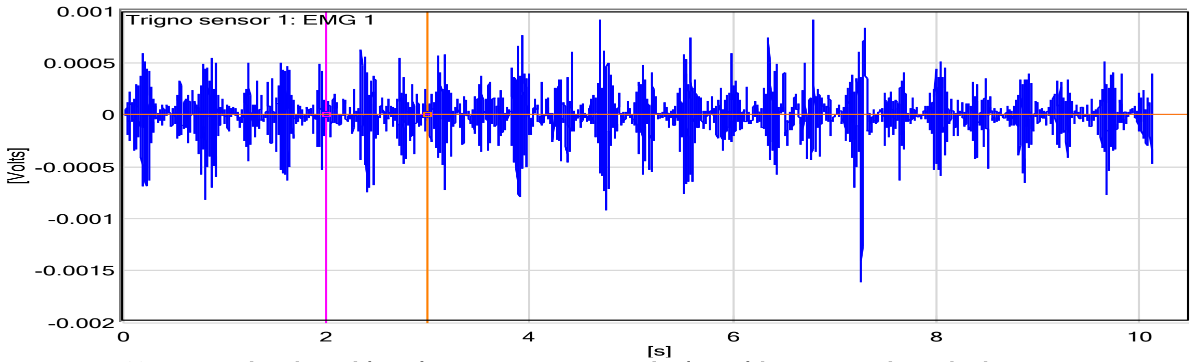

Fig. 6 (a) EMG raw-data obtained for Left Leg Gastrocnemius muscle of one of the participant during the skipping exercise

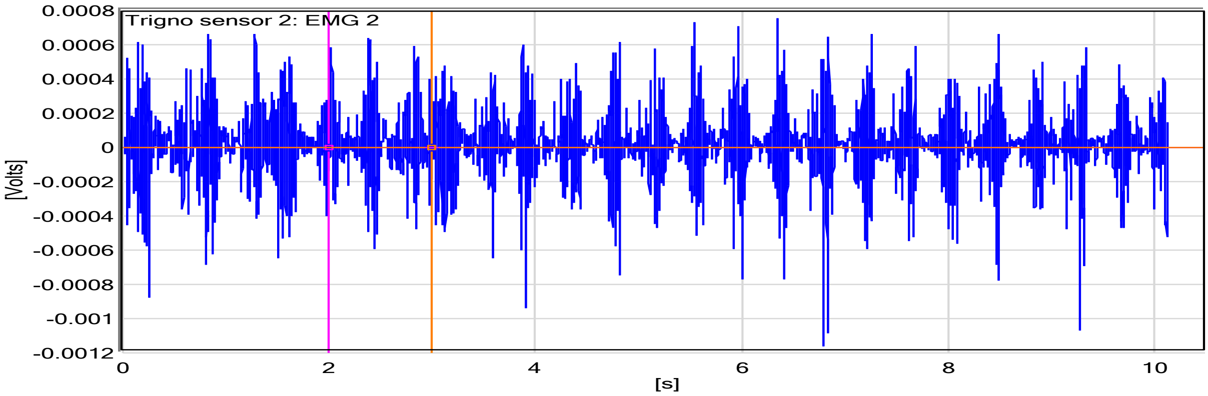

Fig. 6 (b) EMG raw-data obtained for Right Leg Gastrocnemius muscle of one of the participant during the skipping exercise

In figures EMG raw-data x-axis represents time-scale in seconds while y-axis represents the EMG magnitude in volts.

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III. Statistical Analysis

The purpose of the Statistical Analysis is to determining the significant difference between data of both leg muscles for each exercise, i.e., to analyse the difference in the electrical activity between both leg Gastrocnemius muscles once while exercises the Step-up exercise and skipping exercise. To find if the data for both leg muscles differ significantly or not for each exercise first of all test we need RMS Values, RMS values of EMG data obtained during the respective exercises are shown in table 1. This data is useful in knowing the significant difference between the electrical activities of both leg Gastrocnemius muscles. Shapiro-Wilk test is used to check normality following which Friedman's test is conducted to check the statistical significance between the data of both the muscles obtained for each delivery. IBM SPSS Statistics software is used for conducting both the tests. For the statistical analysis the significant value was considered at $p < 0.05$.

TABLE I
RMS VALUES OF THE EMG DATA OBTAINED FOR BOTH LEG GASTROCNEMIUS MUSCLES DURING EXERCISE

Participants	RMS values of EMG Gastrocnemius Muscles (in volts) for both Legs			
	Left Leg		Right Leg	
	Step-up exercise	Skipping exercise	Step-up exercise	Skipping exercise
Participant 1	0.035174	0.030187	0.058075	0.020784
Participant 2	0.156892	0.060128	0.101913	0.060153
Participant 3	0.296936	0.018759	0.104348	0.051834
Participant 4	0.026328	0.018756	0.036118	0.020354
Participant 5	0.153096	0.021697	0.081856	0.047013
Participant 6	0.030526	0.032389	0.031318	0.025107
Participant 7	0.063506	0.023513	0.062225	0.054992
Participant 8	0.026680	0.022988	0.034916	0.034833
Participant 9	0.023406	0.021131	0.086029	0.061687
Participant 10	0.066781	0.027654	0.060827	0.027573
Participant 11	0.033946	0.031299	0.034195	0.022909
Participant 12	0.021355	0.028147	0.018666	0.026186
Participant 13	0.044483	0.033466	0.039461	0.051304
Participant 14	0.050268	0.044068	0.065514	0.020047
Participant 15	0.036218	0.030948	0.056062	0.039674
Participant 16	0.031427	0.035734	0.093774	0.048221
Participant 17	0.105403	0.057305	0.051325	0.088050
Participant 18	0.122715	0.054665	0.106074	0.050672

IV. Results

This section determining the statistical difference between the data of both leg muscles obtained during the different type exercises. Table IIIII shows the results of the Shapiro-Wilk test.

TABLE IVV
RESULT OF THE SHAPIRO-WILK TEST OBTAINED FOR TWO EXERCISE OF BOTH LEG MUSCLES

Different Leg Muscles	Gastrocnemius left leg		Gastrocnemius right leg	
Exercise	Step-up	Skipping	Step-up	Skipping
p-value	.000	0.013	.097	.011

The normality test clearly shows Non-Parametric test like the Friedman's test is required to check for the Statistical difference for the concerned study.

Table VIVIIVIII shows the results of the Friedman's test and also shows other descriptive analysis done for each exercise of both the legs. To indicate whether there is a significant difference between the data for the Legs muscle or not the p-values obtained from the test are used.

TABLE IXXXI
DESCRIPTIVE ANALYSIS AND RESULT OF THE FRIEDMAN'S TEST DONE FOR DATA OBTAINED FROM RESPECTIVE MUSCLES

Muscles	Exercise	Mean ± Std. Deviation	p-value
Gastrocnemius left leg	Step-up	.07361889± .071069918	.011
	Skipping	.03293522± 012966573	
Gastrocnemius right leg	Step-up	.04237200± .019590799	.092
	Skipping	.03896628± .020586642	

DISCUSSION

To analyse the EMG signals Root Mean Square (RMS) values are often used. In this section the findings of previous study concluding that RMS values obtained for EMG signals are in direct relation with the load on the muscles [9] is used for relating the EMG activity with the strain on the muscles and this relationship is used to tell which exercise will benefit more for the concerned muscle as concluded in the following section. Also, in this section the findings of the statistical analysis done on the RMS values, obtained from the EMG data (for the duration of the exercises) are discussed.

For **Gastrocnemius left leg** muscle, considering the comparative statistical analysis, the Friedman's test clearly suggest that there is a significant difference between the EMG data obtained while performing the respective exercises with **p-value** being **0.011**.

For **Gastrocnemius right leg** muscle, the **p-value** obtained from the Friedman's test is **0.92** which clearly shows that there is no significant difference between the data obtained while performing both the exercises for the concerned muscle.

CONCLUSION

From the findings of statistical analysis it can be concluded that the electrical activity produced varies significantly for the Gastrocnemius left leg muscle. From the inferential statistics it can be easily observed that more electrical activity, and thus more strain, is produced during the step-up exercise in comparison with that produced during skipping exercise for the mentioned left leg muscle which shows that for the selected set of population of the participants step-up exercise is more beneficial for the stated left leg muscle. Also from the findings of the analysis it can be concluded that there is not a significant difference in the EMG activity produced in the Gastrocnemius right leg muscle during either of the exercises, thus we can't comment that which exercise will benefit more, for the chosen right leg muscle, considering the selected set of statistical population.

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