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Study the role of muscles under different loading conditions using EMG analysis of lower extremities

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ABSTRACT

As we know, Electromyogram (popularly known as the EMG) is the measure of the biological potentials associated with muscle activity. These potential are measured at the surface of body near a muscle response or electrical activity in response to nerve's stimulation of muscle, to detect for neuromuscular abnormalities. Due to stochastic nature of EMG signal, it becomes difficult to quantify and interpret the procured signal. The aim of our study is to analyze the EMG signal and understand the role and significance of different muscle groups while performing different exercises which would provide us knowledge about the dominant force producing muscles/ muscles groups during a particular test procedure. Although extensive work has been carried out to understand this phenomenon but due to high variations in signal being collected no conclusive evidence are available as yet. The results from these studies may be employed in aiding the disabled and developing smart devices for them in the near future.

INTRODUCTION

Electromyogram (popularly known as the EMG) is the measure of the biological potentials associated with muscle activity. These potential are measured at the surface of body near a muscle response or electrical activity in response to nerve's stimulation of muscle, to detect for neuromuscular abnormalities. The EMG signal is stochastic (random) in nature and can be represented by a Gaussian distribution function. The amplitude of signal ranges from 0 to 10 mV (peak to peak) or 0 to 1.5 mV (rms). The usable energy of signal is limited to 0 to 500 Hz frequency range, with dominant energy being 50 to 150 Hz range. When detecting and recording the EMG signal, there are two main issues of concern that influence the fidelity of the signal. The first is signal to noise ratio (SNR) and the other is distortion of the signal. To obtain useful information from EMG signal it is required that any detecting and recording device processes the signal linearly [1, 2]. The signal should not be clipped and unnecessary filtering is not performed. This is possible by using advanced Biopac MP 150 version available in our lab. The system provides built in signal processing tools specifically designed for biological signal processing and hence aids in signal analysis.

Objective of the work

1. To analyze the muscle activity of lower extremity under different conditions.
2. To compare the muscle response of different persons under varying muscle loading conditions.
3. To analyze the muscle activity during various exercises like resting position, normal walking, fast walking, swing, crouch etc. and then predict the function of each muscle and which muscles are responsible for maximum contraction and force production during a particular type of exercise.
4. To analyze and interpret the results obtained using different signal processing techniques available.
5. The results from these studies may be employed in aiding the disabled and developing smart devises from them in the near future.

MATERIALS AND METHODS

The experiments are performed on following muscles of lower extremities. These are namely as follows:
1. Hamstring
2. Soleus
3. Gluteus maximus
4. Quadriceps
5. Gastrocenimius
6. Biceps Femoris
7. Iliopsoas
8. Tibia anterior [1, 3, 4, 5]

The aim of our study is to analyze the muscle activity of lower extremity under different conditions for persons of diverse background and fields. For this extensive literature survey was carried out. The available literature suggests and provides information about the muscle groups involved but does not provide concrete details as to significant muscle groups involved for a particular exercise protocol. To analyze this muscle activity[6,7,8] during various exercise procedures is undertaken like resting position, normal walking, fast walking, swing, crouch etc. and prediction of the function of each muscle and which muscle is responsible for maximum contraction and force production during a particular type of exercise[9,10,11] is studied. To analyze and interpret the results different signal processing tools available in Biopac MP 150 software are employed.

5.1 Data Acquisition

To record the EMG data, we are using BIOPAC MP 150 system. MP 150 is a data acquisition system which is used for taking biophysical measurements. We are using SS2L electrode lead set because they are entirely shielded configuration and allow high resolution recording of biopotential. One end of SS2L cable has a smart sensor connector which is connected to MP 150 unit and other end divides into 3 smaller cables. One end of each cable is clamped into electrode which is placed on body surface. The EMG signal is carried out by the electrode to MP 150 where it get converted to electrical signal and displayed on CRT or monitor. We are taking reading of 2 minutes of which 1 minute is for exercise and other for resting to estimate muscle fatigue, providing us with significant changes.

5.2 Data Analysis

It is not possible to recommend a single method of recording and processing EMGs. There are several standard types of procedures; however, each researcher selects his or her own methods of data processing based on the actual goals of the study and the researcher's own imagination. Three operations are frequently used in processing a surface EMG.

1. FWR (Full Wave Rectification).
2. RMS (Root Mean Square).
3. FWM (Frequency Weighted Mean).

In time domain two parameters are frequently used Full Wave Rectification and Root Mean Square, while Frequency weighted mean is employed in frequency domain.

5.2.1 Full Wave Rectification

This technique involves turning of all negative values of signal being measured into positive values of equal magnitude. The purpose is to get quantified estimate of the EMG signal. The action potentials are very fast events with typical times of potential change of about a few milliseconds. So a band pass filter in range 30-500 Hz is used which cuts off all the frequencies below 30 Hz and above 500 Hz. Raw EMG signal is squared by using BIOPAC System Software. The desired segment of the wave is selected and then we perform rectification of the same for better signal to noise fidelity. To consider the fatigue factor and for proper signal representation we take integral values of overlapping bins of 20 seconds each. Integrating a Squared EMG will result in an average magnitude of the activity over time of integration. Integration of a squared wave gives a value reflecting total current between the electrodes as well as total resistance hence providing us with integral values [2]. In order to compare integral electromyography measures across subjects, one needs to normalize the integrals. Since, this phenomenon is already provided in Biopac Software hence it is taken care of.

5.2.2 Root Mean Square

The Mean absolute value is the computer calculated equivalent of the averaged rectified value (ARV). The MA value is known as a time domain variable because it is measured as a function of time. It represents the area under the EMG signal once it has been rectified i.e. all negative values have been made positive. The MA value is used as a measure of the amplitude of the EMG signal like root mean square (RMS). The RMS is often preferred over the MA value because it provides a measure of the power of the EMG signal while the MA value does not [2].

RMS or Root Mean Square is a technique for rectifying the RAW signal and converting it to an amplitude envelope, which is easier to view. The rectification process converts all the numbers into positive values rather than positive and negative. The Root Mean Square (RMS) is considered to be the most meaningful, since it gives a measure of the power of the signal. It represents the square root of the average power of the EMG signal for a given period of time [2, 4]. In this, RMS wave of data is analyzed using Biopac software and then mean value is taken.

The above two signal processing techniques of analysis make use of the EMG signal in the time domain, as it was sampled in its original form. The third category of EMG signal analysis relies on the frequency domain, which is discussed below.

5.2.3 Frequency Weighted Mean

In FWM, bins of definite time- frame are taken and then Power Spectrum Density is calculated for this, we calculate both integral and mean values. We achieve the best results with this technique as it is applying both time and frequency domain. Up to Now, we have completed our study and analysis of 5 subjects by using first 2 methods i.e. FWR and RMS methods. We would be further conducting studies on 5 to 7 subjects for generalizing our results. We would also be using our third technique of signal analysis which would give us more significant results. The results will also be simultaneously verified and validated using MATLAB toolbox and other signal processing techniques to determine the accuracy of our results.

Observations

All subjects are asked to undergo weight endurance training to build stamina to perform these exercises comfortably for a period of 2 to 3 weeks. The exercise duration is 2 minutes, 1 minute of exercise and 1 minute of resting to determine muscle fatigue factor. We achieve following graphs for the Full Wave Rectification technique for various physical activities.

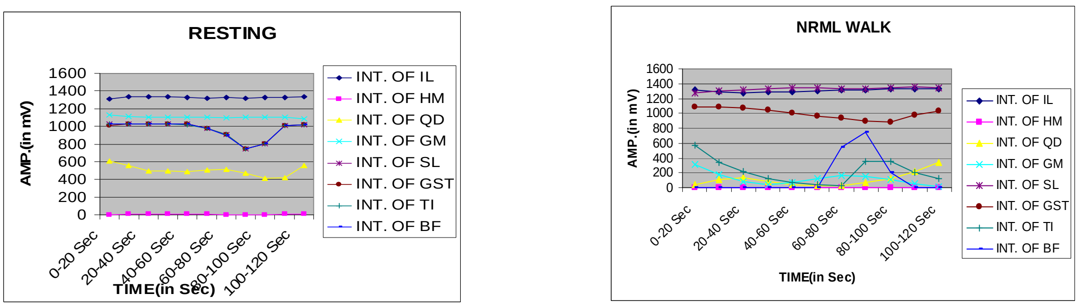

Figure 1: EMG recorded Data for Resting and Normal Walking

In the first exercise position (resting) subject is asked to stand in a relaxed position. The person should not be in contact with any interfering source of noise to cause signal distortion. The graph shows Ileopas and gluteus medius as more active than other muscles. In the second exercise protocol (Normal walking) subject is asked to have a stroll of normal walk for a minute and then is asked to rest for another minute. The total exercise time is 2 minutes. The soleus, GST and IL are more activated compared to other muscles. TI and BF show major fluctuations.

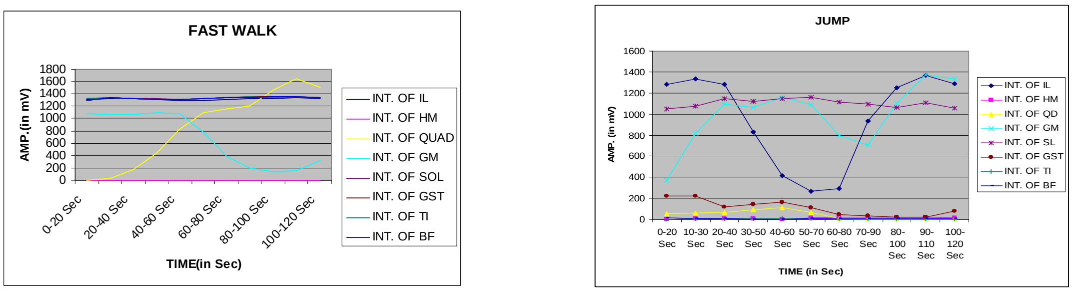

Figure 2: EMG recorded Data for Fast Walk and Jump

In the first exercise subject is asked to move fast for a minute, to determine which muscles get activated more compared to normal walking. In the subsequent exercise subject is asked to jump to and fro for a minute while remaining at approximately the same position.

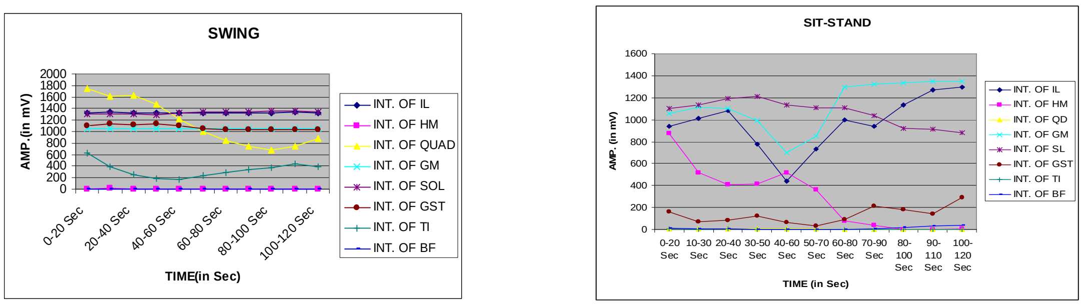

Figure 3: EMG recorded Data for Swing and Sit-Stand

In the first exercise subject is asked to lift the required leg (rite or left) at an angle of 90 degree from the ground while the other leg is on ground. In the second exercise subject is asked to make oscillatory motions up-down for a minute.

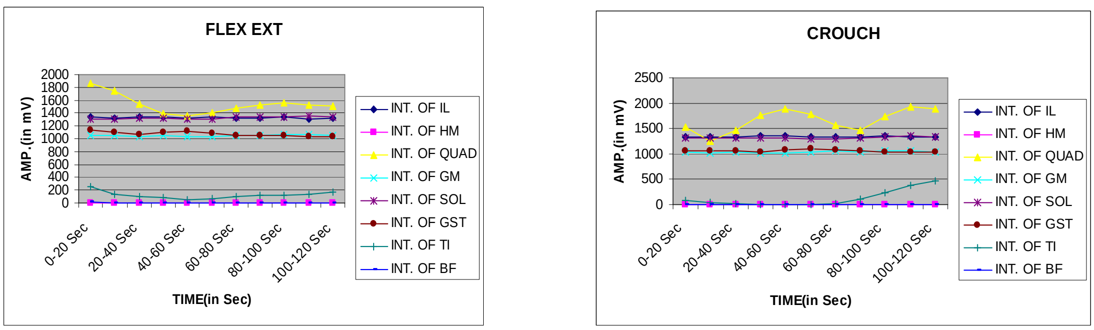

Figure 4: EMG recorded Data for Resting and Normal Walking

In the first exercise subject is asked to move the required leg back and forth while the other leg is on ground. In the subsequent exercise subject is asked to sit in a crouch position without any support for a minute. This appears while sitting on a chair without any actual chair placed underneath. This exercise caused greatest uncomforting to the subjects and hence results were also significant. From these graphs we obtain results of left leg by full wave rectification technique and similarly for other subjects we are able to conclude tables 1 and 2 for both the legs (tables shown at the last). We also obtain graphs of physical activities for the second technique i.e. Root Mean Square and conclude tables 3 and 4 for both the legs (tables shown at the last).

Table 1 : Compiled table for left leg analysis by square wave method

		LEFT LEG ANALYSIS BY SQUARE WAVE METHOD						
SUBJECTS/ EXERCISES	RESTING	NORMAL WALKING	FAST WALKING	SIT-STAND	JUMPING	SWING	FLEX-EXTEN.	CROUCH SITTING
GAGAN	QUAD	TI	TI	SOL	IL	TI	TI	TI
	TI	IL	IL	BF	TI	IL	IL	IL
	IL	HM	GM	TI	HM	SOL	BF	BF
	GM	GST	HM	GST	QUAD	BF	HM	HM
	SOL	GM	SOL	IL	SOL	GAST	GM	GAST
DIVENDER	IL	IL	TI	TI	TI	QUAD	QUAD	QUAD
	GM	SOL	IL	IL	IL	IL	IL	IL
	SOL	GST	GM	GST	BF	SOL	SOL	SOL
	TI	TI	QUAD	SOL	SOL	GAST	GAST	GAST
	GST	GM	SOL	GM	GST	GM	GM	GM
			BF					
GULIA	IL	SOL	IL	HM	QUAD	QUAD	IL	IL
	GM	GST	SOL	QUAD	GST	IL	QUAD	QUAD
	GAST	QUAD	GM	IL	SOL	HM	GST	GM
	QUAD	HM	GST	GM	TI	GM	HM	TI
	SOL	IL	HM	TI	HM	TI	SOL	GST
			QUAD		IL	SOL		
						GST		
SACHINDEEP	IL	IL	SOL	SOL	IL	GM	GM	GM
	GM	SOL	GM	GM	SOL	IL	IL	IL
	SOL	GM	IL	IL	GM	SOL	SOL	SOL
	GST	GST	GST	HM	GST	GST	GST	GST
	HM	HM	QUAD	GST	QUAD	HM	HM	HM
ANIL	SOL	TI	QUAD	EXERCISE	IL	QUAD	IL	GST
	GST	QUAD	TI	NOT DONE	TI	IL	TI	IL
	TI	GST	GM		GST	GM	GM	GM
	GM	GM	IL		SOL	SOL	QUAD	QUAD
	IL	IL	GST		QUAD	TI	GST	TI
			SOL		GM	GST	SOL	SOL

Table 2: Compiled Table for Right Leg Analysis by Square Wave Method

		RIGHT LEG ANALYSIS BY SQUARE WAVE METHOD						
SUBJECTS/ EXERCISES	RESTING	NORMAL WALKING	FAST WALKING	SIT-STAND	JUMPING	SWING	FLEX-EXTEN.	CROUCH SITTING
GAGAN	GM	IL	IL	IL	IL	IL	IL	IL
	IL	SOL	SOL	QUAD	TI	GM	SOL	SOL
	BF	GST	GST	GM	HM	SOL	QUAD	GM
	SOL	BF	GM	SOL	GST	GST	GST	QUAD
	GST	TI	QUAD	GST	BF	QUAD	GM	GST
	TI	GM		TI	GM			
DIVENDER	IL	IL	QUAD	QUAD	QUAD	IL	IL	IL
	GM	QUAD	IL	IL	IL	QUAD	QUAD	GM
	SOL	GM	SOL	GM	SOL	GM	GST	SOL
	TI	SOL	GM	SOL	TI	SOL	SOL	GST
	QUAD	TI	GST	GST	GST	GST	GM	QUAD
		GST	TI	TI			HM	
GULIA	IL	SOL	SOL	QUAD	IL	QUAD	HM	GST
	QUAD	GST	GST	IL	SOL	IL	QUAD	TI
	GM	IL	HM	HM	GST	TI	GST	IL
	SOL	GM	IL	BF	TI	SOL	SOL	SOL
	GST	TI	GM	GM	QUAD	GM	IL	HM
	TI	HM		SOL		GST		BF
SACHINDEEP	IL	QUAD	QUAD	QUAD	QUAD	QUAD	IL	IL
	GM	IL	IL	IL	IL	IL	QUAD	GM
	SOL	GM	SOL	GM	SOL	GM	SOL	SOL
	TI	SOL	TI	GST	TI	GST	GST	GST
	QUAD	TI	GM	TI	GM	SOL	GM	QUAD
		GAST	GAST		GST			
ANIL	GM	TI	GM	EXERCISE	TI	QUAD	QUAD	QUAD
	IL	GM	TI	NOT DONE	IL	GM	IL	GM
	QUAD	IL	IL		QUAD	IL	TI	IL
	TI	QUAD	SOL		GM	TI	GM	TI
	GST	SOL	GST		GST	GAST	BF	GST
	BF	GST	QUAD		SOL	SOL	SOL	SOL
							GST	

Table 3: Compiled Table for Left Leg Analysis by Root Mean Square Method

		LEFT LEG ANALYSIS BY RMS METHOD						
SUBJECTS/ EXERCIES	**RESTING**	**NORMAL WALKING**	**FAST WALKING**	**SIT-STAND**	**JUMPING**	**SWING**	**FLEX.-EXTEN.**	**CROUCH SITTING**
GAGAN	QUAD	TI	TI	TI	IL	TI	TI	TI
	TI	GM	IL	IL	TI	IL	IL	IL
	IL	IL	GM	SOL	HM	SOL	BF	BF
	GM	HM	SOL	BF	GM	GST	HM	HM
	SOL	GST	HM	GM	BF	BF	GM	GST
			BF	HM	GST	GM		
DIVENDER	QUAD	IL	QUAD	IL	IL	IL	TI	IL
	IL	GM	BF	GST	SOL	GM	QUAD	GM
	GST	SOL	GM	SOL	TI	SOL	GM	GST
	SOL	QUAD	TI	TI	QUAD	GST	GST	SOL
	GM	BF	IL	QUAD	GST	TI	IL	TI
	TI	HM	SOL					QUAD
GULIA	IL	SOL	SOL	IL	GST	IL	QUAD	IL
	GM	GST	GST	HM	SOL	HM	GST	QUAD
	GST	QUAD	GM	QUAD	HM	QUAD	HM	GM
	SOL	HM	QUAD	TI	IL	TI	TI	GST
	QUAD	TI	HM	GST	QUAD	GST	SOL	SOL
		GM	IL		TI	SOL	IL	
SACHINDEEP	IL	IL	SOL	GM	SOL	GM	GM	IL
	SOL	SOL	GM	IL	IL	IL	IL	GM
	GM	GM	IL	SOL	GM	SOL	SOL	SOL
	GST	GST	GST	GST	GST	GST	GST	GST
	HM	HM	QUAD	HM	QUAD	HM	HM	HM
	BF	BF	BF	BF				
ANIL	SOL	QUAD	IL	EXERCISE	TI	QUAD	IL	IL
	GST	GST	TI	NOT DONE	IL	GM	TI	GM
	TI	TI	QUAD		GM	IL	GM	QUAD
	GM	GM	GM		GST	SOL	QUAD	GST
	IL	IL	SOL		QUAD	GST	SOL	TI
	QUAD	SOL			SOL	TI		

Table 4: Compiled Table for Right Leg Analysis by Root Mean Square Method

		RIGHT LEG ANALYSIS BY RMS METHOD						
SUBJECT/ EXERCISES		**NORMAL WALKING**	**FAST WALKING**	**SIT-STAND**	**JUMPING**	**SWING**	**FLEX-EXTEN.**	**CROUCH SITTING**
GAGAN	IL	IL	IL	IL	IL	IL	IL	QUAD
	GM	SOL	GM	GM	TI	GM	QUAD	IL
	SOL	GST	SOL	QUAD	HM	QUAD	GM	GM
	GST	TI	GST	SOL	GM	SOL	GST	GST
	QUAD	QUAD	QUAD	GST	BF	GST	SOL	SOL
	TI	BF	TI	TI	GST	TI	TI	TI
DAVENDER	IL	IL	IL	IL	IL	IL	IL	IL
	SOL	GM	QUAD	QUAD	QUAD	QUAD	QUAD	SOL
	GM	QUAD	GM	GM	SOL	GM	GM	GST
	QUAD	SOL	SOL	SOL	TI	SOL	GST	GM
	TI	TI	GST	GST	GM	GST	SOL	QUAD
		GST		TI	GST			
GULIA	IL	TI	SOL	QUAD	IL	QUAD	HM	QUAD
	QUAD	SOL	GST	IL	SOL	IL	QUAD	IL
	GM	IL	HM	BF	GST	TI	GST	GM
	SOL	HM	TI	HM	TI	SOL	BF	TI
	GST	GST	IL	GST	QUAD	GM	SOL	SOL
	TI	GM	GM	GM	HM	GST	IL	GST
			BF	SOL	BF	BF		
SACHINDEEP	GM	SOL	IL	GM	GM	GM	GM	GM
	SOL	GM	SOL	GST	IL	IL	SOL	SOL
	GST	GST	GST	SOL	GST	GST	IL	IL
	IL	IL	GM	HM	SOL	SOL	GST	GST
	QUAD	QUAD	HM	IL	QUAD	QUAD	BF	BF
			BF	QUAD		HM	TI	TI
ANIL	IL	TI	GM	EXERCISE	TI	QUAD	QUAD	QUAD
	GM	GM	IL	NOT DONE	IL	GM	IL	TI
	QUAD	IL	GST		QUAD	TI	GM	GM
	GST	GST	TI		GM	GST	SOL	IL
	TI	QUAD	SOL		SOL	IL	GST	GST
	SOL	SOL	QUAD		GST	SOL	BF	SOL
							TI	

CONCLUSION

By comparing the data obtained from above mentioned techniques we are able to conclude following results for the different physical activities for both the legs. The color coding adopted in our study may be explained as follows:
For blocks indicating PINK: - Muscle active in all subjects during a particular exercise protocol.
For blocks indicating YELLOW: - Muscle active in 1 subject less than Pink Subjects.
For blocks indicating GREEN: - Muscle active in 1 subject less than Yellow Subjects.
For blocks indicating WHITE: - With More subjects this will be further validated.

Conclusion for left leg analysis
As per results compiled, initially the most active muscles are Illioapas, Gluteus Maximus, Soleus, and Gastrocnemius. Quadriceps and Tibias Anterior show activity but their function is to be verified further. During normal walking, the most active muscles is to be verified while in fast walking the most active muscles are Illioapas, Soleus, Gluteus Maximus, Quadriceps. The function of Tibias Anterior, Gastrocnemius is yet to be verified. The most active muscles during jumping are Illioapas, Soleus, Quadriceps, Gastrocnemius and Tibias Anterior. The function of Gluteus Maximus is yet to be verified. In Swing phase the most active muscles are Illioapas, Soleus, Gastrocnemius, Gluteus Maximus, and Tibias Anterior. The function of Quadriceps is yet to be verified. In Sit-Stand the most active muscles are Illioapas, Soleus, Gastrocnemius and Tibias Anteriro. The function of Gluteus Maximus, Hamstrings is yet to be verified. In Flexion-Extension the most active muscles are Illiopas, Gluteus Maximus and function of other most active muscles is to be verified. While in Crouch the most active muscles are Illioapas, Gastrocnemius and Gluteus Maximus. The function of Quadriceps, Tibias Anterior and Soleus is yet to be verified.

Conclusion for right leg analysis
Initially the most active muscles are Illioapas, Gluteus Maximus, Soleus, Tibias Anterior, and Quadriceps. The function of Gastrocnemius is yet to be verified. In Normal Walking the most active muscles are Illioapas, Gluteus Maximus, Soleus, Tibias Anterior and Gastrocnemius. The function of Quadriceps is yet to be verified. While in Fast Walking the most active muscles are Illioapas, Soleus, Gluteus Maximus and Gastrocnemius. The function of Tibias Anterior, Quadriceps is yet to be verified. During Jumping the most active muscles are Illioapas, Soleus, Gastrocnemius, Tibias Anterior and Quadriceps. The function of Gluteus Maximus is yet to be verified. In Swing the most active muscles are Illioapas, Soleus, Gastrocnemius, Gluteus Maximus and Quadriceps. The function of Tibias Anterior is yet to be verified**.** During Sit-Stand the most active muscles are Illioapas, Soleus, Gastrocnemius, Gluteus Maximus, and Quadriceps. The function of Tibias Anterior is yet to be verified. In Flexion-Extension the most active muscles are Illioapas, Gluteus Maximus, Gastrocnemius, Quadriceps and Soleus. The function of Tibias Anterior and Biceps Femoris is to be verified. While in Crouch the most active muscles are Illioapas, Gastrocnemius, Gluteus Maximus, Soleus and Quadriceps. The function of Tibias Anterior is yet to be verified.

Future Aspects
We have done the recording and analysis of EMG data of 5 subjects. By applying different EMG signal processing techniques for interpreting our results as mentioned above we have analyzed

the data and drawn comparative tables. Till now, we have done analysis by using two methods i.e. full wave rectification and root mean square. Now the future aspects of our work are:-

1. Data acquisition of 5-7 more subjects, total subjects to be included in our study 10-12 subjects. This has already been acquired and analysis is under progress to further generalize our findings.
2. Analysis of all data by using Full Wave Rectification , Root Mean Square , & Frequency Weighted Mean/Energy Methods
3. Comparison of all the results with the literature review available.
4. Also we are using different signal analysis toolbox in Matlab thereby interfacing the bio-physiological signals (EMG signal) acquired with Matlab toolkit and verifying results obtained from both.
5. The aim is also to develop an ANN (Artificial Neural Network) which would provide us with muscle excitation with corresponding phase of exercise protocol.

REFERENCES

[1] McMahon, T.A.,*Muscles, Reflexes, and Locomotion*, Princeton University Press, Princeton, NJ, **1984.**
[2] Carlo J. DeLuca, *Journal of Applied Biomechanics*,**1997**, 13 (2), pp. 135-163.
[3] Inman, V.T., Ralston, H.J., & Todd. F., *Human Walking*. Baltimore, Williams and Wilkins, **1981**
[4] Gage, J.R., *An overview of normal walking*, Instructional Course Lectures, 39,**1990**, pp. 291-303.
[5] Rodgers, M.M., *Journal of Orthopedic and Sports Physical Therapy*, *21*,**1995**,pp. 306-316.
[6] Goldberg Saryn R., Anderson Frank C., Pandy Marcus G., Delp Scott L., *Journal of Biomechanics*, 37, **2004**, pp.1189–1196.
[7] Mizner Ryan L., Snyder-Mackler Lynn, *Journal of Orthopedic Research*, 23, **2005**, pp.1083–1090
[8] M. Liu, F. Anderson, M. Pandy, S. Delp, *Journal of Biomechanics*, 39,**2006**, pp. 2623–2630