Rivista Italiana di Filosofia Analitica Junior Vol 14, No. 2 (2023)
ISSN: 2037-4445

A Quantitative Assessment of Muscle Strength in The Upper Limbs with and Without Workout

Amol Kumar
Research Scholar, Deenbandhu, Chhotu Ram University of Science and Technology, Murthal, Sonepat, Haryana, India and Assistant Professor in Institute of Engineering & Technology, Dr Bhimrao Ambedkar University, Agra, India
Corresponding author name: Amol Kumar, email: kumaramol25@gmail.com

Manoj Duhan
Professor, ECE Department, Deenbandhu, Chhotu Ram University of Science and Technology, Murthal, Sonepat, Haryana, India

Poonam Sheoran
Associate Professor, BME Department, Deenbandhu, Chhotu Ram University of Science and Technology, Murthal, Sonepat, Haryana, India

Abstract

The present study has been undertaken to analyze and investigate the forelimb muscles strength with and without workout (exercise). Ten healthy subjects (18 to 25 years) have been chosen on the basis of their age, height, weight and workout (exercises/Gym). The experiment was conducted for with workout and without workout having a set of 5 kg and 10 kg resistance band loads, at three different arm angle positions- 30^0, 90^0 and 150^0 respectively. Three levels of arm angle positions performed by the subjects at 30°, 90°, and 150°, during the above mentioned each resistance band set. The results show that the stress value with workout (exercise) reduces upto 30% as compared to without workout (exercise), so stress reduces with workout.

Keywords: signal; EMG; recordings; digital goniometer; upper limb muscles; with workout; without workout

I. Introduction

Exercises are essential for maintaining physical health in order to carry out daily tasks without becoming fatigued. These physical workouts lower the chance of falling and improve cognitive function. There are numerous workouts that allow the muscles to contract and overcome a fixed resistance to become stronger. Walking is one of the greatest ways to assess an elderly person's level of frailty. Additional approaches include force to exercise muscles that improve its stamina, power, and endurance. Exercises using traditional dumbbells or free weights and elastic resistance devices that change muscle length while producing force are classified as isotonic or isodynamic. The contraction consists of two phases: a concentric phase during which the muscle shortens, and an eccentric phase occurs when muscle overcomes resistance. The eccentric phase has the potential to produce large quantities of force. When a muscle contracts, it produces electrical impulses that can be measured using electrodes on the skin or within the muscle itself. Surface EMG (sEMG) measures the electrical charge of these muscles as they contract or work to determine whether they are isotonic or isodynamic. It is a typical approach utilized in muscle fiber type identification, technical analysis of athletes, and research on muscle exhaustion.

Human creatine kinase (CK), an eccentric and concentric muscle protein, is used to measure the EMG, and is also a contributor to functional alternation of metabolic tissue and mechanical injury to muscle fibers. Although surface electromyography can be used to record and evaluate muscle's physiological properties during exercise and rest, identifying muscle signals is difficult. Noise signals, motion artifacts, and internal body structures, such as skin formation, blood flow rate, and fatty tissue thickness influence EMG signals. It is now possible to quantify the gluteus maximus, gluteus medius, tensor faciaelatae, biceps femoris, semitendinosus, and vastus medialis obliquus in the forelimbs before and after exercise.

Biceps muscles play one of the most important roles in the powerful actions of the hand when performing sports and activities throughout the day. By analyzing the EMG signal generated by the muscle, one can determine the condition of the Biceps brachii muscle. In order to improve the muscle's strength through eccentric contractions, training programs, use eccentric contractions as a means of increasing muscular power of the injured muscle, a reduction in muscle activation occurs because the alpha and gamma motor neurons are less excitable due to damage and inflammation. Numerous studies have been conducted to study and validate the bicep’s brachii muscle across a wide range of age groups, procedures and the positioning of electrodes on various types of muscles. For instance, keeping track of an athlete's muscle strength exercise performance is based on utilizing a dumbbell to produce resistance. Ahamed et al. (2015) corroborated the impact of EMG on the biceps brachii muscles in both male and female volunteers, the mean and the root mean square (RMS) has been used to make comparisons. Moreover, three different age groups have been analyzed for biceps brachii muscle contraction signals: adolescents, vicenarians, and tricenarians. For the biceps brachii muscle, RMS and MAV are the most commonly used amplitude measures. Some researchers have suggested that during EMG measurements, electrodes must be placed between innervation zone & tendon in order to obtain high-quality and stable signals.

So till date, no study has been carried out on the quantitative analyze of muscles with and without workout (exercise), therefore the present study has been carried out to study “A quantitative assessment of muscle strength in the upper limbs without and with workout”.

II. Research Methodology

1. Subjects*:* The present study carried out at the DCRUST, Murthal, Haryana, India. Ten male subjects between the age group of 18 to 25 years chosen on the basis of their age, height, weight and workout (exercises/Gym).

2. Instruments*:* EMG signals from the skin have been acquired using Acknowledge 3.9 software, Biopac MP100 (BIOPAC Systems, Inc., Santa Barbara, CA). In a bipolar differential signal acquisition procedure, the EMG signal has been acquired using two electrodes, with the third electrode serving as a reference electrode, which has been placed in between two surfaces. EMG activity of each muscle has been measured utilizing the Biopac System and bipolar electrodes made of Ag-AgCl of 10 mm. EMG procedures have been followed as per standards endorsed by the International Society of Electrophysiology and Kinesiology, 1999. Sampling rate of 2000 Hz, input impedance of 10^{15} Ω/0.2 pF, and common mode rejection ratio (CMRR> 90 dB) has been used to acquire EMG signals.

3. Procedure: Left hand and right hand biceps brachii muscles have been used to record the EMG data. Each participant in the study has signed an informed consent form certifying that they are free of any muscular diseases. Each exercise has been carried out using a dumbbell weighed 5.0 kg and 10.0 kg. The weight of the dumbbell has been chosen based on preliminary trials to prevent overstress to subjects.

3.1. EMG recordings: After two minutes of rest, the subjects performed three maximal voluntary isometric contractions (MVC). During MVC, subject's sEMG of biceps muscles at standing position have also been recorded. In this study, bipolar electrodes has been used (silver chloride electrodes with a distance between electrodes of 20 mm) over the Biceps of both the left and right hands. To prepare the skin area for electrode placement, it has been rubbed and shaved (with spirit and towel) in the designated area.

Firstly, the readings have been taken without workout with dumbbell of resistance band load of 5 Kg and 10 Kg respectively at three different arm angles position such as 30^0, 90^0 and 150^0. The Medigauge electronic digital goniometer has been used for measuring arm angle position. The subjects held the resistance band for 20 seconds, take a 2-minute rest, and then repeated the process 8 times for each pair of resistance band loads.

Secondly, the readings have been taken after eight days rest with workout of 20 minutes push-ups. Then after putting dumbbell of resistance band load of 5 Kg and 10 Kg at three different arm angles position *viz*. 30^0, 90^0 and 150^0. The Medigauge electronic digital goniometer has been used for measuring arm angle position. The subjects held the resistance band for 20 seconds, take a 2-minute rest, and then repeated the process 8 times for each pair of resistance band loads.

3.2. Signal preprocessing*:* The raw EMG signal pre-processed as follows:

3.2.1. Band pass filtered signal*:* By using a zero lag fourth-order Butterworth filter to reduce high frequency noise and motion artifacts in sEMG signals, band pass filtered signals have been used to reduce high frequency noise and motion artifacts.

3.2.2. Full wave rectifier signal: By taking the absolute value of the signal, full wave rectification has been used. An EMG signal has been analyzed using a full-wave rectifier to retain all the energy of the signal, so that the upper limb motion can be estimated using the EMG signal.

3.2.3. Statistical analysis*:* Average, standard deviation, and RMS values have been calculated for all filtered EMG signals. The Average, SD, RMS, skewness, kurtosis, correlation analysis has been obtained by using the statistical equations as follows-

3.2.4 Average*:* The average mean of EMG data is a valuable metric in understanding the muscle function and provides important insights in a range of fields. It also helps in identification and quantification of muscle fatigue, which is characterized by a reduction in muscle activity over time.

$$\text{Average (Avg) } (\bar{x}) = \frac{1}{N}\sum_{i}^{N} x_i \tag{1}$$

Where N = no of samples,
x_i = values of the sample
$\bar{x} = mean$ of x_i

3.2.5. Standard Deviation: Standard deviation is a measure of the spread of the data points around the mean value. The standard deviation of EMG data is a measure of the variability or dispersion of the signal over time. It provides important information about the characteristics of the signal, such as the amplitude, frequency, and duration of muscle activation. It is also used to identify potential artifacts or noise in the signal that may affect the accuracy of the analysis.

Standard Deviation (SD) (σ) = $\sqrt{\frac{1}{N}\sum_{i=1}^{N}(x_i - \bar{x})^2}$ (2)

Where N = no of samples
x_i = values of the sample
$\bar{x} = mean$ of x_i

3.2.6. Root Mean Square (RMS): RMS value of the EMG signal determines the level of muscle activation. RMS is a commonly used method to quantify the level of muscle activation. The RMS value of an EMG signal represents the average power of the signal over a specified time interval. The RMS value is calculated in EMG analysis that provides accurate measure of muscle activation than the raw EMG signal. The raw EMG signal is affected by noise, artifacts, and other factors that can make it difficult to determine the level of muscle activation. The RMS value of the EMG signal, provides a more robust measure of muscle activation. Calculating the RMS value of the EMG signal, the level of muscle activation during a specific time period can be determined and compared it to other time periods or to other individuals.

Root Mean Square (RMS) = $\sqrt{\frac{1}{N}\sum_{i=1}^{N} x_i^2}$ (3)

Where N = no of samples,
x_i = values of the sample
$\bar{x} = mean$ of x_i

3.2.7. Skewness: Skewness is a measure of the asymmetry of a probability distribution, so the expected skewness of an EMG data set depends on the distribution of the EMG signal amplitudes. EMG signals are often skewed towards positive values, as the amplitude of the signal tends to be higher during muscle contractions than during relaxation. This means that the expected skewness of an EMG data set would likely be positive. A negatively skewed EMG distribution could indicate that the muscle is not firing properly, possibly due to injury or other issues.

Skewness = $\frac{1}{N}\sum_{i=1}^{N}\left[\frac{X_i - \bar{X}}{\sigma}\right]^3$ (4)

Where N = no of samples,
x_i = values of the sample
$\bar{x} = mean$ of x_i

3.2.8. Correlation analysis: A correlation is a statistical relationship between two variables. It measures how closely variables are related to each other. When two variables are correlated, a change in one variable is associated with a change in the other variable. Present study data has been correlated for with and without workout.

III. Results & Discussions

Ten healthy subjects aged between (18 to 25 years), height (1.62 to 1.80 m), weight (48 to 84 kg) and BMI (15.9 to 25.9 kg/m^2) as shown in table 1, have been investigated for with and without workout (exercises/Gym). Each subject performed three levels of the arm angle positions *viz*. 30°, 90° and 150° for 5 kg band load as shown in figure 2. Similarly each subject has been allowed to perform three levels of the arm angle positions *viz*.30°, 90° and 150° for 10 kg band load as shown in figure 3. In this study, EMG signals has been recorded and analyzed using Acknowledge 3.9 software, Biopac MP100 (BIOPAC Systems, Inc., Santa Barbara, CA). In figure 6, the scatter diagram of correlation shows a higher degree of positive correlation between with and without workout.

Table 1 Physical characteristics of subjects (n=10)

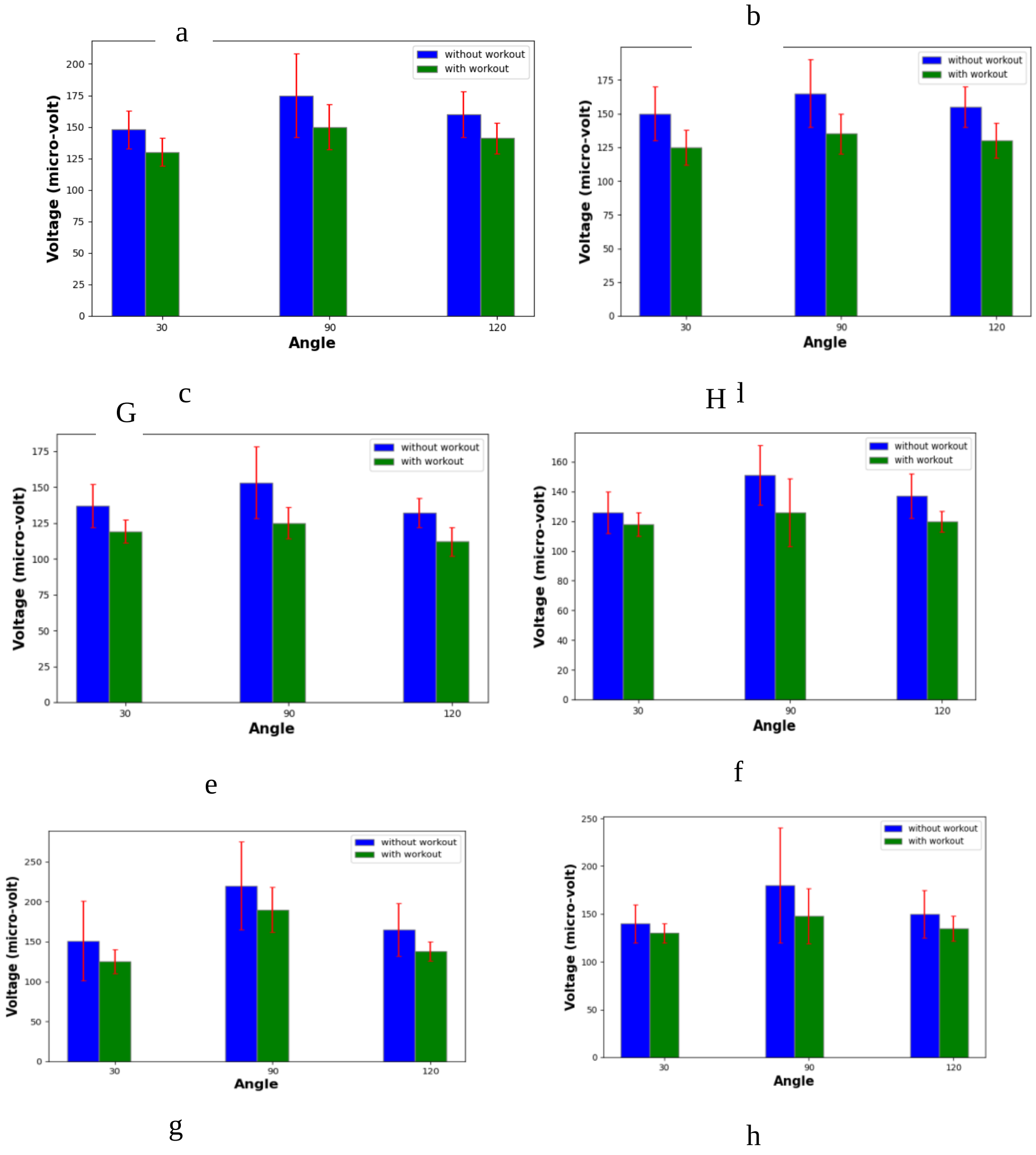
S.No	Gender	Age (Years)	Weight (kg)	Height (m)	BMI (Kg/m^2)
1	Male 1	19	75	1.78	23.7
2	Male 2	18	53	1.63	19.9
3	Male 3	20	84	1.80	25.9
4	Male 4	18	48	1.74	15.9
5	Male 5	18	75	1.75	24.5
6	Male 6	19	54	1.63	20.3
7	Male 7	18	56	1.63	21.1
8	Male 8	19	55	1.62	20.9
9	Male 9	25	76	1.80	23.5
10	Male 10	23	78	1.72	26.3

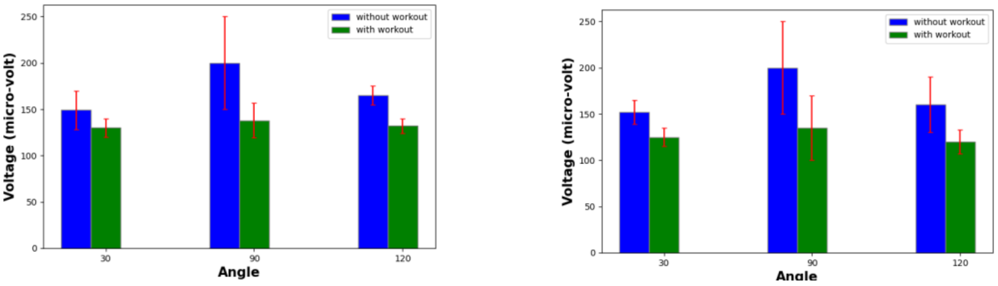
Figure 1 EMG data being recorded


[redacted]

The average mean is useful for identifying and quantifying muscle fatigue, characterized by a decrease in muscle activity over time. Standard deviation (SD) of EMG signals is a common and useful tool for analyzing muscle activity and can provide valuable information for research and clinical applications. Low standard deviation value of data shows that the data are more reliable. RMS value provides accurate measure of muscle activation. RMS evaluated the effectiveness of interventions at increasing or decreasing muscle activation. In obtained results, the degree of skewness towards positive values (figure 4 and 5), which indicates that the amplitude of the signal is higher. The scatter plot (Figure 6) reflects that with and without exercise, there is a greater degree of positive correlation.

Figure 2 Comparison of Right Bicep arm for 5 kg with and without workout for 10 male subjects (a to j)





i

j

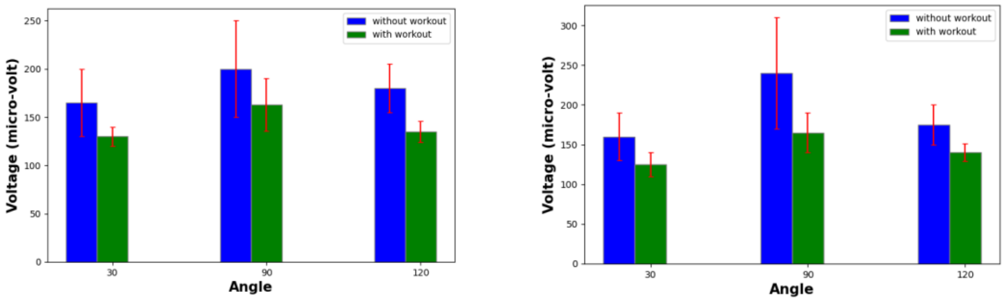
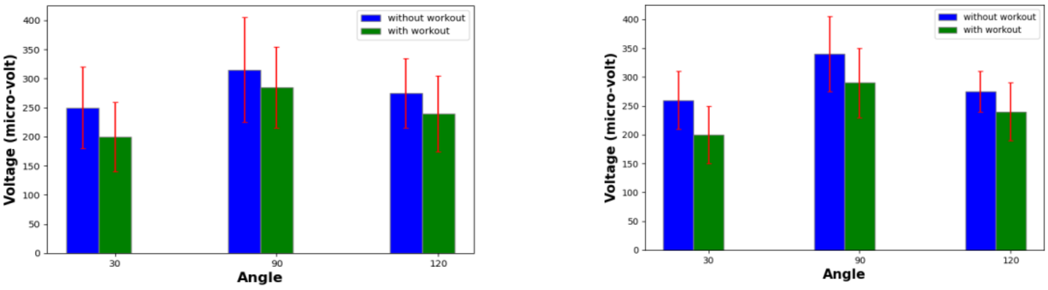


Figure 3 Comparison of Right Bicep arm for 10 kg with and without workout for 10 male subjects (a to j)

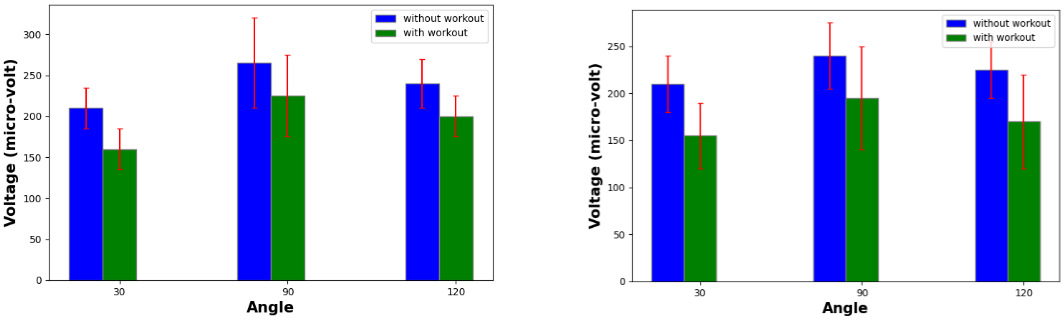
a

b



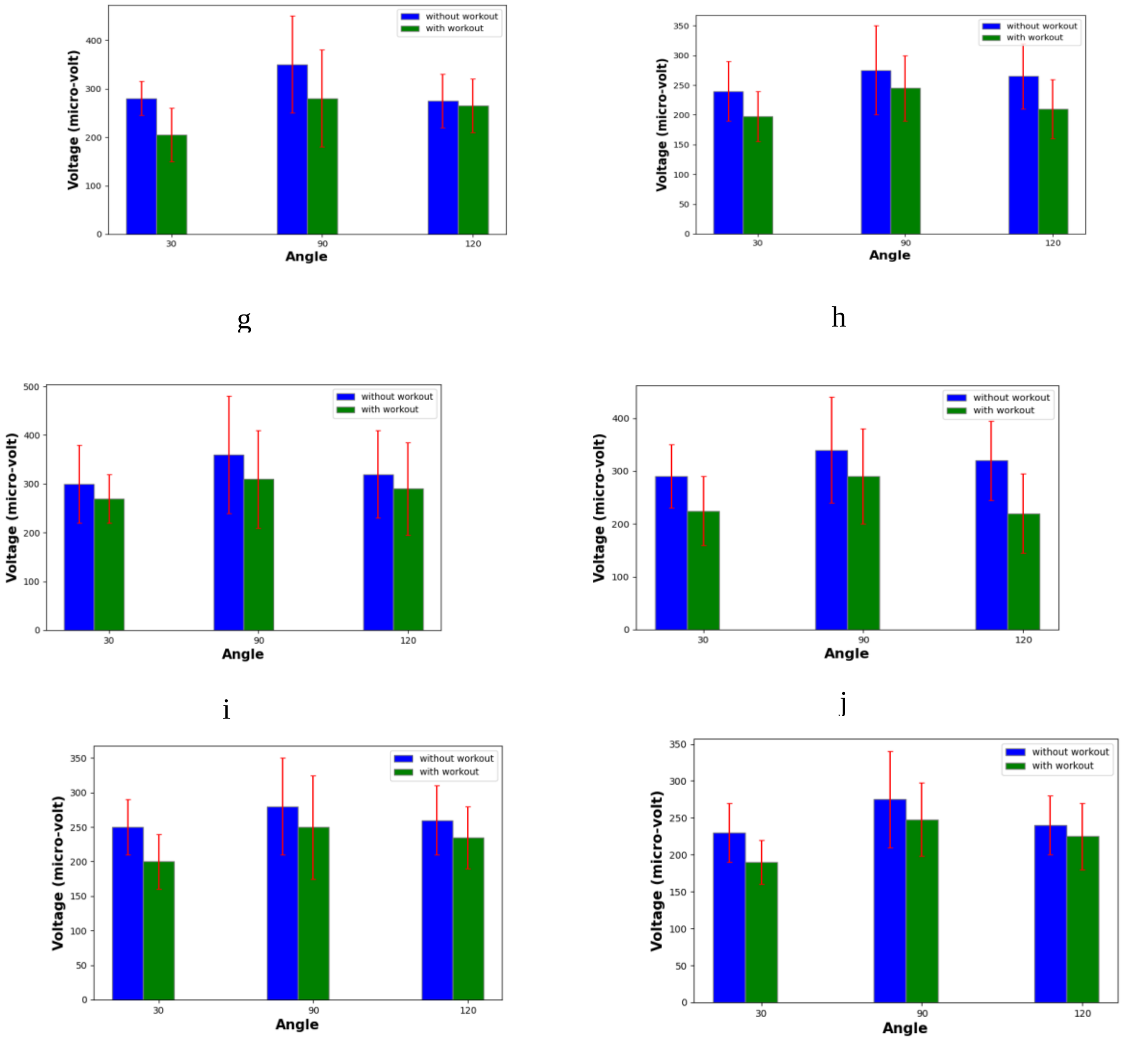
c

d



e

f



g

h

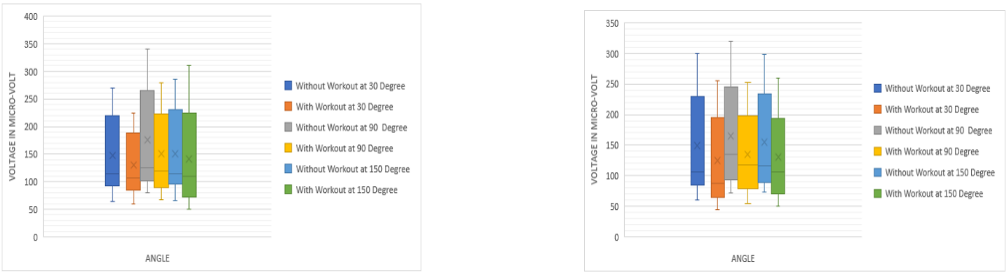
i

j

Figure 4 Comparison of Skewness of Right Bicep arm for 5 kg with and without workout for 10 male subjects (a to j)

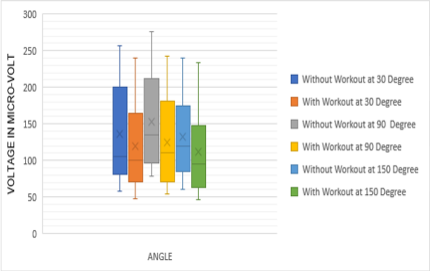
a

b

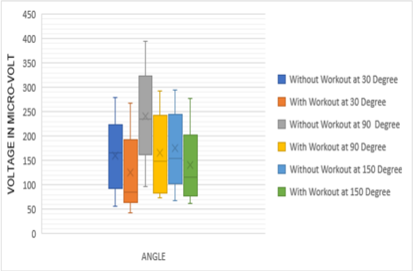


c

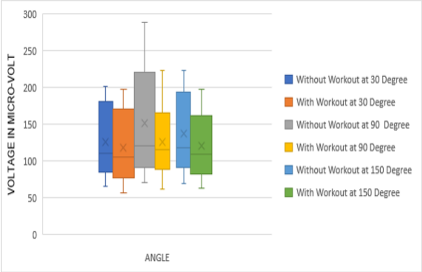
d



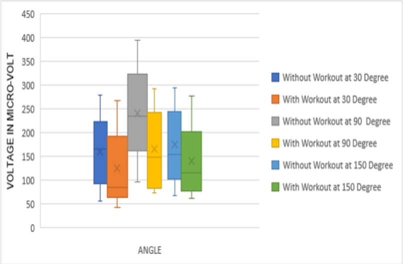
e



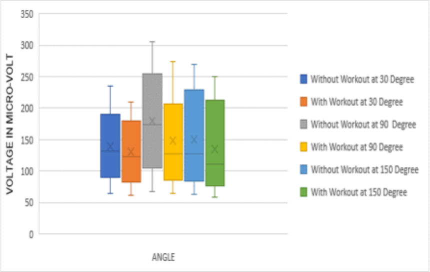
f



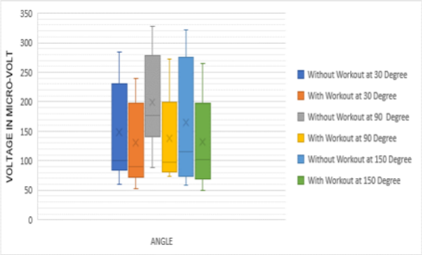
g



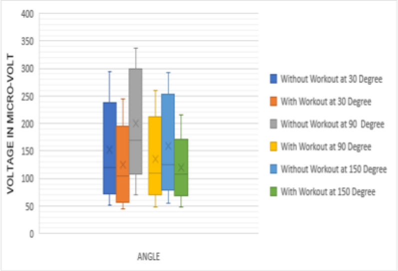
h



i



j



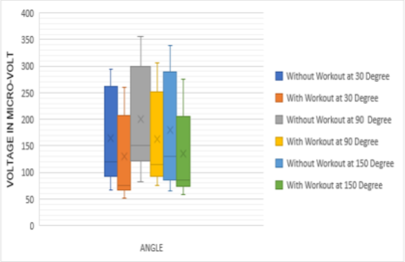
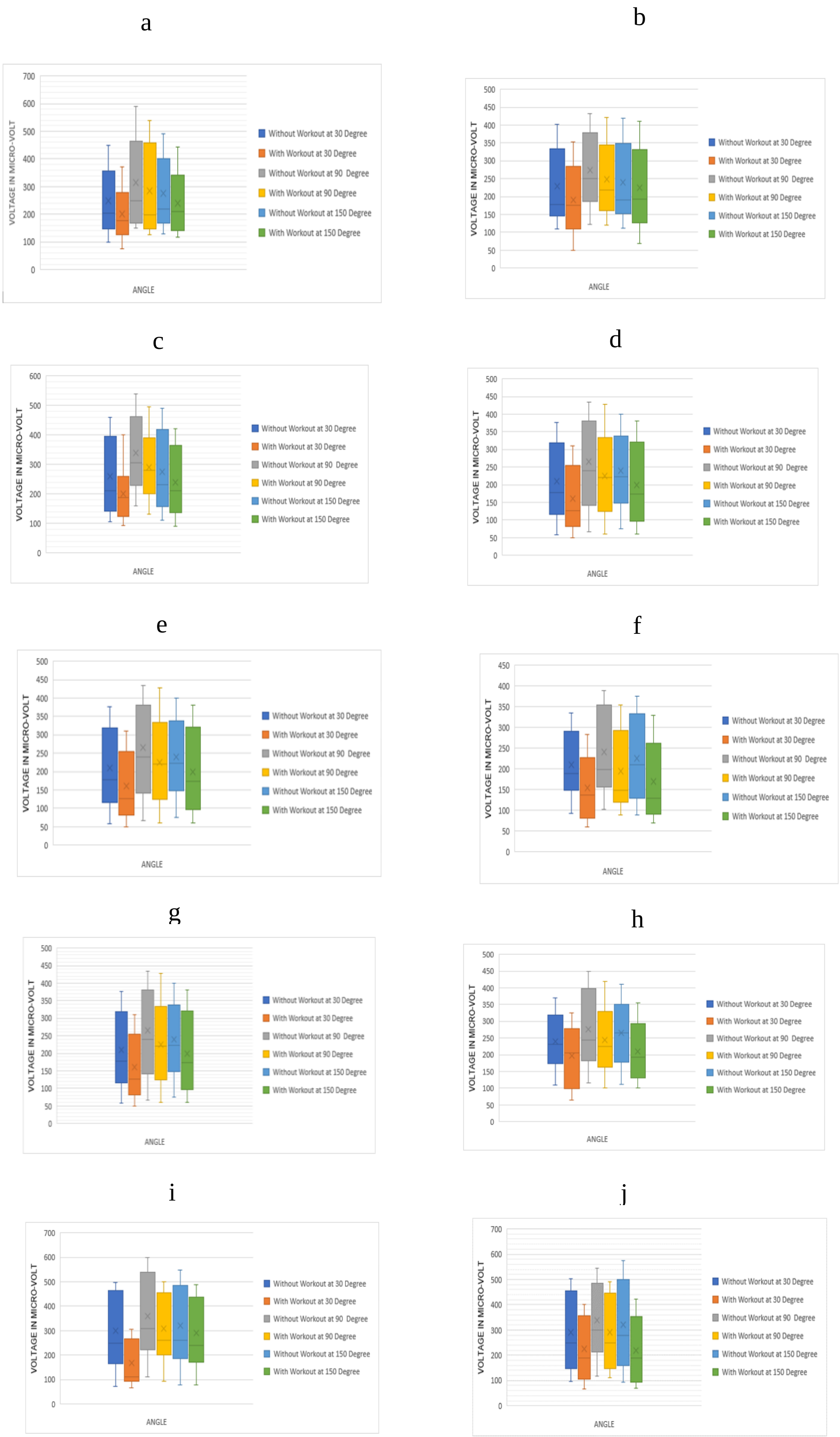
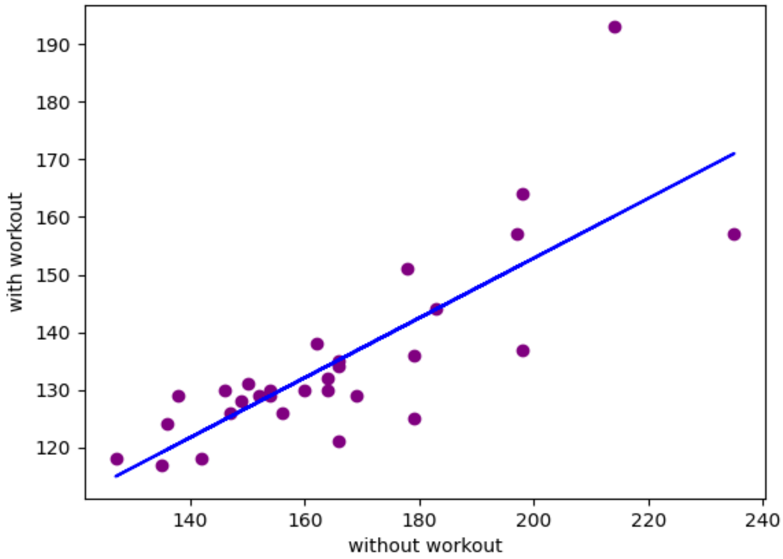


Figure 5 Comparison of Skewness of Right Bicep arm for 10 kg with and without workout for 10 male subjects (a to j)



a b c d e f g h i j

Figure 6 A Scatter graph showing a stronger positive relationship between with workout and without workout



A quantitative analysis of upper limb muscles has been conducted (before and after exercise) to determine how they changed quantitatively. As shown in figure 1, for a 5 kg load (without workout), the muscle strength value is highest at 90^0, and lowest at 30^0, but the observed muscle strength value at 150^0 is between 30^0 and 90^0.

Similarly for 5 kg load (with workout) the muscle strength value is also highest at 90^0, and lowest at 30^0, and at 150^0 the muscle strength value observed is in between at 30^0 and 90^0. But the stress value is reduced with workout as compared to without workout at 30^0, 90^0, and 150^0. So it can be corroborated that the stress value reduces with respect to workout, and simple warming up exercises befor exercise defintely helped in saving muscles.

The similar findings has been observed for 10 kg load as shown in figure 2, the muscle strength value is highest at 90^0, and lowest at 30^0 but the obtained value of muscle strength is more as compared to 5 kg load at angles 30^0, 90^0 and 150^0 for both without workout and with workout.

In our result skewness of EMG signals are skewed towards positive values, as the amplitude of the signal tends to be higher during muscle contractions than during relaxation. This means that the expected skewness of an EMG data set is positive.

Correlation between two variables can be visualized using a scatter plot. If the variables are positively correlated, the points on the scatter plot forms a upward-sloping line, in the present study, observations are same as upward sloping line indicating a positive relation between without and with workout i.e., higher degree of positive correlation.

This study investigated that strength values increases as muscle load increases, which is also in line with Daud et al's previous work. Daud et al.(2013) examined isometric and isotonic EMG signal motion patterns, on the raw data of EMG signals during isometric contractions during the hand-lifting of three distinct loads: (a) 1 kg (b) 3 kg and (c) 5 kg. Lorrain et al. (2011) observed EMG signals for nine hand motions lasting ten seconds, with three seconds between each contraction from eight different patients. Each contraction consists of a stretch of static material (4 seconds in length) and two segments of dynamic material (3 seconds each) that represent the two primary dynamic scenarios found in real movements. Phinyomark et al.(2013) also gave participants, instructions to move their upper limbs in eleven different ways for five seconds each, including extension, flexion, ulnar deviation, radial deviation, pronation, supination, open, close, key grip, pincer grip, and extracting the index finger. Tsai et al. (2014) and Amol kumar et al.(2022) compared the upper limb mobility pattern of the EMG signals in the two circumstances, according to the experimental findings, it is desirable to employ the same kind of muscle contraction during the training and validation phases in order to assess the performance of motion pattern recognition. This study will be helpful for the atheletes, sport person and for rehabilitation exercises as the results indicated that person stress reduces if he/she has already gone through with workout (exercises) as compared to without warm up (exercises).

IV. Conclusions

As result shows that the stress value with workout reduces upto 30% as compared to without workout. The display of positive skewed values in the graphs shows that the tonning values are good for muscle flexibility.It can be concluded that the stress value of EMG without workout is higher than with workout, thus stress reduces with workout (exercises). The best tonning takes place at 90^0 angle, as the weight increases with work out. There is less stress value generated for this angle, so it is more appropriate for the best result. It is recommended to rest at least two minutes between muscle contractions in order to prevent fatigue.

Declaration of competing Interest
None declared

References

[1]. Prentice, W.E.(1999). Rehabilitation techniques in sports medicine' (3rd ed.),1999.

[2]. Boston, M.A., Hill, M. G., Zachazewski, J.E., Magee, D.J. and Quillen, W.S.(1996).'Athletic injuries and rehabilitation', Philadelphia, PA: W.B. Saunders Company, 1996.

[3]. Manoj, D., Chanderpal, S.,Dinesh, B. (2011). Study of signal processing techniques for EMG analysis. Int.J. Biomechatronics Biomed. Robot, 3, 141–148.

[4]. Chawla, M. and Duhan, M. (2014). Applications of recent metaheuristics optimisation algorithms in biomedical engineering: a review. International Journal of Biomedical Engineering and Technology, 16(3), 268-278.

[5]. De Luca, C. J., Gilmore, L.D., Kuznetsov, M., Roy, S. H. (2010). Filtering the surface EMG signal: movement artifact and baseline noise contamination. Journal of Biomechanics, 43, 1573–1579.

[6]. Masuda, T. M. S. I. K. (1999). Changes in surface EMG parameters during static and dynamic fatiguing contractions. Journal of Electromyography and Kinesiology, 9, 39-46.

[7]. Rainoldi, G. M. C. A. (2004). A method for positioning electrodes during surface EMG recordings in lower limb muscles. Journal of Neuroscience Methods, 134, 37-43.

[8]. Burhan, N., Kasno, M.A., Ghazali, R., Said, R., Abdullah, S.S., Jali, M.H.(2017). Analysis of the Biceps Brachii muscle by varying the arm movement level and load resistance band. Journal of healthcare Engineering, 1-8.

[9]. Taha, Z., Ming, C., Ahamed, N. U., Joseph, S., Omar, S. F. S. (2016). Performance analysis in strength training: an innovative instrumentation. Procedia Engineering, 147, 455– 460.

[10]. Ahamed, N.U., Yusof, Z., Alqahtani, M., Altwijri, O., Rahman, M., Sundaraj, K.(2015). Gender effects in surface electromyographic activity of the biceps brachii muscle during prolonged isometric contraction. Procedia Computer Science, 61, 448–453.

[11]. Ahamed, N. U., Alqahtani, M., Altwijri, O., Rahman, M. and Sundaraj, K. (2016). Age-related EMG responses of the biceps brachii muscle of young adults. Biomedical Research, 27,787–793.

[12]. Hermens, H. J., Freriks, B., Disselhorst-Klug, C., Rau, G. (2000). Development of recommendations for SEMG sensors and sensor placement procedures. Journal of Electromyography and Kinesiology, 10, 361–374.

[13]. Daud, W.M.B.,Yahya, A.B., Horng, C.S., Sulaima, M.F., Sudirman, R. (2013). Features Extraction of Electromyography Signals in Time Domain on Biceps Brachii Muscle. International Journal of Modeling and Optimization: Bucharest, Romania, 3(6), 515-519.

[14]. Lorrain, T., Jiang, N., Farina, D. (2011). Influence of the training set on the accuracy of surface EMG classification in dynamic contractions for the control of multifunction prostheses. J. Neuroeng. Rehabil. 11, 8–25.

[15]. Phinyomark, A., Qu, F., Chrbonnier, S., Serviere, C., Tarpin-Benard, F., Laurillau, Y. (2013). EMG feature evaluation for improving myoelectric pattern recognition robustness. Expert Syst. Appl., 40, 4832–4840.

[16]. Tsai, A.C., Hsieh, T.H., Luh, J.J., Lin, T.T. (2014). A comparison of upper-limb motion pattern recognition using EMG signals during dynamic and isometric muscle contractions. Biomed. Signal Process. Control, 11, 17–26.

[17]. Kumar, A., Duhan, M., Sheoran, P.(2022). Electromyography signal acquisition, processing, optimization and its applications. NAMSP, 332, 58-69.