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Estimation of Forearm muscle force in Eccentric, Concentric and Isometric Contraction at different MVC level

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Abstract-The purpose of this study was to examine forearm muscle activation during Eccentric, Concentric and Isometric Contraction at the MVC Level of 25%, 50% and 75% . 10 healthy males and 6 females participants wererecuited for this study.The EMG data was collected from forearm deep muscles like flexor digitorumprofunds, flexor policies lungus,extensor policies lungus and extensor policies brevis by surface EMG and needle EMG during all the phases.The features like RMS , IEMG and WL were extracted from EMG . From our study RMS and IEMG Value increased in all force level during all the phase and there was no linear relationship in the feature of WL.There was no significant difference between surface and needle EMG feature in isometric contraction($p \leq 0.05$) andWL was not good feature in isometric contraction.In dynamic contraction there was significant difference in surface and Needle EMG ($p \leq 0.05$) and RMS value was not good feature in dynamic contraction.

Keywords: Maximum voluntary contaction, Root means Square Value, Integrated EMG, Waveform length, Surface Electromyography, Needle Electromyography

I.INTRODUCTION

Muscle Contraction is key factor in task performance of the dailyactivities (1) and performance of athletics, sports persons (2). It is generally classified in two types i.e., Isometric contraction (Static contraction) which means muscle length is constant and muscle tension is changed. Isotonic (Dynamic contraction) which means muscle length is changed but tension is maintained constant. Isotonic contraction further is classified into Concentric and Eccentric. During concentric muscle contraction the muscle length decreases. Instead, during the eccentric contraction, muscle length is increased (3).

The strength of muscle is ability to generate the force for balancing the mechanical work (4). The force generation is sequence of events starts from nerve triggers passes through CNS. CNS decides the recruitment of motor neuron for performing the mechanical work by stimulating muscle fiber (5). The results show that generation of force that can estimate by EMG. So EMG is useful because it is one of thefew methods that provide a window on muscle activity and hencemuscle force production during functional movements (6).

The surface electromyography (sEMG) signal represents the summationof the electrical activity of active motor units within the recordingarea of the surface electrodes placed over a muscle of interestand is often referred to as a global measure ofmotor unit (MU) activity as electrical signal(7). Furthermore, the sEMG signal is qualitativelyrelated to the amount of force produced by a muscle and is dependenton the factors such as the membrane properties of muscle fibers, thetiming of MU action potentials (i.e.,MU behavior), and non-physiologicalfactors such as the thickness of subcutaneous layers or the shape ofthe volume conductor(8).But SEMG is not applicable for deep muscle; to overcome this needle EMG is employed. In the Needle EMG, recording the electrical signs that are created from muscle filaments by embedding needle Electrode (9). Standard EMG examines include embedding an recording electrode into a muscle, gradually moving the needle through various districts of muscle, and recording the electrical signals that are happening very still, started by the needle development, and during voluntary muscle contraction(10,11).

In the forearm, flexor muscle involves for concentric contraction and extensor muscles for eccentric contraction (12).There is insufficient knowledge about in forearm muscle about isometric and dynamic activity force production during different load level because of forearm has some of the muscle are in deeplike flexor digitorumprofunds, flexor policies lungus,extensor policies lungusand extensor policies brevis which is not applicable to EMG using Surface EMG , in that case we can use for needle EMG.

The aim of our study was therefore to add to the existing knowledgeof forearmmuscle force production. In particular, Isometric, concentric and eccentric exercises may have different effects on force production in different load level. There is insufficient knowledge in activation of MUs in deep muscle during different loading condition. This problem is analyzed with needle EMG different contraction and MVC level. This information may be useful for both researchers and clinicians because it would helpto increase our understanding of the effects of muscle fatigue and/or damage on the neuro muscular system.

II. MATERIALS AND METHODS

2.1 Subjects demography-

In this study, the participants consist of ten healthy males and six females with the mean and standard deviation of demography as follows:

Mean and SD of Subjects

Variables	Male(n=10)	Female(n=6)
Age	20±1.2	20±1.2
Height(m)	1.70± 0.3	1.60± 0.2
Weight (kg)	65± 2.4	63.2±2.2
Body Mass IndexKg/(m)^2	22.3±0.6	23.6±0.8

The Subjects were no history upper limb injury and no more musculoskeletal disorder.Experimental procedures were explained to the subjects before the data collection and their signatures were collected on the consent form approved by the local institutional ethics Board.

2.2 Experimental Design and protocol-

Before the signal recording process, subjects were given sufficient information about the experiments and their informed consents were taken. All EMG measurement protocol was carried out recording to the recommendation of SENIAM Project for SEMG acquisition and proper guidelines followed in needle EMG acquisition.

2.2.1 Isometric Exercise Protocol –

Bend your arms so that your forearms are parallel to the floor with the palms of your hands facing downwards. Straighten your fingers out and curl them under until your fingers are pushing against the heels of your hands. Keeping your fingers straight, push them against the heels of your hands as hard as possible. Hold for 10 seconds**.** Hold the dowel with both hands out in front of you, palms facing down, and attempt to snap it by bending it upwards (maybe someday you will). Hold for 10 seconds. Now attempt to snap it by bending downwards and hold for 10 seconds

Fig 1. Isometric Excise Protocol

2.2.2 Concentric and Eccentric Exercise Protocol –

Sit on the Chair,Keep the left and Right forearm in corresponding thigh and extend fingers and palm from knee. Keep the dumbbell in the palm. Movein upwardsand downwards for 10 sec. Take 2 sec. Rest

Fig.2 Concentri cand Eccentric Excise Protocol

2.3 Electromyography

2.3.1 Surface EMG Recording –

Dominant arm was selected to get SEMG from forearm muscles. A four pair of Bipolar Ag/AgclSurface electrode was placed over in the forearms like flexor digitorumprofunds, flexor policies lungus, extensor policies lungus and extensor policies brevis. The electrodes was placed over in the muscle belly of IZ with inter electrode distance of 2cm to get better result. Electrodes were placed over in the fiber direction and movement direction of muscle followed by SENIAM norms (13).To reduce skin impedance ground electrode was placed over on the lateral epicondyle of the dominant arm and all the recording places were shaved of the hair with cleaning of alcohol before to place the electrodes.

2.3.2Needle EMG Recording -

The Needle EMG gives better noise resolution than Surface EMG in deep muscle and we can analyze the individual motor unit activations during all the phases. After cleaning with alcohol on the skin surface, disposable concentric needle electrode with diameter 0.3mm was inserted in each muscle. The needle was sterilized before inserting and moved in 0.5mm to 1mm through the muscles to analyze MU activations.The needle was inserted in each of Distal position following the guide lines of Needle Electromyography data aqusition(11).

2.4. Datacollection andprocessing-

Raw EMG from surface electrode and Needle electrode were further analyzed .The raw SEMG were filtered using a band pass filter (second order Butterworth)with the frequency range of 10-500Hz.The raw EMG from the needle electrode was band pass filtered with cutoff frequency of 2-500Hz with sampling rate of 10KHz.In order to find the MU activation, smoothened EMG was needed .So filtered signal was rectified then rectified EMG signals were further aranalyzed to obtain smoothened EMG using a lowpassfilter with50Hz cut off frequency.

2.5 Feature Selection

2.5.1 RMS of EMG-

Mean RMS (Root Mean Square) EMG signals were calculated from smoothened EMG signals for the window of every 500-ms. Subsequently, RMS was normalized to the RMS of EMG signals recorded duringtheMVC and calculated from

$$RMS=\sqrt{\frac{1}{N}\sum_{n=1}^{N} Xn^2}$$

Where Xn is EMG magnitude in segment n and N represents the number samples

2.5.2 Integrated EMG-

Integrated EMG is defined as the addition of MEG magnitude over the samples of N.It is calculated as,

IEMG $=\sum_{n=1}^{N} | Xn|$

2.5.3 Waveform length –

Waveform length is cumulative length of the waveform over the segment and it denotes the value of EMG over the segment. It is calculated by

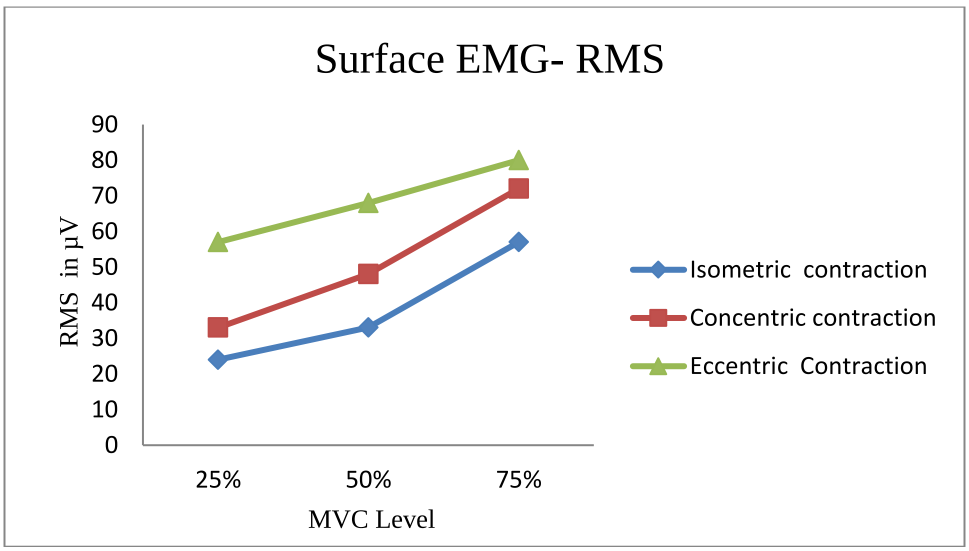
WL$=\sum_{n=1}^{N} Xn - Xn - 1$

All the features were processed by a custom- developed program, written in MATLAB R2014a(Math Works) with I3 processor.

III. RESULT

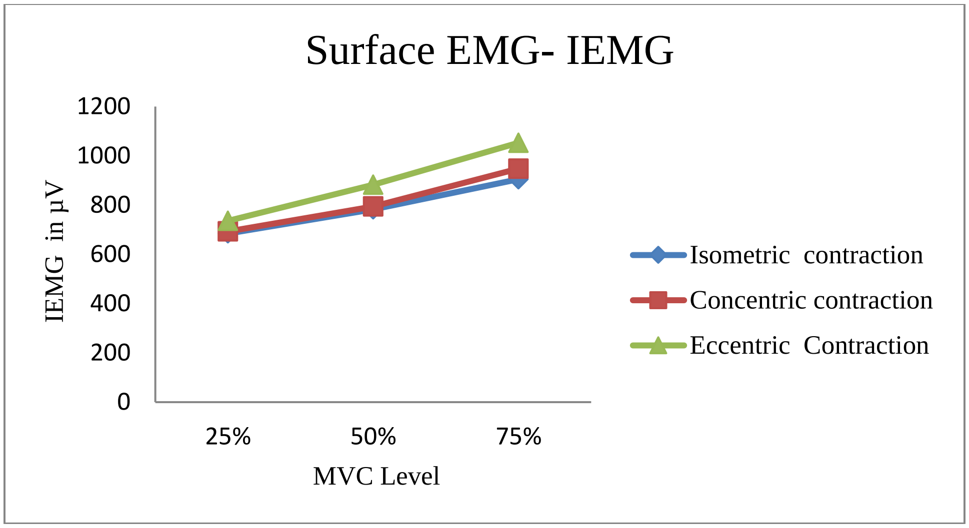
Contraction Level	Isometric Contraction			Concentric Contraction			Eccentric Contraction		
	RMS (µV)	IEMG (µV)	WL (µV)	RMS (µV)	IEMG (µV)	WL (µV)	RMS (µV)	IEMG (µV)	WL (µV)
25%	24.6±3.2	684.6±245.2	153.6±52.4	32.8±6.2	692.6±312.4	150.4±32.6	56.7±6.2	736.4±322.5	163.2±36.8
50%	36.8±5.7	783.6±327.6	247.4±64.2	48.3±5.6	794.6±274.8	283.2±73.2	68.2±5.1	883.5±335.5	305.3±53.1
75%	64.2±5.2	905.4±376.4	287.4±75.2	72.5±4.6	947.7±431.6	165.8±53.2	80.4±3.8	1053.6±473.4	264.3±43.2

Table 2. Shows Predictd RMS , IEMG and WL from Surface EMG



In all three phases the RMS and IEMG value increased when the force level was increased. The RMS value was lower in isometric contraction and lower than concentric contraction in all force levels and smaller than next eccentric contraction at 50% level($p \leq 0.05$). The RMS value increased up to 75% in isometric and increased up to 50% in dynamic contraction. The IEMG Value was higher in isometric than dynamic in all force levels. At the force level of 25% the isometric IEMG was lower than it followed dynamic contraction up to 75%. WL was high in 50% and low in 75% level isometric contraction compared to 25% and in dynamic contraction WL value decreases.

Intramuscular EMG measured during Isometric, Concentric and Eccentric phase was no significant difference with SEMG in all force conditions with all features extracted but it showed single MU activation. When comparing Concentric and Eccentric contractions force at the force level of 25% and 50% was higher in eccentric than concentric and at 75% force level concentric contraction was more than eccentric .The RMS value of EMG in 25% and 50% force level of concentric was higher than eccentric. WL was lower in all force level in eccentric contraction than concentric.



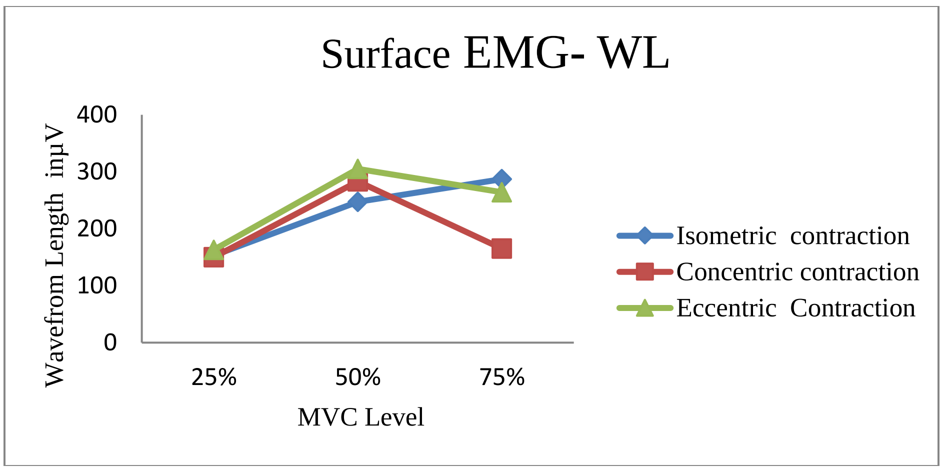
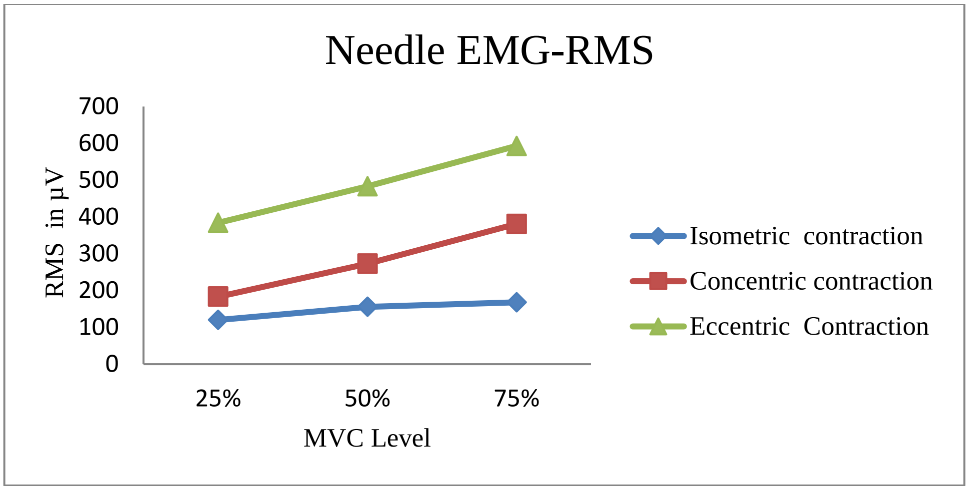
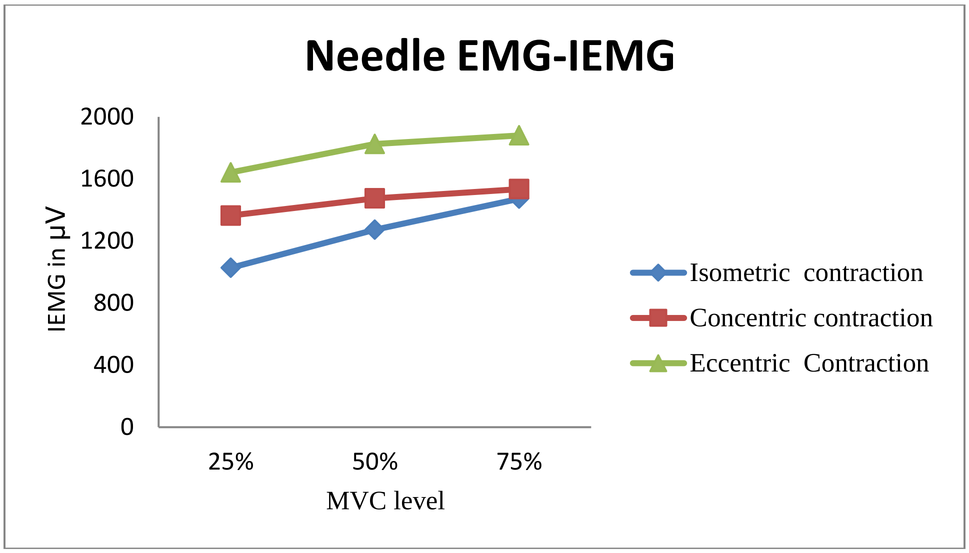


Fig 3. RMS , IEMG and WL analysis at MVC level of 25% , 50% and 75% in Surface EMG

Contraction Level	Isometric Contraction			Concentric Contraction			Eccentric Contraction		
	RMS (µV)	IEMG(µV)	WL (µV)	RMS (µV)	IEMG (µV)	WL (µV)	RMS (µV)	IEMG (µV)	WL (µV)
25%	120±36.5	1027.5±329.4	382.6±104.5	183.5±56.8	1364.7±428.3	384.2±94.2	384.6 ±103.5	1642.4±523.5	437.4±142.5
50%	156.3±32.6	1273.4±384.2	452.5±126.9	274.2±79.3	1475.3+635.5	638.7±279.4	483.5±146.5	1826.5±638.5	526.3±251.4
75%	168±45.2	1472.6±483.2	339.4±96.5	381.4±89.3	1534.6+638.3	482.5±132.2	593.2±210.4	1880.3±635.5	492.5±142.3

Table 3. Shows Predictd RMS , IEMG and WL from Surface EMG





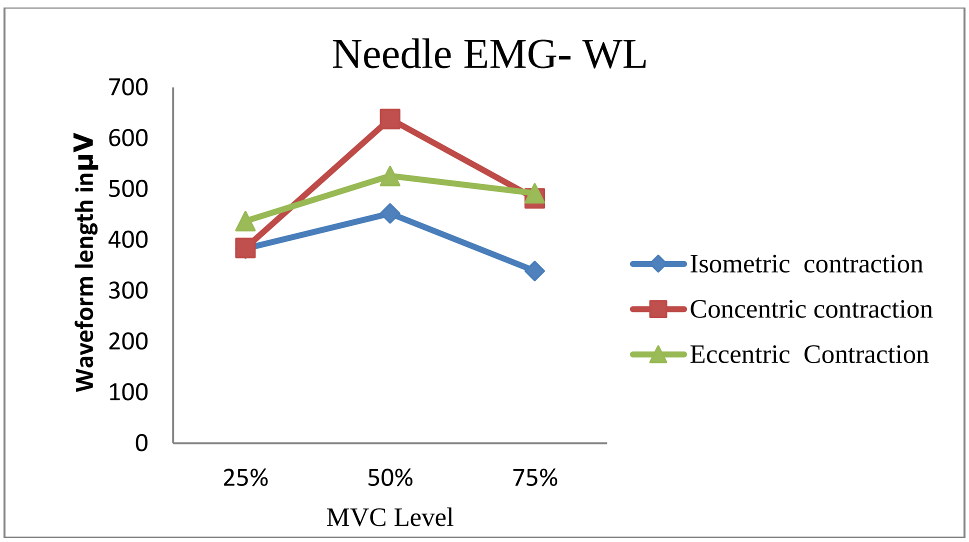


Fig 4. RMS , IEMG and WL analysis at MVC level of 25% , 50% and 75% in Needle EMG

IV. DISCUSSION

In this Study we examined the activation of forearm muscles in concentric,eccentric and Isometric phase at different force level. We compared the result Needle EMG with surface EMG during this phase. By using needle EMG the individual motor unit activation was observed during this study. The present methodology, gives a change to examine the behavior of several MUs and present more information than available in Surface EMG. From the result of our experiment1.The mean RMS and IEMG was higher in all the phase which was examined through SEMG and intramuscular EMG.2. While surface EMG does not give any better difference between the action modes, the intramuscular RMS amplitude was normally higher in dynamic contraction than the isometric phase. This proves that MU recruitment limit inisometric and dynamic are not same because of motor unit fIring rates. The recruitment threshold in dynamic contraction is lower compared to isometic so high threshold MU are activated in dynamic phse and when the force level increased fast and larger MU are recruited to balance external force(14,15 ,). So that RMS and IEMG was increased when force level was increased.

When examined VI muscle with SEMG and Needle EMGin isometric contraction, there was no siginificant difference between them (16), the same result was obtained in our study . In the isometric contraction by considering average value of RMS and IEMG which was given better results in MU activation than WL .Among our three force level, it can be resulted that the nearly half of the force level, there was significant difference between WL and RMS/IEMG .Additionally considering isometric contraction in the maximum no. of predictions, RMS results was closest to the actual force levels. Even RMS was the best feature in force estimation, the performance of IEMG was not poor in force estimation because RMS and IEM G gave the same results in many conditions .The significant different was not found between RMS and IEMG in the most of the forcelevel.But the RMS results showed more number of accurate results in terms of Qunatification. When compared with WL performance in isometric contraction, WL produces bad ouputs than other two features in this phase.soit was is not advisable for isometric contraction.

During concentric and Eccentric phase WL was given accurate results than RMS and IEMG.Because WL showed the Signal amplitude and frequency and time duration of signal over the segment. Due to non stationary(17) charactristics of EMG in dynamic phase, WL was the best feature in that phase.

V .CONCLUSION

In our study, we have evaluated the most frequently used time domain features like RMS value, integrated EMG and Waveform length to analyze the MU activation in Isometric and Dynamic contraction with different MVC level.The Signal was acquired in deep muscle of forearm in Suraface EMG and validated with needel EMG. Our Result showed there was no significant difference observed in Isometric contraction.RMS and IEMG were the best features in isometric contraction and WL was the best feature in Dynamic contraction.

REFERENCES

[1] B. Brenner and E. Eisenberg, “The mechanism of muscle contraction Biochemical, mechanical, and structural approaches to elucidate cross bridge action in muscle”, cardiac Energetic, Springer, 1997.

[2] Albert szent-gyorgyi, “The Mechanism of Muscle Contraction” Proceedings of national science, Vol.71, No.9, pp-3343-3344, 1974.

[3] Varick L. Olson, M.A., Gary L. Smidt and Richard C. Johnston, “The Maximum Torque Generated by the Eccentric, Isometric, and Concentric Contractions of the Hip Abductor Muscles” , physical therapy , 1972.

[4] Predrag Nemec, Milos Milosevis, Vesna Nemec and Milenko Milosevic , “Production and development of muscle force in elite male volleyball players Spike”, Sport Science , Suppl 2: 32-40,2016.

[5] C.J. Heckmana and Roger M. Enokab, “Physiology of the motor neuron and the motor unit”, Clinical Neurophysiology of Motor Neuron Diseases Handbook of Clinical neurophysiology, Chapter 6, Vol. 4,2004.

[6] NuriaMasso , Ferran Rey, Dani Romero, Gabriel Gual, Lluis Costa and Ana German, “Surface electromyography applications in the sport”, apunts Del Sports , Elesvier, pp.121-130, 2010.

[7] M.A. Cavalcanti Garcia and T.M. M. Vieira, “ Surface electromyography: Why, when and how to use it”, Medicina del Deporte Rev Andal Med Deporte, pp.17-28, 2011.

[8] Nurhazimah Nazmi, MohdAzizi Abdul Rahman,Shin-Ichiroh Yamamoto, SitiAnom Ahmad, HairiZamzuri, and SaifulAmriMazlan’ “ A Review of Classification Techniques of EMG Signals during Isotonic and Isometric Contractions”, Sensors , 2016.

[9] Devon I.Rubin,MD, “ Needle Electromyography: Basic Concepts and Patterns of Abnormalities”, Neuro Clinic, Elsevier, 2012.

[10] Erik Stalberg , Hans van Dijk , Bjorn Falck , Jun Kimura , Christoph Neuwirth , Matthew Pitt Simon Podnar , Devon I. Rubin, Seward Rutkove , Donald B. Sanders ,Masahiro Sonoo HaticeTankisi, MachielZwart, “Standards for quantification of EMG anneurography, Clinical Neurophysiology, Elsevier , 2019.

[11] Daniel L.Menkes and Robert Pierce, "Needle EMG muscle identification: A systematic approach to needle EMG examination", Elsvier, Clinical Neurophysiology Practice 4, pp.199-211, 2019.

[12] Mohan Singh and Peter V. Karpovich, "Strength of forearm flexors and extensors in men and women", Journal of Applied Physiology, Vol.25, No.2, 1968.

[13] Dick F .Stegeman and Hermie J Hermens, "Standards for surface electromyography: The European project Surface EMG for non-invasive assessment of muscles", 2007.

[14] T.Moritani,M.Muro , Motor unit activity and surface electromyography power spectrum during incresed force of contraction", European journal of applied physiology, 56, pp.260-265,1987.

[15] Kukulka P.Clamann, Comparision of the recruitment and discharge properties of motor motors units in human brachial biceps and adductor pollicis during isometric contractions, Brain Research 219, pp. 45-55, 1981.

[16] Kohei Watanabe and Hiroshi Akima, " Validity of surface electromyography for vastus intermedius muscle assessed by needle Electromyography", Journal of Neuroscience Methods , 198(2) , pp.332-335.

[17] P.A Karthick and Ramakrishnan Swaminathan, " Surface electromyography based muscle fatigue progression analysis using modified B distribution time-frequency features", Biomedical Signal Processing and Control , pp.42-51, 2016