International Journal of Physical Education, Sports and Health 2021; 8(6): 06-10

P-ISSN: 2394-1685
E-ISSN: 2394-1693
Impact Factor (ISRA): 5.38
IJPESH 2021; 8(6): 06-10

www.kheljournal.com
Received: 04-09-2021
Accepted: 06-10-2021

Priyam Chatterjee
M.Sc., Department of Physiology, Serampore College, Affiliated to University of Calcutta, 9, William Carey Road, Serampore, Hooghly, West Bengal, India

Priya Nandy
Research Scholar, Department of Physiology, Serampore College, Affiliated to University of Calcutta, 9, William Carey Road, Serampore, Hooghly, West Bengal, India

Anupam Bandyopadhyay
Associate Professor, Department of Physiology, Serampore College, Affiliated to University of Calcutta, 9, William Carey Road, Serampore, Hooghly, West Bengal, India

Corresponding Author:
Anupam Bandyopadhyay
Associate Professor, Department of Physiology, Serampore College, Affiliated to University of Calcutta, 9, William Carey Road, Serampore, Hooghly, West Bengal, India

Formulation of regression equation on the basis of endurance time and fatigue indices in biceps brachii by using surface-EMG of 14-19 years aged trained male volleyball players

Priyam Chatterjee, Priya Nandy and Anupam Bandyopadhyay

DOI: https://doi.org/10.22271/kheljournal.2021.v8.i6a.2270

Abstract
The key component of this study is to analyze the change in fatigue Indices during muscular exhaustion by applying this connection. Forty male volleyball players aged 14-19 years having no muscular injury participated in this study. Surface-EMG was done in biceps brachii of dominant hand in each player. Endurance time was recorded by holding 30 percent of MVC in each subject until breakpoint was attained. Fatigue Indices were computed from the raw EMG signals using FFT. Pearson's correlation and regression with the best fitting curve analysis were performed to establish the relationships between the variables. Fatigue indices were shown to have a positive correlation with endurance time ($p<0.05$). Analysis has been done and best-fitted curves indicated the best feasible relationship. Endurance time is a direct indicator of muscle fatigue i.e. increased endurance time suggests that muscle is less vulnerable to fatigue and vice versa. The relationship between endurance time and fatigue indices (MNF and MDF) can be mathematically stated as y=f(x). 'Power' & 'Growth' associations respectively and were found to be best-fitted according to the regression analysis. According to those correlations, the relationship between both the fatigue indices (MNF and MDF) were developed.

Keywords: electromyography, endurance time, muscle fatigue, muscle strength, regression

Introduction
The relationship of EMG activity to muscle force depends on several factors. It appears monotonic in the sense that an increase in muscle tension is paralleled by an increase in myoelectric activity and nonlinear in many circumstances. These relationships were often described with piecewise linear regression or by using power functions [1]. It had been shown in a study that when the muscle was rested, the mean frequency of the myoelectric signal may be twice that found when the muscle was fatigued [2]. Researchers in their study had expressed that when a single muscle was monitored where multiple muscles were sharing the load and this muscle fatigue was associated with increased self-reported discomfort [3]. Another research was done using EMG to evaluate not only relative muscle activity but also localized muscle fatigue. Such an estimate of muscle fatigue relies on a change in the spectral characteristics of the EMG and a comparison of the electrical activity from the biceps brachii during three stages of a fatiguing static contraction and shown that both the increase in amplitude and decrease in frequency with fatigue [4].
It was reported that repetitive movements during sports activities may lead to cumulative tissue loading, muscle fatigue, and strain injuries. During repetitive movements, muscle fatigue may be accompanied by changes in movement patterns and by changes in joint proprioception [5]. The proprioception alteration due to muscle fatigue is very important especially in sports activities where optimal movement patterns and appropriate motor control are required [5]. It was reported that changes in movement patterns due to muscle fatigue may contribute to acute or overuse injuries and too many musculoskeletal disorders. Evaluation of muscle fatigue is usually done by sEMG signal spectral frequency analysis. But signal processing methods may be different even if the final parameters are the same.

Therefore, the differences in the clinical use of different methods of sEMG signal processing in the evaluation of muscle fatigue due to physical effort need a comprehensive investigation [5]. A proper relationship results in improper interpretations associated with muscle fatigue.

Muscle activities can be detected by EMG. Proper evaluation of any muscular activity by using EMG requires precise and relevant relationships among the measured variables. According to different reported studies, Theoretical and mathematical relationships are there to define mean frequency (MNF) and median frequency (MDF) for representing fatigue indices [6]. Although MNF and MDF are termed as fatigue indices, their changes and direct relationship with muscle fatigue must be observed. Endurance time is also a direct indicator of muscle fatigue. So relating endurance time and fatigue indices may have a relevant result and will help to conclude the relationship of fatigue indices with muscle fatigue.

Materials & Methods

Selection of participants and ethical permission

Forty male volleyball players aged 16.40±1.75 years having 3.98±2.26 years of training experience participated in the study. Participants undergoing the study should not have any muscular injury or any drop out phenomenon. Participants and the respective club management committee were provided with the brief of the purposes and requirements of the study 15 days prior to volunteering and gave written informed consent prior to participating. The study was approved by the Human Ethical Committee (HEC, Serampore College, affiliated to University of Calcutta, Serampore, Hooghly, West Bengal, India) numbered SC/HEC/2018/ P1.

For the myoelectric study, participants were brought to the Sports and Exercise Laboratory. One of the major muscles engaged in volleyball was selected as subjecting muscles i.e. Biceps Brachii. Players were brought to the laboratory and given rest and the recordings were taken in the following steps.

Electromyographic recording and study design

EMG recording kit (iWorx) was set up and prepared for recording. Then the Biceps Brachii muscle was isolated and surface button electrodes were placed applying the gel on the skin, hair was removed if needed. Participants were asked to stand and the recorder was started to record muscle activity in real time.

Participants were then given the FT-325 handgrip dynamometer and asked to perform his maximum hand grip strength and recorded real-time. Everyone was allowed to perform 10 attempts and the maximum was taken into account as MVC (kg).

Thereafter the subjects were asked to hold the fixed value of 30% of their respective MVC (kg) constantly for endurance time recording. The breakpoint was obtained when the participants were unable to maintain holding the same frequency. Thus endurance time was calculated. Fatigue indices i.e. mean frequency (MNF) and median frequency (MDF) were recorded after Fast Fourier Transformation (FFT) from the raw EMG signal.

The time related (Endurance time) and frequency related (MNF and MDF) Endurance time is the time for how long the subject can hold the given load, breakpoint suggests that muscle is fatigued and unable to continue the workload. Mean Frequency (MNF) is the mathematical mean of the spectrum curve. It is an average frequency which can be calculated by taking the sum of the product of the EMG power spectrum and the frequency divided by the total sum of the power spectrum. Median Frequency is an important parameter which divides the total power spectrum into two equal parts. MDF is also defined as half of the total power [6].

Statistical Analysis

Statistical analysis of all data was done by IBM Statistical Package for Social Sciences (SPSS) version 24. Correlations among the parameters were obtained by Pearson's product moment correlation at 'α' level of 0.05, $p<0.05$ were considered to be significant. Correlated parameters were further analyzed by regression followed by best fitting curve analysis to establish their relationship.

Results

Mean±SD and Range of the parameters are shown in the Table-I. Positive correlations were found between the Endurance time and Fatigue Indices (MNF and MDF) at $p<0.05$ (Table-II). As Correlations were found among the parameters, Regression analysis has been done between Endurance time and fatigue indices i.e. MNF (Fig 1), MDF (Fig 3) based on best fitting curve estimation (Table 1II). Endurance time vs. MNF and MDF were found to be best fitted in Power (Fig 2) and Growth (Fig 4) considering the R, R^2 and adjusted R^2 value (Table 1II).

Table 1: Mean±SD and Range of the parameters (n=40)

Variables	Mean±SD	Range
Age (years)	16.4±1.75	5.4
Body Height (cm)	165.79±9.66	47.7
Body Weight (kg)	59.28±12.82	47.4
Years of Training	3.98±2.26	10
Endurance Time (sec)	32.45±18.65	56.88
Mean Frequency (MNF)	219.5±22.54	93.42
Median Frequency (MDF)	193.55±28.03	148

Table 2: Pearson's Correlations between Endurance time and Fatigue indices (MNF, MDF)

	MNF	MDF
Endurance time	**0.828***	**0.379***
*Correlation is significant at $p<0.05$		

Table 3: Endurance time vs Fatige Indices (MNF and MDF) Regression analysis

		Dependent Variable= MNF			Dependent Variable= MDF		
S. No	Equations	R Value	R^2 Value	Adjusted R^2 Value	R Value	R^2 Value	Adjusted R^2 Value
1	Linear	0.828	0.685	0.677	0.379	0.144	0.121
2	Logarithmic	0.84	0.705	0.698	0.35	0.123	0.1
3	Inverse	0.808	0.653	0.644	0.304	0.093	0.069
4	Quadratic	0.838	0.703	0.687	0.392	0.153	0.108
5	Cubic	0.844	0.716	0.693	0.426	0.182	0.114
6	Compound	0.829	0.687	0.678	0.382	0.147	0.124
7	Power	0.847*	0.717*	0.71*	0.368	0.136	0.113

8	S	0.82	0.673	0.664	0.331	0.11	0.086
9	Growth	0.829	0.687	0.678	0.384*	0.148*	0.125*
10	Exponential	0.829	0.687	0.678	0.382	0.147	0.124
11	Logistic	0.829	0.687	0.678	0.382	0.147	0.124
Independent Variable: Endurance Time (sec) *Best fitted							

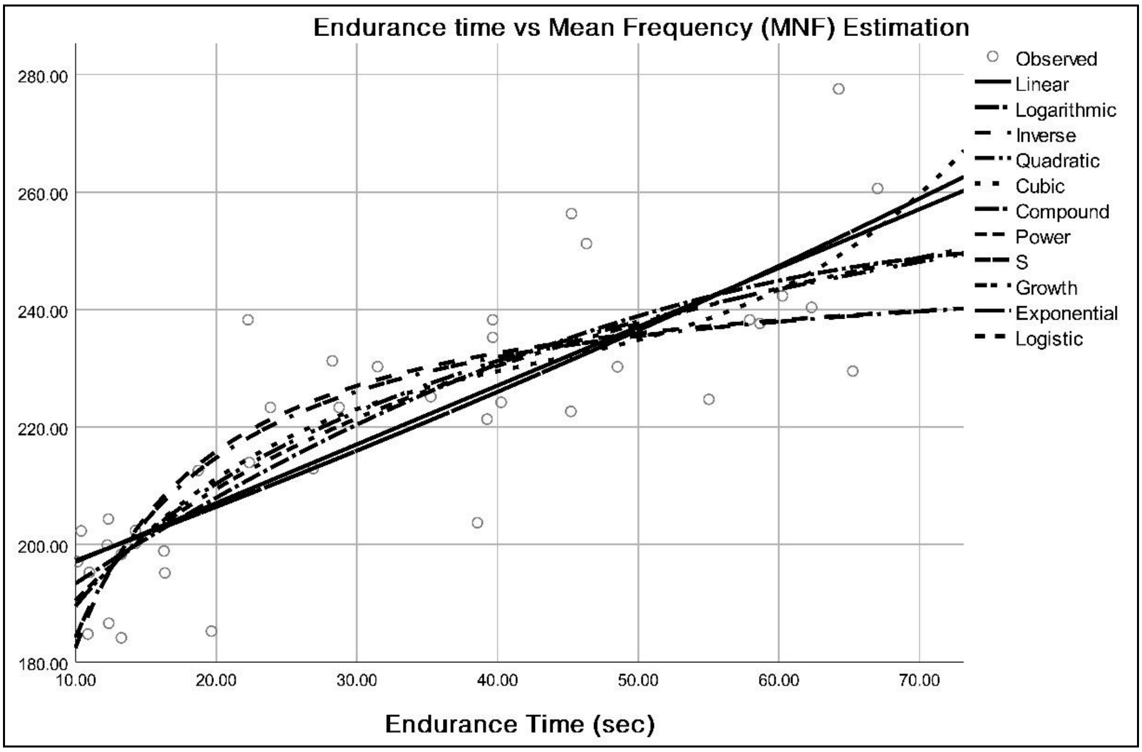

Fig 1: Endurance time vs Mean Frequency (MNF) Regression analysis

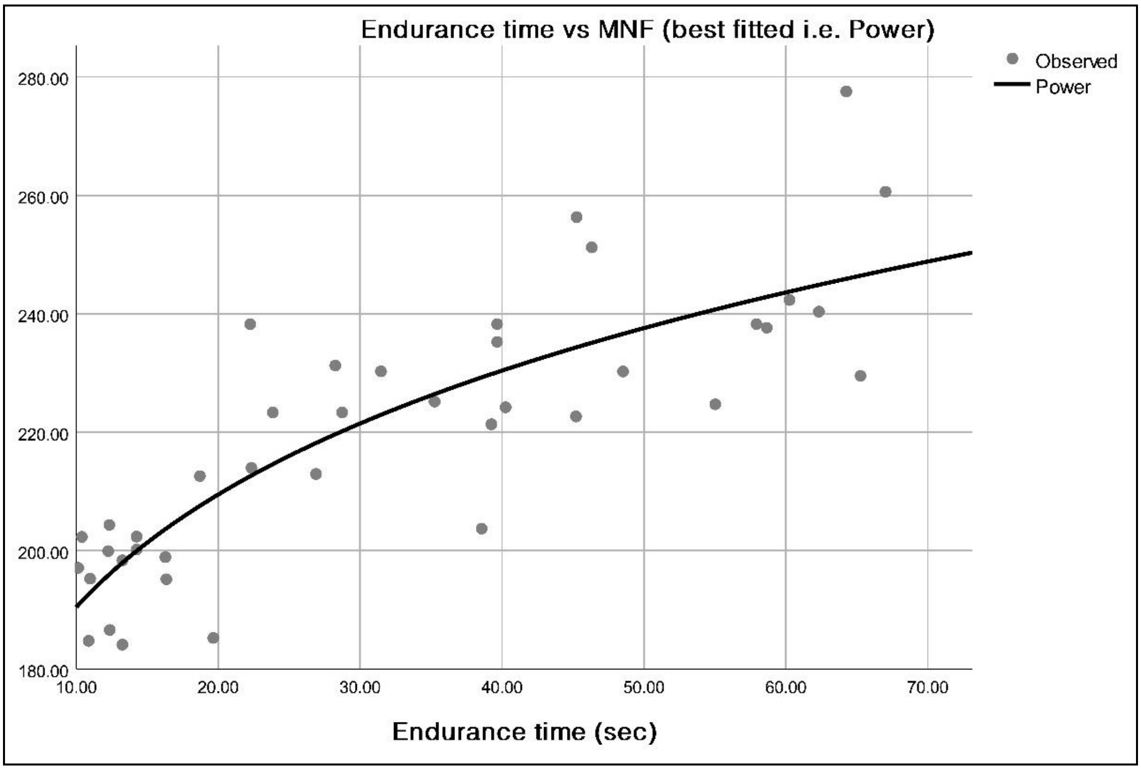

Fig 2: Endurance time vs Mean Frequency (MNF) Best Fitted Curve (i.e. Power)

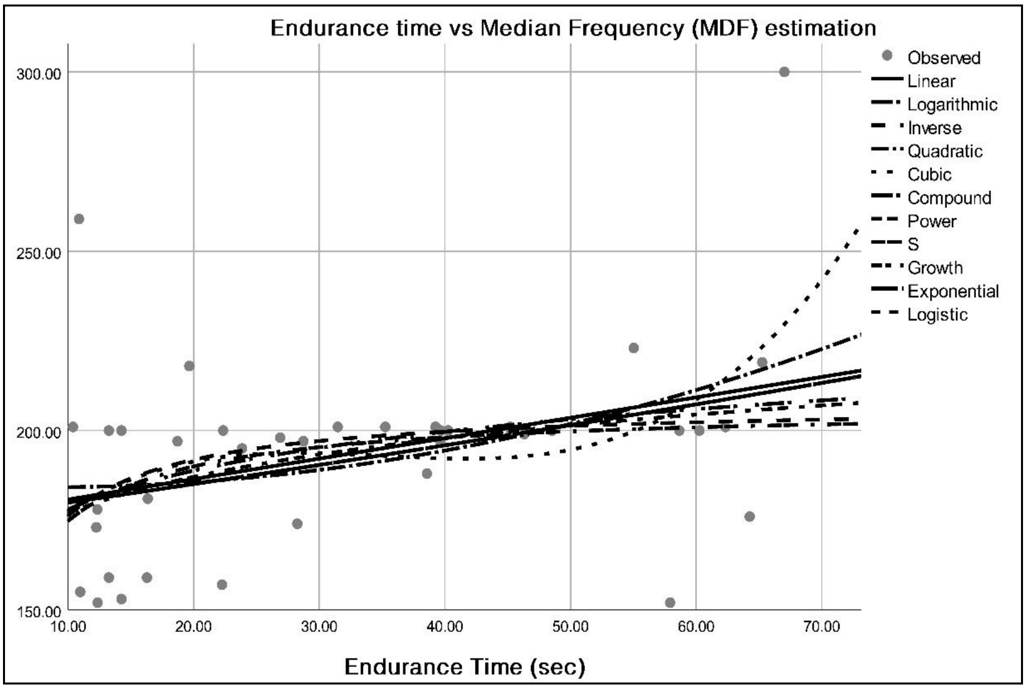

Fig 3: Endurance time vs Median Frequency (MDF) Regression analysis

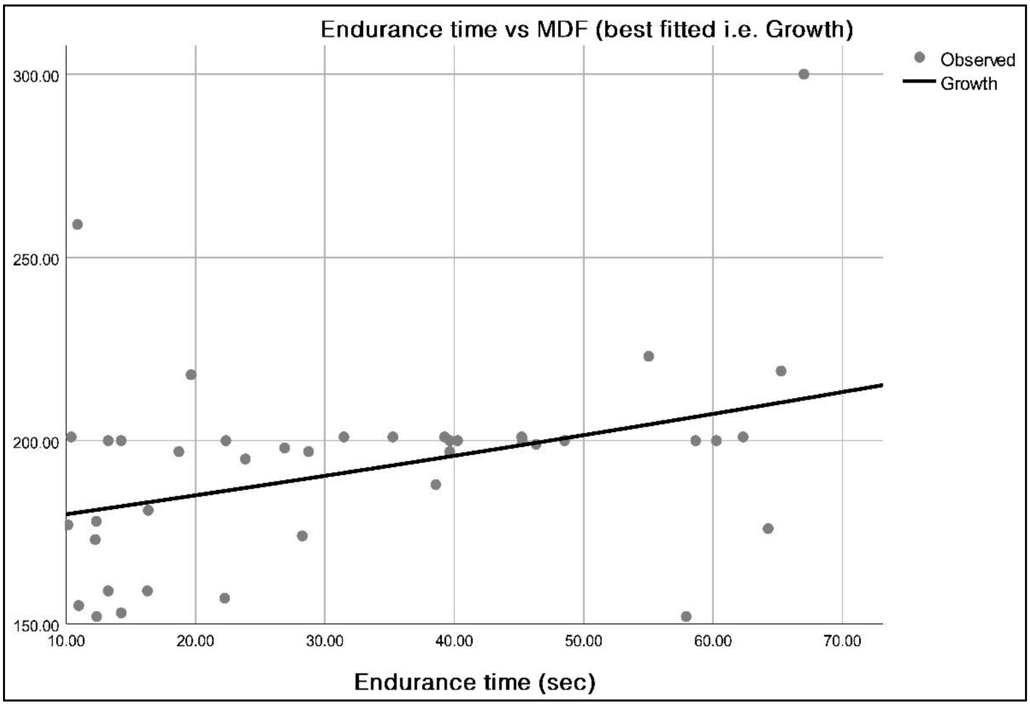

Fig 4: Endurance time vs Median Frequency (MDF) Best Fitted Curve (i.e. Growth)

Discussion

In the volleyball game, the percentage of predominant energy sources usually comes 55% from ATP-CP source, 30% from glycolytic source and only near about 15% from the aerobic source. IIb muscle fibres are more fatigable than others [7]. Surface electrode EMG can be a useful tool to study different task as it records the complex motor unit potential resulting from the superimposition of several muscle fibres known as Muscle action potential [8]. The measurement of sEMG is dependent on the amplitude of sEMG signal and frequency domain properties [9-12].

It is known that the muscle is less susceptible to fatigue as endurance time is delayed. So the fatigue and fatigue indices (MNF, MDF). From the Fig.1 it is observed that endurance time is proportional to the values of mean and median frequencies. So increased value MNF and MDF indicates that the muscle is less susceptible to fatigue and vice versa.

The relationship between endurance time and fatigue indices (MNF and MDF) by regression can be mathematically presented as y=f(x). 'Power' & 'Growth' relationships were found to be best-fitted according to the regression analysis. The equations found by the regression are:

- ln(MNF)=4.93+0.137ln(Endurance time)
- ln(MDF)=5.164+0.003(Endurance time)

Therefore the obtained relationship between the fatigue indices and endurance time is:

$$\frac{\ln(\text{MNF})}{\ln(\text{MDF})} = \frac{4.93+0.137\ln(\text{Endurance time})}{5.164+0.003(\text{Endurance time})}$$

Conclusion
Endurance time is a direct indicator of muscle fatigue. So on the basis to that, using surface electromyography a regression equation was formulated to find out the relationship between fatigue and fatigue indices (MNF and MDF). Where best-fitted curves interpreted the best possible relationship.

Acknowledgments
It is a pleasure to acknowledge gratefully the help, willingness and co-operation of Mr. Sudipta Hazra and his team of Dilip Smriti Sangha, Mr. Sandip Ghoshal and his team of Rishra Yuvak Samity and all the participants who voluntarily participated in the project work, without which it could not have been carried out. The authors would like to convey gratitude to the Department of Physiology, Serampore College for their support. The financial support was received from the Departmental funding since no external financial support was received for this work.

Practical implication
- The correlation between different parameters will help the researchers to formulate a good design study in the future.
- The relationship between the endurance time and both of the fatigue indices will help in further findings related to sports and muscle physiology.
- The findings of the present study may have useful applications in the supervision of the health safety of any players or a normal person.
- This study has a limitation as other groups of muscles involved in volleyball games could not be taken into account.

References
1. Chaffin DB, Lee M, Freivalds A. Muscle strength assessment from EMG analysis. Med Sci Sports Exerc [Internet]. [Cited 2018 Aug 6] 1980;12(3):205-11. Available from: http://www.ncbi.nlm.nih.gov/pubmed/7402058
2. Stulen FB, De Luca CJ. Frequency Parameters of the Myoelectric Signal as a Measure of Muscle Conduction Velocity. IEEE Trans Biomed Eng [Internet]. [Cited 2018 Aug 7] 1981;BME-28(7):515-23. Available from: http://www.ncbi.nlm.nih.gov/pubmed/7275132
3. Öberg T, SANDSJö L, Kadefors R. Subjective and objective evaluation of shoulder muscle fatigue. Ergonomics [Internet]. 1994 Aug [cited Aug 7] 2018;37(8):1323-33. Available from: http://www.tandfonline.com/doi/abs/10.1080/00140139408964911
4. Potvin JR, O'Brien PR. Trunk muscle co-contraction increases during fatiguing, isometric, lateral bend exertions. Possible implications for spine stability. Spine (Phila Pa 1976) [Internet]. [cited 2018 Aug 7] 1998;23(7):774-80; discussion 781. Available from: http://www.ncbi.nlm.nih.gov/pubmed/9563107
5. Oleksy L, Czarny W, Bajorek W, Krol P, Mika A, Kielnar R. The Evaluation of Shoulder Muscle Fatigue in Volleyball Players. J Nov Physiother [Internet]. [Cited 2018 Nov 26] 2018;08(02):1-6. Available from: https://www.omicsonline.org/open-access/the-evaluation-of-shoulder-muscle-fatigue-in-volleyball-players-100576.html
6. Ruchika SD. An Explanatory Study of the Parameters to Be Measured From. Int J Eng Comput Sci 2013;2(1).
7. Yamaguchi GT, Sawa AGU, Moran DW, Fessler MJWJ. A survey of human musculotendon actuator parameters. In: Winters JM, Woo SL (eds.). Berlin: Springer. 1990. p. Multiple Muscle Systems, 717-773.
8. De Luca CJ. The Use of Surface Electromyography in Biomechanics. J Appl Biomech [Internet]. [Cited 2018 Aug 6] 1997;13(2):135-63. Available from: http://journals.humankinetics.com/doi/10.1123/jab.13.2.135
9. Basmajian JVDLC. Muscle Alive: Their Function Revealed by Electromyography. Baltimore: Willians & Wilkins 1985, 201-22.
10. Gerdle B, Karlsson S, Day S, Djupsjöbacka M. Acquisition, Processing and Analysis of the Surface Electromyogram. In: Modern Techniques in Neuroscience Research [Internet]. Berlin, Heidelberg: Springer Berlin Heidelberg; [cited 2018 Aug 13]. 1999, 705-55. Available from: http://link.springer.com/10.1007/978-3-642-58552-4_26
11. Oskoei MA, Hu H. Myoelectric control systems—A survey [Internet]. Biomed. Signal Process. Control 2007;2:275-294. Available from: https://www.google.com/search?q=oskei+and+hu+2008+emg&client=firefox-b-ab&biw=1366&bih=631&source=lnms&sa=X&ved=0ahUKEwjh7LGcy-rcAhVLro8KHU4WDw0Q_AUICSgA
12. Phinyomark A, Thongpanja S, Hu H, Phukpattaranont P, Limsakul C. The Usefulness of Mean and Median Frequencies in Electromyography Analysis. Comput Intell Electromyogr Anal - A Perspect Curr Appl Futur Challenges [Internet] 2012. Available from: http://www.intechopen.com/books/computational-intelligence-in-electromyography-analysis-a-perspective-on-current-applications-and-future-challenges/the-usefulness-of-mean-and-median-frequencies-in-electromyography-analysis