CHARACTERIZATION OF BICEPS BRACHII MUSCLE ACTIVITY DURING CONTRACTIONS USING SURFACE ELECTROMYOGRAPHIC SIGNAL ANALYSIS

by

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بسم الله الرحمن الرحيم

(In the name of Allah (S.W.T.), the Most Gracious and the Most Merciful)

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LIST OF ABBREVIATIONS

AVG	-	Average
A/D	-	Analog-to-Digital
ARV	-	Average Rectified Value
Ag/AgCL	-	Silver/Silver Chloride
AP	-	Anthropometric parameter
ANOVA	-	Analysis of Variances
ACC	-	Asian Cricket Coach
'A'	-	Adolescents
BB	-	Biceps Brachii
BMI	-	Body Mass Index
BC	-	Back-foot Contact
CV	-	Coefficient of Variance
CL	-	Confidence level
CC	-	Concentric Contraction
Cad	-	Computer Aided Design
CCD	-	Charge-coupled device
CMRR	-	Common-Mode Rejection Ratio
Comp	-	Competitors
CSV	-	Comma Separated Value
DAMV	-	Difference Absolute Mean Value
DAQ	-	Data Acquisition
DLL	-	Dynamically Linked Libraries

DDR II	-	Double Data Rate II
EMG	-	Electromyography
EBB	-	Entire Biceps Brachii
EC	-	Eccentric Contraction
EA	-	Elbow angle
FB	-	Fast Bowlers
FC	-	Front-foot Contact
FFT	-	Fast Fourier Transform
FT	-	Follow Through
GUI	-	Graphical User Interface
GHz	-	Giga-Hertz
GSR	-	Galvanic Skin Response
GPRS	-	General Packet Radio Services
GL	-	Graphics Library
GSM	-	Global System for Mobile Communications
Hz	-	Hertz
ICC	-	Inter-class Correlation Coefficient
I/O	-	Input/Output
IC	-	Integrated Circuit
IEMG	-	Integrated Electromyography
Isom	-	Isometric
Isok	-	Isokinetic
KHz	-	Kilo-Hertz
IDE	-	Integrated Development Environment

KHz	-	Kilo-Hertz
LSP	-	Location of Sensor Placement
LSB	-	Least Significant Bit
LCD	-	Liquid Crystal Display
km/h		Kilometer per hour
Max	-	Maximum
MAV	-	Mean Amplitude Value
MSA	-	Mean Spike Amplitude
MSF	-	Mean Spike Frequency
MSD	-	Mean Spike Duration
MSS	-	Mean Spike Slope
MTA	-	Mean Turn Amplitude
MTF	-	Mean Turn Frequency
MTD	-	Mean Turn Duration
MU	-	Motor Unit
MUAP	-	Motor Unit Action Potential
MUAPT	-	Motor Unit Action Potential Train
MVIC	-	Maximum Volitional Isometric Contractions
MB	-	Mid Bound
MPF	-	Mean Power Frequency
MDF	-	Median Frequency
MC	-	Muscle Contraction
MVC	-	Maximum Voluntary Contraction

NM	-	Not Mentioned
PDA	-	Personal Digital Assistance
PS	-	Pre-Delivery Stride
PSD	-	Power Spectral Density
PP	-	Performance parameter
QTM	-	Qualisys Track Manager
RMS	-	Root Mean Square
RU	-	Run-up
RB	-	Release of the Ball
SB	-	Spin Bowlers
SE	-	Standard Error
SD	-	Standard Deviation
SENIAM	-	Surface ElectroMyoGraphy for the Non-Invasive Assessment of Muscles
sEMG	-	Surface Electromyography
SP	-	Sensor Placement
SPE	-	Sensor Placement Effect
TB	-	Triceps Brachii
'T'	-	Tricenerian
'V'	-	Vicenerian
WAF	-	World Arm Wrestling Federation

LIST OF SYMBOLS

V	-	Volt
mV	-	Milivolts
μV	-	Microvolts
Ω	-	Ohm
KΩ	-	Kilo Ohm
μF	-	Micro Farad
mA	-	Miliamps
mW	-	Kilowatts
dB	-	Decibel
C#	-	C Sharp
VC++	-	Visual C Plus Plus
σ	-	Statistical Significant Level for Hypothesis Testing
p	-	Probability Value for Hypothesis Testing
×	-	Literatures not found
✓	-	Literatures found

Analisis Isyarat Pencirian Aktiviti Otot Bisep Brachii Semasa Kontraksi Menggunakan Electromyographic Permukaan

ABSTRAK

Analisis permukaan isyarat Electromyography (EMG), mengukur aktiviti elektrik otot, adalah salah satu bidang yang penting pada masa kini untuk memahami ciri-ciri otot yang sesuai semasa pengaktifannya. Isyarat EMG pada otot rangka memberikan korelasi yang tinggi antara daya otot dan kontraksi. Antara semua bahagian atasan otot rangka, brachii bisep (BB) adalah yang sering bertanggungjawab dalam mengakibatkan kesakitan, kecacatan, kelemahan, kelembutan dan ketidakfungsian disebabkan oleh berlebihan pergerakan lengan atas. Oleh itu, pemahaman yang betul tentang fungsi otot dan ciri-ciri BB adalah penting dari perspektif bioperubatan dan biomekanik. Dengan itu, tujuan tesis ini adalah untuk menyiasat amplitude isyarat EMG untuk memahami aktiviti-aktiviti otot BB semasa kontraksi statik dan dinamik yang dihasilkan oleh daya beban dan cengkaman, serta pergerakan sukan secara paksa. Tesis ini juga bertujuan untuk menyediakan satu tablet tangan berasaskan komputer peranti maklum balas EMG yang boleh dimuatkan ke dalam sesuatu otot. Tesis ini dibahagikan kepada tiga fasa. Fasa pertama membentangkan aktiviti otot BB, semasa kontraksi yang dihasilkan oleh kedua-dua beban dan daya cengkaman dari segi lokasi penempatan sensor, pelbagai sudut sendi siku dan parameter antropometri. Fasa kedua menyiasat aktiviti otot BB, fungsi dan keletihan semasa kontraksi yang dihasilkan oleh dua aktiviti sukan aktif (iaitu, gusti lengan dan bowling kriket). Isyarat EMG dibandingkan berdasarkan penempatan sensor, parameter antropometri, parameter prestasi dan pelbagai mekanik lengan. Fasa terakhir membincangkan proses reka bentuk dan pembangunan sistem perolehan data mudah alih (DAQ) EMG dan keputusan daripada sistem tersebut akan dikategorikan berdasarkan otot BB. Dua puluh empat subjek yang sihat (lelaki: 21 dan perempuan: 3) telah mengambil bahagian dalam eksperimen ini. Nilai punca kuasa dua min amplitud isyarat EMG yang dicatatkan telah dinormakan kepada amplitud diperhatikan semasa kontraksi maksimum atau sub-maksima secara sukarela dalam tempoh masa tertentu. Beberapa kaedah statistik telah dijalankan untuk menilai dan membandingkan aktiviti otot serta hubungan parameter yang berbeza. Akhirnya, tesis membentangkan ciri-ciri berkesan untuk otot BB ditentukan daripada ujian isyarat EMG semasa pengeluaran tenaga dan pengecutan otot. Keputusan menunjukkan bahawa amplitud isyarat EMG berbeza bergantung kepada jenis kontraksi otot, prosedur penempatan sensor, pelbagai sudut siku, parameter antropometri dan prestasi yang berbeza. Tesis juga berjaya melengkapkan sistem EMG DAQ yang boleh dipercayai, di mana isyarat boleh diakses secara grafik dan disimpan dalam bentuk teks. Hasil daripada projek ini boleh memainkan peranan permulaan yang penting dalam garis panduan BB otot khusus dan protokol rawatan untuk mengurangkan kerosakan otot atau keletihan, membangunkan program-program pemulihan yang lebih baik, dan meningkatkan prestasi latihan yang sengit di bawah keadaan yang berbeza.

Characterization of Biceps Brachii Muscle Activity during Contractions using Surface Electromyographic Signal Analysis

ABSTRACT

Analysis of surface electromyography (EMG) signal, measuring electrical activity of muscles, is one of the key areas of recent interest to understand the appropriate muscle characteristic during its activation. EMG signal on skeletal muscle provides a high correlation between muscle force and contraction. Among all the upper extremity skeletal muscles, the biceps brachii (BB) is most commonly responsible for causing pain, disability, weakness, tenderness and dysfunction due to overuse of upper arm movements. Therefore, proper understanding of the muscle function and characteristics of BB is essential from the biomedical and biomechanical perspective. Thus, the purpose of the present thesis is to investigate the EMG signal amplitudes to understand the BB muscle activities during static and dynamic contractions produced by load and grip force, and forceful sports movement. The thesis also aims to provide a hand-held tablet computer based EMG feedback device that can fit into the single muscle. The thesis is divided into three phases. The first phase presents the BB muscle activity, during the contractions produced by both load and grip force in terms of sensor placement locations, range of elbow joint angle and anthropometric parameters. Phase II investigates the BB muscle activity, function and fatigue during contractions generated by two active sport activities (namely, arm wrestling and cricket bowling). The EMG signals were compared on the basis of sensor placement, anthropometric parameters, performance parameters and various arm mechanics. The last phase discusses the design and development process of a portable EMG data acquisition (DAQ) system and obtained results from the system were analyzed to characterize the BB muscle activity. Twenty four healthy subjects (male: 21 and female: 3) participated in the entire experiments. The recorded root mean square EMG signal amplitude was normalized to the amplitude observed during the maximal or sub-maximal voluntary contraction (MVC) over a certain period of time. A number of mathematical and statistical analyses were performed to evaluate and compare the muscle activity as well as the relationship among different parameters. Finally, the thesis presents the effective characteristics of BB muscle determined from testing of EMG signal during production of force and contraction. The results indicate that EMG signal amplitudes differ depending on the type of muscle contractions, sensors placement procedures, range of elbow angle, different anthropometric and performance parameters. The thesis also successfully completes a reliable EMG DAQ system, where signals are accessible graphically and stored in text form. The results from this thesis may play a pivotal role in initiation of BB muscle-specific guidelines and treatment protocols to decrease muscle damage or fatigue, develop better rehabilitation programs, and improve the intense exercise performance under different conditions.

CHAPTER 1

INTRODUCTION

1.1 Background

The analysis of the electromyography (EMG) signals generated by living individuals is an established area of research that was initiated by Francesco in 1666, Walsh in 1773, and Galvani in 1792 (Murguia et al., 2009; Reaz et al., 2006a). Since then, it has been widely accepted that the processing of EMG signals is essential for understanding how muscular activity (during contraction) generates electrical signals that control the joint movements in the human body (Benedetti et al., 2001). According to a research article published by Putatunda, each muscle in the human muscular system is composed of thousands of tiny fibres and cells, and these control the movement of the various parts of the human body (Putatunda, 2009).

In general, EMG signals are generated from these skeleton muscles in the human body as a result of the contraction of the muscles fibres, and these signals are always stochastic (random) (Komi & Viitasalo, 1976). Biceps brachii (BB) is one of the active skeleton muscles in the upper extremity, and EMG signals are repeatedly generated by this muscle during contraction due to the elbow flexion-relaxation phenomenon (Clark et al., 2003). As a result, these random raw and integrated EMG signals need to be recorded for further analysis. There are 2 types of recording processes that are mainly used to record the signals generated by muscle contraction: needle (invasive) and surface (non-invasive) EMG procedures. Compared with the needle-based process, the surface EMG sensor (electrode) is used more frequently because it is preferred by the subjects and because it is a non-invasive and painless technique that minimizes the signal interference (Mandryk et al., 2006; Pullman et al., 2000). Based on these advantages of the surface EMG technique, this research work has used surface EMG sensor to record the EMG signals from the subjects. It is therefore important to understand how well the surface EMG signals of motor units represent the activity of the BB muscle in the upper extremity.

1.1.1 Anatomical Study of the Biceps Brachii Muscle

One of the fundamental challenges of this thesis is to analyze and characterize the muscle activity of the BB muscle during voluntary contractions with respect to different measurement parameters. Therefore, it is essential to understand the elementary characteristics (anatomy and physiology) of the BB, the rationale underlying the characterisation of activity of this muscle, and how electrical signals are generated from this muscle. According to the anatomical and muscle-mechanics perspective (see Figure 1.1; the image was obtained from the Google database) of the human upper extremity, the BB muscle is normally described as a two-headed muscle that originates proximally through a long head and a short head (Rai et al., 2007). This muscle extends from the shoulder to the elbow on the front of the upper extremity and is responsible for moving the upper limb in different angles due to the strong connectivity of 2 biceps tendons (Naito, 2004). The lower tendon is called the distal tendon, and the upper tendon is called the proximal tendon (*i.e.*, short and long heads, respectively) (Muscle, 2008). These tendons are composed of a huge number of parallel collagen fibres that run the length of the tendon and play the pivotal role in muscle control (Valour et al., 2003).

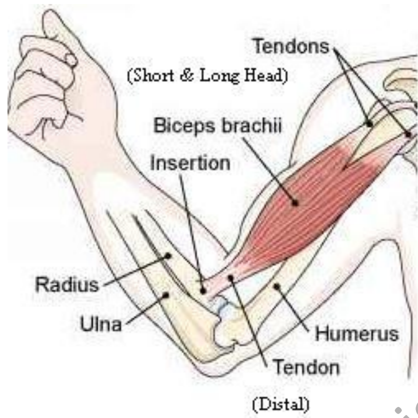

Figure 1.1: Frontal view of the upper arm BB muscle

The muscle fibres are innervated by neurons, the cell bodies of which are located in the spinal cord. The nerve fibres or the axons of these motor neurons leave the spinal cord and are circulated to the motor nerves. Each motor axon branches several times and innervates a large number of muscle fibres (Presentation, 2012), and the collection of a single motor neuron with all of the muscle fibres that it innervates is denoted a motor unit (MU). In summary, the MU is a component of the entire neuromuscular system and includes an anterior horn cell, its axon, and all of the connected muscle fibres. The motor units have overlapping territories, although the muscle fibres of a particular motor unit tend to be situated close to one another. A muscle fibre depolarizes as the signal is reproduced next to its surface and the fibre twitches (contracts) in response to an action potential from the neuron. This depolarization action generates an electric field in the surrounding area of the muscle fibres that can be identified by a skin surface electrode or sensor situated close to the generated field or by a fine-wire electrode inserted in the muscle. The resultant signal is known as the muscle fibre action potential, and the combination of the muscle fibre action potentials from all of the muscle fibres of a particular motor unit is the motor unit action potential (MUAP). All of the muscle fibres in a motor unit are fired each time that a motor unit fires, and the recurring firing of a motor unit generates a train of impulses called the motor unit action potential train (MUAPT). In addition, the summation of the electrical activity generated by each active motor unit is called myoelectrical or electromyography (EMG) signals (Figure 1.2, available from: www. gatlineducation.com).

Therefore, the detection, analysis, and characterization of this EMG signal using appropriate and advance methodologies are becoming an essential tool in the biomedical signal decomposition, and normalization and processing area. To record the process used to understand these signals, this thesis recorded and investigated EMG signals generated by the BB muscle contraction using a non-invasive approach.

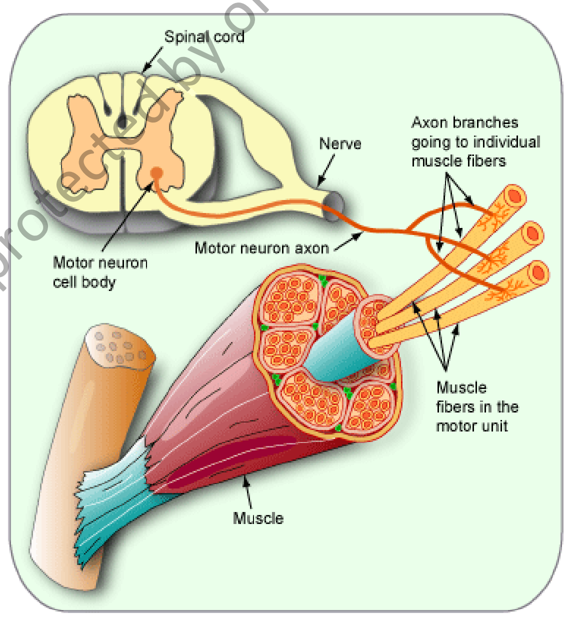

Figure 1.2: MUAP generated from the muscle fibres

The main reasons for this thesis interest in the analysis of the EMG signals generated by this particular muscle (BB) are:

i) It can easily be activated with good control and shows maximum recruitment of motor units during its contractions.

ii) It is in good agreement with the previous findings by other authors.