UNIVERSITI PUTRA MALAYSIA

MEASUREMENT AND MODELING OF HAND GRIP STRENGTH AND ENDURANCE OF MALAYSIAN FEMALE

NOR HADZFIZAH BINTI MOHD RADI

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By

NOR HADZFIZAH BINTI MOHD RADI

Thesis Submitted to the School of Graduate Studies, Universiti Putra Malaysia, in Fulfilment of the Requirements for the Degree of Master of Science

January 2015
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Abstract of thesis presented to the Senate of Universiti Putra Malaysia in fulfilment of the requirement for the degree of the Master of Science

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By

NOR HADZFIZAH BINTI MOHD RADI

January 2015

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Faculty: Engineering

Gripping is an important physical activity in daily routine. The capability of muscular force during gripping can be evaluated in terms of Hand grip Strength (HGS) and Hand grip Endurance (HGE). There are two types of movements that are associated with HGE which are dynamic or repetitive (HGEd) and static (HGEs) movements. In the literature, there are many studies which have been performed to investigate the relationship between demographics and hand anthropometric dimensions factors with HGS. These factors have been used as predictive factor for rehabilitation and recovery. However there is lack of studies showing the relationship combined of demographics and hand anthropometric dimensions to HGE which are important factors in hand rehabilitation and recovery. The aim of this project is to develop predictive model of young female HGS and HGE based on the demographic and hand anthropometric collected. Thus, the specific objectives of this study are; (1) to develop a optimal grip size electronic hand grip strength measuring system that records and analyze the HGS and HGE time series signals, (2) to determine the correlation between demographic and hand anthropometric dimensions, and the HGS as well as HGE of young Malaysian female, and (3) to develop an intelligent predictive model of HGS and HGE. There are three assessments in evaluating the HGS, HGEd and HGEs: single- repetition, 20-repetition and 30-seconds static hold. In addition 6 demographics and 9 hand anthropometrics data are recorded from each volunteer in order to investigate the correlation between HGS, HGEd and HGEs and these data. By using all the associated data, the predictive model of HGS, HGEd and HGEs are developed using Adaptive Neuro Fuzzy Inference System (ANFIS) model. In this study 45 females of the age group 18 to 30 years were recruited. The assessment of grip strength and endurance was measured using the fabricated hand grip measuring device and followed the America Society of Hand Therapy (ASHT) protocols of seating to maintain the consistency of each volunteer’s measurement. By comparing with similar study performed on western
population, the results show that the female HGS in this study is much higher probably due to optimal grip size of the fabricated measuring device. Meanwhile for HGEd and HGEs, these measurements are lower and it is found that the hand dominant was significantly stronger than non-hand dominant for HGS, HGEd and HGEs. In addition the HGS was correlated with weight, Body Mass Index (BMI), hand breadth across thumb, wrist thickness and wrist circumference. Meanwhile HGEd and HGEs were correlated with age and occupation but not correlated with any of the hand anthropometric dimensions. Non-parametric predictive model based on ANFIS is used to develop the predictive HGS and HE model. In developing predictive ANFIS modeling, the input selection was executed and the most significant inputs with respect to HGS, HGEd and HGEs for both hands are obtained. In ANFIS model, there is small discrepancy between actual and predicted average output for training and checking datasets. Nevertheless, this study has shown that ANFIS can be potentially used as an effective predictive model with larger dataset.
Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk Ijazah Sarjana Sains

PENGUKURAN DAN PEMODELAN KEKUATAN GENGGAMAN DAN DAYA TAHAN TANGAN DIKALANGAN WANITA MALAYSIA

Oleh

NOR HADZFIZAH BINTI MOHD RADI

Januari 2015

Pengerusi: Y.M. Raja Kamil bin Raja Ahmad, PhD, Ir

Fakulti: Kejuruteraan

Genggaman adalah aktiviti fizikal yang penting dalam kehidupan sehari-hari. Kebolehan ketahanan otot semasa menggenggam boleh dinilai dalam terma Kekuatan Genggaman Tangan (HGS) dan Daya Tahan Tangan (HGE). Pergerakan HGE terbahagi kepada dua jenis iaitu pergerakan dinamik atau perulangan (HGEd) dan statik (HGEs). Dalam literatur, banyak kajian telah dibuat untuk mengkaji hubungkait antara faktor demografi dan antropometri tangan dengan HGS, yang merupakan sebagai faktor ramalan untuk rehabilitasi dan pemulihan. Namun, terdapat kekurangan kajian yang menunjukkan hubungkait antara gabungan demografi dan antropometri tangan dengan HGE, yang juga boleh diambil kira sebagai faktor penting dalam rehabilitasi tangan dan pemulihan. Matlamat projek ini adalah untuk membina model ramalan bagi HGS dan HGE di kalangan wanita muda berasaskan demografi dan antropometri tangan yang direkodkan. Oleh itu, objiktif kajian ini adalah; (1) untuk membangunkan sistem pengukuran dan merekodkan kekuatan genggaman tangan elektronik yang mempunyai saiz yang optimal dan dapat menganalisis HGS dan HGE dalam isyarat masa siri, (2) untuk menentukan korelasi antara demografi dan antropometri tangan dengan HGS serta HGE di kalangan remaja wanita di Malaysia, dan (3) untuk membangunkan model ramalan pintar HGS dan HGE. Terdapat tiga penilaian dalam menilai HGS, HGEd dan HGEs: pengulangan tunggal, 20-pengulangan dan 30 saat memegang statik. Di samping itu 9 data demografi dan 15 data antropometri tangan direkodkan dari setiap sukarelawan untuk menyiasat hubungan antara HGS, HGEd dan HGEs dengan data tersebut. Dengan menggunakan semua data yang berkaitan, model ramalan HGS, HGEd dan HGEs dibangunkan dengan menggunakan model Adaptive Neuro Fuzzy Inference System (ANFIS). Kajian ini mengambil 45 sukarelawan wanita bagi kumpulan umur 18 hingga 30 tahun. Penilaian kekuatan genggaman dan daya tahan diukur menggunakan alat pengukur yang direka dan mengikuti protokol cara duduk oleh America Society of Hand Therapy (ASHT) untuk mengekalkan
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I certify that a Thesis Examination Committee has met on 30 January 2015 to conduct the final examination of Nor Hadzfizah binti Mohd Radi on her thesis entitled “Measurement and Modeling of Hand Grip Strength and Endurance of Malaysian Female” in accordance with the Universities and University Colleges Act 1971 and the Constitution of the Universiti Putra Malaysia [P.U.(A) 106] 15 March 1998. The Committee recommends that the student be awarded the Master of Science.

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<tr>
<td>CPU</td>
<td>Central Processing Unit</td>
</tr>
<tr>
<td>HGSحد</td>
<td>Hand grip Strength Hand dominant</td>
</tr>
<tr>
<td>HGSنحد</td>
<td>Hand grip Strength Non-hand dominant</td>
</tr>
<tr>
<td>HGEdحد</td>
<td>Hand grip Endurance dynamic Hand dominant</td>
</tr>
<tr>
<td>HGEdنحد</td>
<td>Hand grip Endurance dynamic Non-hand dominant</td>
</tr>
<tr>
<td>HGEشد</td>
<td>Hand grip Endurance static Hand dominant</td>
</tr>
<tr>
<td>HGEنشد</td>
<td>Hand grip Endurance static Non-hand dominant</td>
</tr>
<tr>
<td>RMSE</td>
<td>Root Means Square Error</td>
</tr>
<tr>
<td>FIS</td>
<td>Fuzzy Inference System</td>
</tr>
<tr>
<td>MF</td>
<td>Membership Function</td>
</tr>
<tr>
<td>SD</td>
<td>Standard Deviation</td>
</tr>
</tbody>
</table>
CHAPTER 1

INTRODUCTION

1.1 Background

The anatomy of the hand is complicated and interesting. Its uniqueness is absolutely essential for our daily routine. The function of upper limb especially the hand in normal human daily activity includes light activity such as opening a door by squeezing the doorknob, and heavy activity such as lifting heavy box and transporting it to another place. Hand functions are classified into prehensile (grasping or gripping) and non-prehensile (non-grasp) like pushing and lifting (Napier, 1956). Of all human physical activities none is more important than gripping that generally employs a combination of hand-wrist-forearm movements (Adams, 2006; Imrhan, 2006).

Gripping is one of the hand activities that involves the movement of approximately 35 muscles in the forearm and hand. During gripping activities, the muscles of the flexor mechanism in the hand and forearm create grip strength while the extensors of the forearm stabilize the wrist (Waldo, 1996). There are two types of gripping namely, power grip and precision grip. For the power grip, the object is pressed against the palm of the hand for the generation of force by the fingers and thumb (Napier, 1956) as depicted in Figure 1.1(a). For the precision grip, the object is manipulated between the thumb and the fingertips in a fine movement without the involvement of the palm (Napier, 1956) as depicted in Figure 1.1(b). Power grip is commonly used as an index to assess impairment and treatment outcome of hand function (Talsania and Kozin, 1998).

Figure 1.1. Example of gripping. (a) Power grip. (b) Precision grip. (Source: Napier, 1956)
The capability of muscular force during power grip can be evaluated in terms of Hand grip Strength (HGS) and Hand grip Endurance (HGE). The HGS is typically examining maximum force during a single repetition. Meanwhile the HGE is examining activities that refers to the ability of maintaining a constant desired force over time (Nicolay and Walker, 2005). There are two types of movements that are associated with HGE which are dynamic or repetitive (HGED) and static (HGEs) movements. An example of HGED is typing using the typewriter, while carrying a furniture is an example for HGEs.

It is important to study both HGS and HGE due to the increasing prevalence of Cumulative Trauma Disorders (CTD’s) such as carpal tunnel syndrome, strained muscle, tendonitis, rheumatoid arthritis and many others. Evaluation of HGS and HGE may help to identify individuals at risk of CTDs and improvement of treatment and rehabilitation processes (Robertson et al., 1996). In addition, due to the importance of gripping in many daily activities, HGS is often used in several fields for example, in medical, as an indicator of overall physical strength and health (Boissy et al., 1999; Chilima and Ismail, 2001; Pieterse et al., 2002; Massy-Westropp et al., 2004; Kaburagi et al., 2011) and medical therapy for rehabilitation and recovery (Bohannon, 2001) as well as sports that involves hand performance such as tennis and weightlifting (Fry et al., 2006; Lucki and Nicolay, 2007). The information of HGS can also be used in designing ergonomic hand tools (Nicolay and Walker, 2005; Imrhan, 2006). Other study that focuses on women health, states that normal grip strength is highly related to normal bone mineral density in postmenopausal women (Kärkkäinen et al., 2009) and they suggest that grip strength is a potential screening tool for women at risk of osteoporosis (Di Monaco et al., 2000).

1.2 Problem Statements

There are many studies which have been done to investigate the correlation of socio-demographic variables, for example, age, gender, BMI, occupation and ethnicities with hand grip strength (Nicolay and Walker, 2005; Bandyopadhyay, 2008; Koley and Singh, 2009; Wu et al., 2009). Similar studies on factors that influenced hand grip strength, which are, hand dominance, gender, occupation, height and weight have also been done on Malaysian population, (Kamarul et al., 2006b; Moy et al., 2011; Hossain et al., 2012). Comparing the studies between Asian and Western populations indicate the studies using Western based data do not necessarily applies to Malaysian population as reported (Kamarul et al., 2006a).

Those studies concluded that Western norm of hand grip strength measurement were different to the Asian people, since the hand dimension of Asian were slightly smaller that Westerners. Furthermore there are many studies which have been done to check the relationship such as demographic factors with HGS. This has been used as a predictive factor for rehabilitation and recovery. However there is lack of evidence showing the relationship of
demographics and hand anthropometric dimensions to HGE which is considered to be factors for hand rehabilitation and recovery. And to narrow down, there is lack of study for Malaysian population that has been done to investigate the influences of demographic hand anthropometric dimensions to HGS and HGE.

Hence, the need of study arises due to the lack of study in Malaysian population. This study is conducted to investigate two main points. Firstly is the relationship between HGS and demographic data as well as anthropometric of hand dimensions. The second study is the relationship between HGE and demographic data as well as anthropometric of hand dimensions. And this study is constrained to Malaysian women population only. In the process of this investigation the hand grip strength, hand gripping system is designed for Asian hand size. In addition, the HGS and HGE data analysis for Malaysian population are compared with the Western population based study.

This study is useful for post hand surgery rehabilitation tracking. For example, a carpal tunnel syndrome patient will undergo rehabilitation process to regain their grip strength and endurance back to his or her original level. However the actual level cannot be determined since the patient whom admitted for surgery has a compromised hand function. Due to that motivation, there need such model of HGS and HGE to predict his or her normal level of grip strength based on Asian population.

1.3 Objectives

By referring to the problems explained in Section 1.2, this research focuses on developing models that can be used to predict HGS and HGE using demographic and hand anthropometric dimensions information of young Malaysian female.

The objectives of the research are listed as follows:

1) To develop a electronic hand grip strength measuring system that records and analyze the HGS and HGE time series signals.
2) To determine the correlation between demographic and hand anthropometric dimensions, and the HGS as well as HGE of young Malaysian female.
3) To develop an intelligent predictive model of HGS and HGE.
1.4 Scope

The scope of the research includes the recruitment of selected 45 female volunteers with age mean of 22.40 ± 3.71 years. Volunteers were taken from students and staff of the Electrical and Electronic Engineering Faculty, Universiti Malaysia Pahang. This group of volunteers is assumed to represent young Malaysian female population. The inclusion and exclusion criteria in recruiting the volunteers are listed as follows:

Inclusion criteria:

i. Normal healthy female volunteer in age group of 18 to 30 years. (Which was assessed by questionnaire SF-36)

ii. Volunteer with right hand dominance or left hand dominance. (Dominant hand is defined as the preferred hand used in daily activity like writing, eating and handling heavy objects).

Exclusion criteria:

i. any history of hand, forearm, elbow or shoulder problems
ii. any injury to upper extremity

After considering the inclusion and exclusion criteria, volunteers’ HGS and HGE were assessed for both hands. The device which is designed for the assessment fulfills the criteria of optimal grip span sizes which can produce maximal grip strength. This device is linked to the designed Graphic User Interface (GUI) that records grip force applied versus time. During the assessment, volunteers followed the data collection protocol outlined by American Society of Hand Therapist (ASHT).

There are several assumptions that have been made during the experiments. Firstly, the volunteers exerted maximum effort during all tests. Then, the testing environment was sufficiently stable to rule out any effect due to factors such as room temperature and lighting. Lastly an adjustable chair is assumed comfortable for all volunteers to alter the seat height to accommodate their different size.

1.5 Thesis Outline

This thesis is divided into six main chapters that are organized as follows. In Chapter 1, introductory which includes the background, problem statement, objectives and scope of the research are presented. Literature reviews related to this research are covered in Chapter 2. Chapter 3 presents the development of hand grip strength and endurance measuring system. In this section the
description of the related hardware components and the software designed to carry out the experiment are presented. Next, the details of data collection process, analysis of the data and the development of the intelligent predictive model are presented in Chapter 4. Chapter 5 presents the result of the correlation and discusses the performance analysis of ANFIS predictive model. Lastly, the conclusion of this project and some recommendations for future work are discussed in Chapter 6.
REFERENCES


