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

By

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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

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Genggaman adalah aktiviti fizikal yang penting dalam kehidupan seharian. 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, objektif 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 keseragaman data setiap sukarelawan. Dengan membandingkan kajian yang sama dilakukan ke atas penduduk barat, pengukuran HGS dalam kajian ini menunjukkan lebih tinggi ini berkemungkinan kerana saiz alat pengukur yang optimal. Manakala bagi HGEd dan HGEs, pengukuran ini adalah lebih rendah dan didapati tangan yang dominan adalah jauh lebih kuat daripada tangan bukan dominan untuk HGS, HGEd dan HGEs. Dalam korelasi didapati HGS mempunyai korelasi dengan berat badan, Index Jisim Badan (BMI), lebar tangan termasuk ibu jari, ketebalan pergelangan tangan dan lilitan pergelangan tangan. Manakala HGEd and HGEs mempunyai kolerasi dengan umur dan pekerjaan langsung tiada kaitan dengab dimensi anthropometri tangan. Model ramalan non-parametrik berdasarkan ANFISdigunakan untuk membangunkan model bagi HGS dan HGE. Dalam membangunkan model ramalan ANFIS, pilihan input dilaksanakan dan input yang paling signifikan dengan HGS, HGEd dan HGEs untuk kedua-dua tangan diperolehi. Dalam model ANFIS, terdapat perbezaan kecil di antara keluaran purata sebenar dengan keluaran purata ramalan bagi kedua-dua set data untuk latihan dan periksa. Walau bagaimanapun, kajian ini telah menunjukkan bahawa ANFIS berpotensi digunakan sebagai model ramalan yang efektif dengan dataset yang lebih besar.

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LIST OF ABBREVIATIONS

HGS	Hand grip Strength
HGE	Hand grip Endurance
HGEd	Hand grip Endurance dynamic
HGEs	Hand grip Endurance static
CTD	Cumulative Trauma Disorder
BMI	Body Mass Index
GUI	Graphic User Interface
ASHT	America Society of Hand Therapy
ANFIS	Adaptive Neuro Fuzzy Inference System
DC	Direct Current
DAQ	Data Acquisition
AC	Alternate Current
VDC	Voltage Direct Current
A/D	Analog to Digital
VI	Vitual Instrument
UMP	Universiti Malaysia Pahang
UPM	University Putra Malaysia
CPU	Central Processing Unit
HGShd	Hand grip Strength Hand dominant
HGSnhd	Hand grip Strength Non-hand dominant
HGEdhd	Hand grip Endurance dynamic Hand dominant
HGEdnhd	Hand grip Endurance dynamic Non-hand dominant
HGEshd	Hand grip Endurance static Hand dominant
HGEsnhd	Hand grip Endurance static Non-hand dominant
RMSE	Root Means Square Error
FIS	Fuzzy Inference System
MF	Membership Function
SD	Standard Deviation

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).

(a) (b)

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 ethnics 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.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

This chapter contains the review of previous research that has been done on data collection and analysis, as well as correlation studies of HGS and HGE. The tools of measuring HGS and HGE that have been used in several studies are also reviewed. The influence of the grip span which is known as a factor in influencing the maximum hand grip strength is also discussed. Finally, studies related to predictive models are discussed.

2.2 Hand Grip Strength

HGS measurements are commonly used in the assessment of hand disorders and injuries to evaluate and compare treatments, and to document the progression of recovery or to provide feedback during the rehabilitation process (Bohannon, 2001). It has come to be regarded as the most reliable clinical measure of human strength. Grip strength is also used as a performance index to assess an athlete in sports medicine (Bohannon et al., 2006).

The interest on this study spans across several field, such as medical therapy for rehabilitation (Bohannon, 2001), sports that involved performing using hand (Bohannon et al., 2006), the design of ergonomics tools (Nicolay and Walker, 2005) and others. Hand grip is a measure of muscle strength in the hand and forearm. These muscles play a vital role in the performance of daily activities. The HGS is the result of forceful flexion of all fingers joints with maximum voluntary force that the volunteer is able to exert under normal system for restoring and maintaining energy (Bohannon, 1997).

2.3 Hand Grip Endurance

Endurance of the muscle refers to its capacity to maintain the power produced during activity. Meaning to say, Hand grip endurance (HGE) is the ability to sustain a muscular force for a certain time period. The ability is significantly associated with the strength of brief maximum effort. Therefore, a measurement of HGE may provide additional information for assessment of disability in patients with loss of muscle control, weakness of muscle conditions. Coronell et al. (2004) showed that dysfunction of the quadriceps muscle in patients with chronic obstructive pulmonary disease is underestimated if measured by strength only. Russell et al. (1983) found that HGS was more sensitive to nutritional deprivation than HGE. It has been suggested that strength and endurance change independently and their values may depend on the nature and duration of nutritional deprivation.

Previous research on grip endurance utilized a sustained sub-maximal measurement protocol, representing 50% of the participant's maximal voluntary contraction (MVC) (Desrosiers et al., 1997; Reuter et al., 2011). A grip dynamometer was utilized but no visual feedback was provided to participants. The above methodology had limitations, as it required high levels of concentration and motivation on the part of the participant, and consistent verbal encouragement from the assessor was needed as some participants could not effectively maintain the exact target (Desrosiers et al., 1997). Maximal intermittent tests involving a 10- repetition maximal contraction was used previously to quantify grip endurance (Nicolay and Walker, 2005). Endurance was quantified by comparing the mean value of the first 3 repetitions to the mean value of the last 3 repetitions, and most participants showed a significant decline over the 10 repetitions (Nicolay and Walker 2005).

2.4 The influences of Hand grip Strength and Endurance

Grip strength has been found to be influenced by a number of factors such as body size and shape, age, sex, occupation, social status, ethnic group, lifestyle and other socioeconomic and demographic variables. Previous reports associate grip strength measures with anthropometric measurements and socioeconomic factors with variations between different ethnic and racial communities (Agnew and Maas, 1982; Bandyopadhyay, 2008; Chong et al., 1994; De et al., 1980; Günther et al., 2008; Koley and Singh, 2009; Koley et al., 2011; Mateo Lázaro et al., 2008; Mitsionis et al., 2009; Nicolay and Walker, 2005; Rantanen et al., 1998; Wu et al., 2009). And it also found that the dominant hand approximately 10% stronger grip strength than the non-dominant hand (Chatterjee and Chowdhuri, 1991).

Koley et al. (2011) conducted a study to evaluate the HGS and some anthropometric characteristics of Indian university female handball players to search the correlations of these physical traits among themselves and they concluded that dominant right hand grip strength has significantly positive correlations with all the variables, except the left hand width and right upper extremity length.

Yildrim et al. (2010) studied the correlation of dominant and non-dominant HGS with various anthropometric variables of super league male handball players and concluded that hand ball player's hand dominant grip strength are stronger than non-dominant hands and there is positive correlation between dominant hand grip strength with extension biceps circumference, forearm circumference, wrist circumference and upper arm diameters.

Visnapuu and Jürimäe (2007) investigated the influence of general body and hand specific anthropometric dimensions on HGS in boys participating in hand ball and basketball training and found that general anthropometric parameters determine the maximal hand grip strength more accurately than did specific hand anthropometric parameters. These three studies (Koley et al., 2011; Yildrim et al., 2010; Visnapuu and Jürimäe 2007) show that HGS is an important indicator to assess people in sport field that involves hand performance such as handball, badminton, squash, tennis and more.
Massy-Westropp et al. (2011) investigated and described normative data for hand grip strength in a community-based Australian population and established the relationship between BMI and HGS, and to compare Australian data with international HGS norms and found that higher HGS was weakly related to higher BMI in adults under the age of 30 and over the age of 70, but inversely related to higher BMI between these ages.

Puh (2010) conducted a study to quantify age-related changes in HGS among male and female participants. The highest values of HGS were found for males in the age group 35-49 years, and for females in age groups 20-34 and 35-49 years.

Günther et al. (2008) conducted a study to update the reference data of HGS for healthy adults of both genders spanning a wide age range. It was found that mean HGS was about 41% less in women (right hand 29 kg; left hand 27 kg) than in men (right hand 49 kg; left hand 47 kg) resulting in a ratio of left to right hand slightly above 0.95 in both genders. During the course of life, hand strength develops comparably in both genders peaking at 35 years of age and decreasing continuously further on. The above studies (Massy-Westropp et al., 2011; Puh, 2010; Günther et al., 2008) show that age is one of important factor that influenced the HGS. It can be said that the muscle loss in the aging people are related to decline of HGS.

Koley and Singh (2009) studied the correlation of dominant HGS and 12 anthropometric variables. They concluded that there exists a strong association of right hand grip strength with all anthropometric variables, except biceps skinfold in male students and with height, weight, BMI, total arm length and upper arm circumference in female students.

Norman et al. (2011) in their study summarized the studies investigating HGS as prognostic marker or nutritional parameter. It was concluded that as muscle function reacts early to nutritional deprivation, HGS has also become a popular marker of nutritional status and is increasingly being employed as outcome variable in nutritional intervention studies.

Pieterse et al. (2002) did a study on nutritional status and HGS in older Rwandan refugees and found that poor nutritional status is associated with poor HGS independent of gender, age and height. These two studies (Norman et al., 2011; Pieterse et al., 2002) show that nutritional status is also related to investigate HGS.

Incel et al. (2002) designed a study to evaluate the HGS different between sides for the right and left handed population. It was concluded that the dominant hand is significantly stronger in right handed subjects but no such significant difference between sides could be documented for left handed people. The percentage of stronger non-dominant HGS was 10.93% and 33.33% for right and left handed groups respectively.
Shetty et al. (2012) did a study to assess the gender differences and also assess the correlation between HGS and HGE and various demographic parameters (e.g. weight, height and BMI) in young males and females. It was concluded that there are gender differences in correlation between HGS and HGE and various demographic parameters indicating that there may be several factors besides demographic parameters which influence HGS and HGE. The correlation was assessed by calculating Pearson's correlation coefficient. The Table 2.1 shows the correlation between HGS of dominant hand and weight, height and BMI as well as HGE of female subjects. There exist significant positive correlation between HGS and weight as well as BMI only in females while significant positive correlation is observed between HGE and all the parameters (weight, height and BMI) in males only.

Table 2.1. Correlation between HGS and demographic data as well as HGE and demographic data (Source: Shetty et al., 2012)

Parameter	**HGS**				**HGE**			
	male		**female**		**male**		**female**	
	***r*-value**	***p*-value**	***r*-value**	***p*-value**	***r*-value**	***p*-value**	***r*-value**	***p*-value**
Weight	0.126	0.212	0.402*	0.000	0.266*	0.008	0.063	0.536
Height	0.045	0.645	0.156	0.121	0.216*	0.031	-0.01	0.922
BMI	0.128	0.205	0.386*	0.000	0.222*	0.026	0.078	0.443

*Correlation is significant at the 0.05 level (2-tailed)

Many HGS studies involving healthy adults have shown that variables such as height, weight, BMI, hand length and hand width are positively associated with grip strength (Chatterjee and Chowdhuri, 1991; Vas et al., 2002) and it was found that the dominant hand had approximately 10% stronger grip strength than the non-dominant hand (Ertem et al., 2005).

Nicolay and Walker (2005) examined HGS and HGE in three experiments: single repetition, 10-repititions and 30 second static hold. It was found that measurements of forearm and hand were better predictors of grip strength than were height and weight. While males produced greater HGS than females, no significant differences existed between genders in measures of HGE. The dominant hand was significantly stronger than the opposite hand, but also suffers from fatigue more rapidly. This trend was more pronounced in females than in males. Table 2.2 shows the correlation between HGS and demographic data and anthropometrics of hand as well as HGE and demographic data and anthropometrics of hand.

However in Nicolay study, the dynamometer used to measure grip strength unfortunately not a really compatible device. It is because the distance between the posts of the dynamometer cannot be adjusted and somewhat wider to account for differences in the sizes of the hands of different individuals.

Table 2.2. Correlation of HGS and HGE for demographic data and anthropometrics of hand (Nicolay and Wakler, 2005)

Measurement	HGS	HGEd	HGEs
	Dominant [opposite]	**Dominant [opposite]**	**Dominant [opposite]**
Forearm length	0.788[0.745]	n/s [n/s]	n/s [n/s]
Forearm circumference	0.738[0.749]	n/s [n/s]	n/s [n/s]
Wrist circumference	0.786[0.784]	n/s [n/s]	n/s [n/s]
Palm width	0.826[0.820]	n/s [n/s]	n/s [n/s]
Palm length	0.738[0.702]	n/s [n/s]	n/s [n/s]
Finger length	0.403[0.385]	n/s [n/s]	n/s [n/s]
Weight	0.656[0.649]	n/s [n/s]	n/s [n/s]
Height	0.757[0.722]	n/s [n/s]	n/s [n/s]

Cell contain correlation coefficients (*r*-value), n/s = correlation is not significant ($p<0.05$)

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).

(a) (b)

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 ethnics 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.

CHAPTER 3

DEVELOPMENT OF HAND GRIP STRENGTH AND ENDURANCE MEASURING SYSTEM

3.1 Introduction

This chapter discusses the methodology used in developing the hand grip strength and endurance measuring system. Firstly, this chapter begins with an overall view of the complete system. In the next section, the selection of main components in developing the hardware is explained. Subsequently the software interface designed using LabVIEW™ that records and export the data to MATLAB® software is described. Next, the process of calibration of this hand grip strength measuring system is explained. This chapter ends with a summary.

3.2 Overview of the System Design

This hand grip strength and endurance measuring device consists of two major sub-systems. The first sub-system is a hardware component which includes the hand gripper. This hand gripper was designed according to the characteristic of hand dynamometer that been used by (Nicolay and Walker, 2005; Nicolay et al. 2008) from Qubit System Inc., Kingston Ontario, as explained in Chapter 2. In addition some modification of handle distances was made according to the optimal grip span size of female Malaysian population. This optimal size is between size two and three of the JAMAR® dynamometer as discussed in Chapter 2. The integration between the hand grip measuring device and the software is depicted in Figure 3.1. Forces exerted during the assessments, were measured using load cell built into the hand gripper. Because of the small direct current (DC) voltage (mV) generated during load cell compression, an amplifier is used.

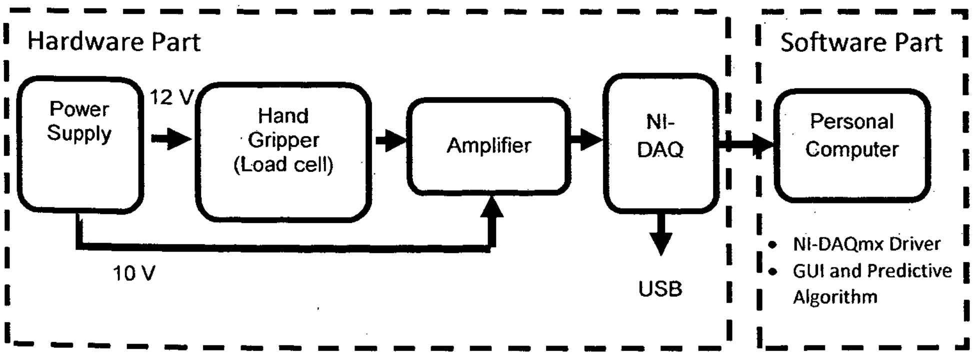

Figure 3.1. Diagram of hand grip strength measurement system

The next sub-system comprises the hand grip software. A National Instrument NI-6008 DAQ (Data Acquisition) card is used to enable communication between the hand grip device and the computer system. The primary function of DAQ is to convert the analog signal to digital signal, and feed it into the computer for further processing. Then, LabVIEW™ data acquisition software (National Instruments) was used to sample and store the voltages measured by the load cell. The Graphical User Interface (GUI) was build using LabVIEW™, as a tool to display the signals and store the desired data. In order to analyze the data and perform HGS and HGE predictives, MATLAB® software is used.

The main feature of this system is its ability to record grip force data throughout the time period of the experiment. The signal recorded over the experimental period is then used to calculate the average grip strength and endurance for further interpretation and analysis (Massy-Westropp et al. 2004).

3.3 Hardware Development

The hardware components used in developing the hand grip measuring device are discussed in the following sub-sections.

3.3.1 Power Supply

A DC power supply is used to power up the main components of the system. It consists of two DC outputs; +10V (to power up the amplifier) and +12V (to power up the load cell). Figure 3.2 shows the block diagram of the power supply. The 12V block contains of the switching power supply unit BWSE12SX-U by ETA-USA. The details of this power supply can be referred at Appendix A1. Meanwhile the block of 10V consists of regulation diagram. The output of 12V will be regulated by LM317 (can be referred at Appendix A2) to obtain a steady 10V DC at its output. Output 10V is calculated as shown in Equation 3.1 I_{ADJ} is typically 50μA and negligible in most applications.

$$Vo = V_{REF}\left(1 + \frac{R_2}{R_1}\right) + \left(I_{ADJ} \times R_2\right) \tag{3.1}$$

A photograph of the fabricated circuit of the power supply is shown in Figure 3.3.

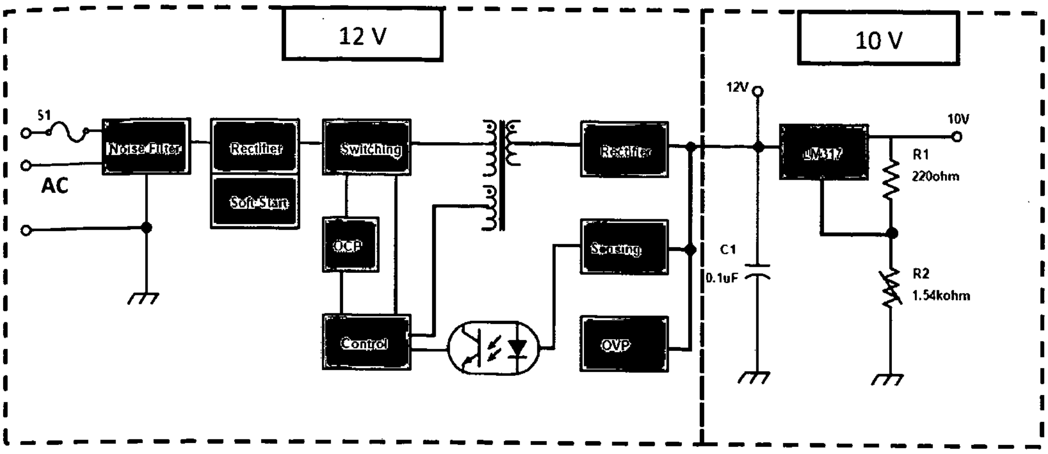

Figure 3.2. Block diagram of power supply

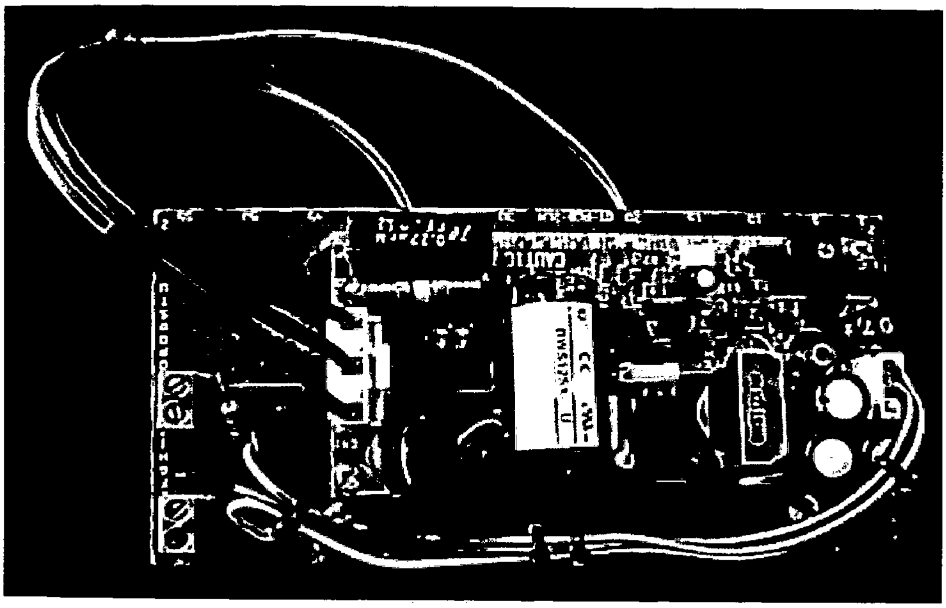

Figure 3.3. DC power supply

3.3.2 Hand gripper

The hand gripper is essentially a sensor that detects hand grip strength exerted by volunteers. This study has developed a hand gripper as shown in Figure 3.4.