INVESTIGATING THE EFFECT OF HAND GRIP DURATION ON HAND GRIP STRENGTH FOR FEMALE YOUNG ADULTS

This report is submitted in accordance with requirement of the University Teknikal Malaysia Melaka (UTeM) for Bachelor Degree of Manufacturing Engineering (Hons.)

by

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I hereby, declared this report entitled "Investigating the Effect of Hand Grip Duration on Hand Grip Strength for Female Young Adults" is the result of my own research except as cited in references.

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Date : 28 June 2024

APPROVAL

This report is submitted to the Faculty of Industrial and Manufacturing Technology and Engineering of Universiti Teknikal Malaysia Melaka as a partial fulfilment of the requirement for Bachelor Degree of Manufacturing Engineering (Hons). The member of the supervisory committee is as follow:

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(DR. RADIN ZAID BIN RADIN UMAR)

ABSTRAK

Kekuatan cengkaman tangan, yang ditakrifkan sebagai daya maksimum yang dikenakan oleh tangan, adalah penting dalam banyak situasi tempat kerja. Cengkaman yang berpanjangan boleh menjejaskan prestasi kerja dan produktiviti pekerja. Memandangkan cengkaman berterusan adalah perkara biasa di tempat kerja, memahami kesan tempoh pada kekuatan cengkaman adalah penting namun terdapat kurang kajian yang mengkaji kesan tempoh cengkaman terhadap kekuatan cengkaman tangan. Oleh itu, kajian ini mempunyai tiga objektif, pertama untuk mengenal pasti faktor yang mempengaruhi kekuatan cengkaman tangan di persekitaran tempat kerja dalam kalangan wanita muda Malaysia melalui semakan kertas penyelidikan terdahulu. Objektif kedua adalah untuk mengukur kekuatan cengkaman populasi ini untuk kedudukan lengan yang berbeza. Kekuatan genggaman tangan 125 peserta dalam postur lengan yang berbeza iaitu neutral, pronasi dan supinasi akan diukur menggunakan dinamometer tangan Jamar dalam keadaan berdiri dan duduk. Objektif ketiga adalah untuk menganalisis kesan tempoh genggaman tangan terhadap kekuatan genggaman tangan dalam kalangan wanita muda Malaysia. Untuk itu, 39 peserta dikehendaki menggenggam 20%, 40%, 60%, 80% dan 100% daripada kekuatan maksimum dan masa aktiviti cengkaman direkodkan. Penemuan mendedahkan bahawa tugasan kerja, suhu persekitaran, masa dalam sehari, dan reka bentuk alatan tangan mempengaruhi kekuatan cengkaman tangan di tempat kerja. Selain itu, wanita dewasa muda mempamerkan kekuatan cengkaman tangan yang lebih besar semasa berdiri berbanding duduk, dan dalam kedudukan lengan neutral dan supinasi berbanding pronasi. Tambahan pula, masa daya tahan berkurangan dengan ketara apabila daya yang diperlukanmeningkat. Kajian ini menyediakan data tentang kekuatan cengkaman tangan, menunjukkan kepentingan rintangan masa dan kedudukan optimum. Pengetahuan yang diperoleh boleh membantu industri mereka bentuk sistem kerja yang cekap dan alatan tangan yang meminimumkan risiko kesihatan dan meningkatkan prestasi pekerja.

ABSTRACT

Hand grip strength, defined as the maximum force exerted by the hand, is crucial in many workplace settings. Prolonged gripping can negatively impact work performance and employee productivity. Since sustained grips are common in the workplace, understanding the impact of duration on grip strength is essential but there is a lack of studies examining the effect of grip duration on hand grip strength. Therefore, this study has three objectives, first to identify factors that affect hand grip strength in the workplace environment among young Malaysian women through a review of previous research papers. The second objective was to measure hand grip strength in Malaysian young adult women for different arm positions. The hand grip strength of 125 participants in different arm postures i.e. neutral, pronation and supination will be measured using a Jamar hand dynamometer in standing and sitting conditions. The third objective is to analyze the effect of hand grip duration on hand grip strength in young Malaysian women. For that, 39 participants were required to hold 20%, 40%, 60%, 80% and 100% of the maximum voluntary contraction (MVC) and the time for each grip activity was recorded. The findings revealed that job tasks, ambient temperature, time of day, and hand tool design significantly influence hand grip strength in the workplace. Additionally, young adult women exhibited greater hand grip strength while standing compared to sitting, and in neutral and supination positions compared to pronation. Furthermore, endurance time decreased significantly as the exertion force increased. This study provides valuable data on hand grip strength, highlighting the importance of time resistance and optimal positioning. The insights gained can help industries design efficient work systems and hand tools that minimize health risks and enhance worker performance.

DEDICATION

I would like to thank my mother, Che Saniyah binti Che Soh and my friends for giving me moral support, cooperation, encouragement and also understandings. I also would like to thank Dr Radin Zaid bin Radin Umar for guiding me through this project.

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LIST OF ABBREVIATIONS

ANOVA	-	Analysis of Variance
ASHT	-	American Society of Hand Therapists
BMI	-	Body Mass Index
CTS	-	Carpal Tunnel Syndrome
DOSH	-	Department of Safety and Health
DOSM	-	Department of Statistic Malaysia
HGS	-	Hand grip strength
MSD	-	Musculoskeletal disorders
MVC	-	Maximum voluntary contraction
REBA	-	Rapid Entire Body Assessment
SD	-	Standard Deviation
UTeM	-	Universiti Teknikal Malaysia Melaka
WMSD	-	Work-related musculoskeletal disorder

LIST OF SYMBOLS

%	-	Percent
ϵ	-	Epsilon (Measure of Departure from Sphericity)
kgf	-	Kilograms-force
p	-	Level of Marginal Significance
r	-	Pearson’s Correlation Coefficient

CHAPTER 1

INTRODUCTION

1.1 Research Background

Hand grip means the act of grasping an object, while hand grip strength is the strong flexion of the finger joints with the highest voluntary force that a person is capable of exerting under regular limitations (Indira & Rajeswari, 2015). Hand grip strength serves a reliable measure of musculoskeletal performance by measuring bone mineral density and bone area at the hand and forearm (Koley & Yadav, 2009). Moreover, hand grip strength provides an indication of total strength through the assessment of upper limb muscle performance, and it is notably reliable when measured regularly.

Hand grip strength is also an important consideration in occupational ergonomics as it can be impacted by job tasks that require repetitive or forceful hand movements, prolonged gripping, or the use of vibrating tools. Modarres (2006) discovered that hand grip strength data is crucial to take into consideration while developing and establishing a workstation, process operation and related system in engineering applications to ensure that there is no working hazard during machine-human interactions. This is as a matter of engineering risk mitigation to avoid working hazard. The hang grip strength data is valuable for optimizing workstation design in applications that involve manual labor, machinery operation, or tool handling. This optimization guarantees that the arrangement and tools employed are appropriately tailored to the physical capabilities of the workers, thereby enhancing productivity and minimizing the likelihood of work-related musculoskeletal disorders (WMSDs).

On the other hand, one limiting factor for manual lifting and carrying loads has been identified as hand grip strength (Leyk et al., 2007). This relates to the workers, mainly the labor workers in the industry. While there is high technology machine and automation implementation at work, there is still manual handling task involved, including in the manufacturing industry (Mean et al., 2013 as cited in Yusuf and Shalahim, 2021). For instance, in the preproduction materials need be manually handled, then in the assembly line for example during the assembly of electrical components involves fastening of rivets and bolts, soldering and micro-welding, as well as in the distribution stage where the final products need to be packed in boxes, transported with forklifts or other types of machinery, and loaded onto trucks. Therefore, hand grip strength norms are frequently necessary for safe manual labor as well as designing of tools and products that need grip strength because fatigue and even injuries may arise if workers or users consistently exceed their strength limitations (Eksioglu et.al, 2016). The performance and productivity of workers will be impacted when individuals surpass their grip strength limitations, as they may face challenges in maintaining a consistent and efficient work pace. Consequently, this can lead to a decline in overall productivity, affecting both individual tasks and the broader workflow.

Generally, an increased grip force is associated with a greater risk of developing Musculoskeletal Disorders (MSDs) as well as Carpal Tunnel Syndrome (CTS). The number of occupational injuries caused by WMSDs in manufacturing industries are attributed to many tasks being done manually such as lifting, lowering, pushing, and pulling. Besides, the risk factors such as contact stress, vibration and holding and restraining tasks are added into account. As a result, occupational accidents are most prevalent in the manufacturing industry, as reported by the Department of Safety and Health (DOSH) from January to October in 2023. The data is shown in Table 1.1.

Table 1.1: Occupational Accidents Statistics by Sector from January to October 2023

SECTOR	NPD	PD	DEATH	TOTAL
Hotel and Restaurant	176	0	0	176
Utilities (Electricity, Gas, Water and Sanitary Service)	147	0	4	151
Finance, Insurance, Real Estate and Business Services	554	15	15	584
Construction	106	8	45	159
Transport, Storage and Communication	326	7	9	342
Manufacturing	3,961	175	45	4,181
Wholesale and Retail Trade	145	2	0	147
Public Services and Statutory Authorities	117	2	0	119
Mining and Quarrying	23	1	4	28
Agriculture, Forestry and Fishery	1,020	25	19	1,064
TOTAL	6,575	235	141	6,951

Source: DOSH, 2023

Besides, gender has effect on the hand grip strength where females are found to have lower hand grip strength compared to males, as many research stated (Eksioglu, 2016; CD et al., 2020). A study from CD et al. (2020) reported that males have higher grip strength about 35% to 40% compared to females.

Moreover, duration of hand gripping also plays an important attribute to the hand grip strength. Prolonged gripping may result in reduced maximal force exerted by the hand due to muscle fatigue and in the long run can lead to musculoskeletal injury. As prolonged gripping is common in workplace settings, it is important to identify how duration may affect the hand grip strength of an individual. Many studies of hand grip strength for adults have been conducted in Malaysia, including those by Hossain et al. (2012), Keevil et al. (2013), Daruis et al. (2019) and CD et al. (2020) but none of them emphasizes the effect of duration on hand grip strength.

Furthermore, there are arising in the number of females workers in Malaysia over the past few years, as evidenced by data from the Department of Statistic Malaysia (DOSM). The patterns in the labor participation rate for females have shown growth, rising from 54.1% in 2015 to 55.3% in 2020, and by 2025, it is targeted to achieve 57.0%. To support, the data of labor participation rate by gender from 2010 to 2018 are presented in Figure 1.1. Among the labor participation, the distribution of the data by age group is also presented in Figure 1.2. The data demonstrates the notable increase in the percentage of labor force for age group of 15 to 24 years. However, the youths of age 15 to 19 years old may not contribute significantly to this distribution as most of them are either in the secondary education level or upper secondary education level. Therefore, the aim of this study is to investigate the effect of hand grip duration on hand grip strength for female young adults ages from 20 t0 24 years old in Malaysia that would give significant value by providing valuable database that will help the engineers design workplace, tools and work tasks that incompliance with the capabilities of this population as the demand for their forces in the industry increases.

Figure 1.1: Labor Participation Rate by Gender from 2010 to 2018 (Labor Force Survey Report, DOSM)

Figure 1.2: Labor Participation Rate by Age Groupfrom 2010 to 2018 (Labor Force Survey Report, DOSM)

1.2 Problem Statement

Labor works involve many tasks that require gripping, making the hand grip strength is a crucial component of efficiency, productivity, and safety in manual labor. The works load on both females and males in workplace are commonly equivalent. Understanding these variables is essential for promoting the health, welfare, and productivity of this group as well as for developing methods to improve work environments and practices for female employees in Malaysia as the demand for their labor forces increases. However, many researchers conducted on hand grip strength in Malaysia such as Kamarul et al. (2006), Keevil et al. (2013), Shahida et al. (2015) and Moy et al. (2011) but do not focus on the young female population.

Position is also one of the factors that affects the hand grip strength (El-Sais & Mohammad, 2014). Comprehensive understanding on this information is crucial for optimizing workplace environments and practices to enhance the hand grip strength, especially for female employees as in the workplace setting there are many sorts of working position involves. However, the previous study regarding the effect of different positions on the hand grip strength among the Malaysian population is limited. Many studies are only conducted for a certain body position. A study by Kamarul et al. only conducted hand grip strength test for one position where the subject is seated upright, shoulder adducted, elbow flexed at 90 degrees and the wrist was in an inward-facing neutral position. This making the reference on employees regarding the different positions for hand grip is difficult. For instance, Figure 1.3 shows neutral forearm position is employed by worker to perform task, Figure 1.4 shows worker uses pronation forearms position.

Figure 1.3: Neutral Forearm Position Is Employed by Worker to Perform Task (Philips Morris International, 2020)

Figure 1.4: Worker Employs Pronation Forearms Position (Stacker 2022)

A study by Deros et al. (2020) found a group of 11 workers engaged in manual material handling at a sintered metal parts manufacturing company located in Port Klang were at high risk of WMSD. The is due to the positions during lowering, twisting, and lifting were rated 9 on the Rapid Entire Body Assessment (REBA) score. The authors recommended that employers improve the layout of the workplace, decrease the load depending on the duration of the task as such 30% reduction for tasks repeated once or twice a minute, 50% for tasks repeated 5-8 times a minute, and 80% for tasks repeated more than 8 times a minute, followed by alternate heavy tasks with lighter ones, encourage diverse job responsibilities to minimize repetitiveness. In conjunction with that, the problems are due to tasks usually needing extended static holding or intense dynamic gripping repeatedly (Nicolay & Walker, 2005). While hand grip strength is recognized as a crucial factor in various workplace settings, there exists a gap in understanding how the duration of gripping influences hand grip strength, particularly among female Malaysian young adults.

1.3 Objective

To cater the problems mentioned in the problem statements the objectives of this study are as the following:

i) To identify factors influencing hand grip strength in workplace settings among female Malaysian young adults.

ii) To measure the hand grip strength in female Malaysian young adults for neutral, pronation and supination forearm positions in sitting and standing.

iii) To analyze the effects of hand grip duration on hand grip strength in female Malaysian young adults for 20%, 40%, 60%, 80% and 100% of maximal voluntary contraction (MVC).

1.4 Scope of study

The main subject of this study is Malaysian female young adults with range of age from 20 to 24 years old. There are some exclusion criteria that are included in assessing the potential subjects where participants with heart disease, diabetes and physical impairments are allowed to conduct the testing. The hand grip strength testing is measured by using Jamar hand dynamometer. The testing accounts for several forearm positions which are supination, pronation and neutral in both standing and sitting position. Subsequently, the hand grip endurance testing that regards hand grip duration for 20%, 40%, 60%, 80%, and 100% MVC are performed as it is the main goal of this study. This will provide a database that will serve as a reference for designing tools and workplace layout and system in order to improve work performance of this particular population.

CHAPTER 2

LITERATURE REVIEW

This chapter specifically delves into the previous researchers' theories and study findings, focusing on the exploration hand grip strength and hand grip duration. Relevant information and findings from previous studies extracted as references, serve as a basis for discussions and analyzing the gap. This chapter encompasses an overview of hand grip strength, the procedure for measuring hand grip strength, factors influencing hand grip strength, the importance of hand grip strength data, and the methodologies used for hand grip strength data collection.

2.1 Overview of Hand Grip Strength

Hand grip strength provides the measurement of maximum voluntary muscle strength. Hand grip strength also has been widely used as an indicator that represents overall muscle strength and it is varies according to age, sex, and race. As in a large-scale study, hand grip strength is the most basic and accurate indicator of an individual's muscle strength status.

2.2 Role of Hand Grip Strength in Occupational Settings

A study by Trajanoska et al. (2018) investigated the genetic and clinical determinants of fracture risk. The authors found that hand grip strength was inversely associated with fracture risk, although this result was not significant after multiple testing correction. This suggests that hand grip strength may play a role in fracture risk, but further research is needed to confirm this association and account for potential confounding factors (Trajanoska et al., 2018).

2.3 Factors Affecting Hand Grip Strength

This section in literature review provides discussion of the findings from previous researchers regarding the factors that affect hand grip strength. Individual, environment, occupational and work tools design factors shall be elaborated further later in this section.

2.3.1 Individual

There are several individual factors that may affect hand grip strength. The factors that are considered are gender, age, anthropometry, position, health status and diet.

2.3.1.1 Gender

Gender differences in hand grip strength measurements have been a topic of interest in research. Several studies have explored these differences where studies performed on both genders and the comparison of hand grip strength value between males and females have been carried out (Ashraf et al., 2022; CD, 2020; Almashaqbeh et al., 2022; Dağ and Erdoğan, 2022; Baek et al. 2023). Based on an experiment by CD (2020), males have higher grip strength compared to female by 35% to 40%. On the other hand, Eksioglu (2016) develop the gender-and-age based reference value for hand grip strength in the normal population of Turkey, with a particular focus on occupational needs. The finding demonstrates that males are generally much stronger than females where the females possess approximately 57% of males' hand grip strength value. Furthermore, the manual employees' group, the group exclusively for males in the study, seems to be the strongest group overall compared to non-manual employees (NME) for students, s-NME and non-student, ns-NME. The study by Amaral et al. (2019) also reported that males possessed higher mean and median hand grip strength values than females. A study by

Mohd et al. (2019) investigated the effect of gender on hand grip strength in Malaysian young adults and found that males had significantly higher grip strength compared to females, indicating a gender difference in hand grip strength measurements.

These findings indicate variations in hand grip strength measurements between genders. However, there is a notable gap in research specifically addressing hand grip strength among young Malaysian adult females. Consequently, there is a significant need for studies targeting this specific population.

2.3.1.2 Age

According to research by Carish and Kennedy (2003), one of the ageing processes that reduces handgrip strength is a decrease in muscle mass and size, as cited in Moy at. al (2011). The study by Eksioglu (2016) shows that there is a curvilinear correlation between hand grip strength and age. The study shows that the grip strength for both female and male, and age-group relationships were found to be non-linear, with female relationships being more prominent. Furthermore, the study also demonstrated that the grip strength of females in non-manual employees (NME) rises and peaks between the ages of 30 and 39, then gradually declines until roughly 49, at which point it begins to decline significantly as muscle size and architecture are both altered with advanced adult age. On the other hand, men continue to have their grip strength high for at least ten more years.

However, the study by MA CD (2020) shows that peak strength at 40 years old and then gradually decreases for both genders. A study by Lim et al. (2017) examined hand grip strength in Malaysian female young adults and found that there were significant differences in grip strength between different age groups. Younger females had higher grip strength compared to older females, suggesting that age may influence hand grip strength in this population. Generally, age have effects on the hand grip strength whereby the young adults possess higher hand grip strength compared to the elderly, however there is uncertainty regarding the age at which the hand grip strength decreases and the effect on genders might varies.

2.3.1.3 Position

Several studies have explored the influence of various arm positions on hand grip strength, particularly in sitting and standing postures. CD et al. (2020) found that hand flexion angle variations affect hand grip strength values, demonstrating differences between 2.2 and 0.2 to 1.0 kg for young males and 5.8 kg for young females. Additionally, Ashraf et al. (2022) observed changes in hand grip strength among individuals with normal BMI based on different body positions, with the highest strength in standing (36.60±10.79) and the lowest in prone (27.52±8.01), across five positions which are standing, sitting, supine, side lying, and prone.

Furthermore, Akbar and Setiati (2018), as cited by Ashraf et al. (2022), highlighted that grip strength tends to be higher in standing and sitting positions with extended elbows. This aligns with the physiological understanding that muscle activity increases in the standing position, while sitting promotes relaxation. The standing position, without arm support, requires greater muscle effort, resulting in higher hand grip strength compared to the sitting position (Barut and Demirel, 2011).

These findings highlight the significance of considering forearm positions when measuring hand grip strength. Despite numerous studies comparing body segments, standardized procedures may not universally apply to diverse occupational settings as varying body positions applied when performing tasks. This dynamic nature has prompted researchers to investigate grip strength in different body segment positions. Although some studies have explored combinations of postures and upper limb positions, yielding inconclusive results, a noticeable gap remains in addressing the various forearm positions employed during hand gripping tasks including supination, neutral and pronation, as demonstrated in the Figure 2.1.

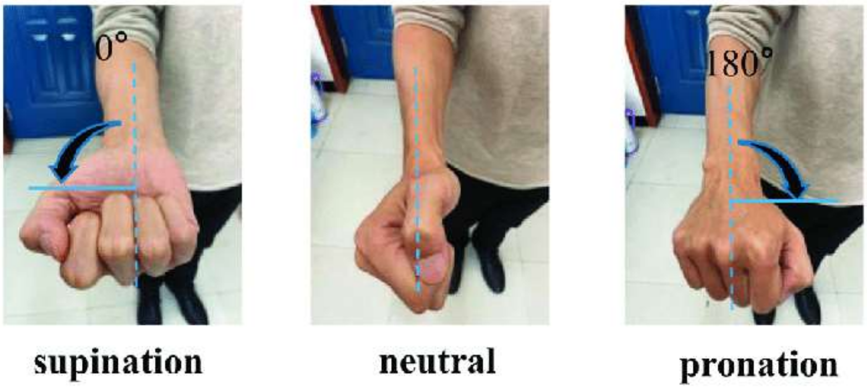


Figure 2.1: Supination, Neutral and Pronation Forearm Positions

2.3.1.4 Anthropometry

The hand grip strength of the young females is moderately influenced by hand breadth (CD, 2020). It was also reported that higher grip strength in African men was linked to higher height, being not underweight, and a lower functional disability, whereas higher grip strength in African women was linked to higher height, improved cognitive functioning, and a lower functional disability. A gender-dependent relationship between height, body mass, BMI, and hand dimensions (Eksioglu, 2016). Significant correlations were found between the anthropometric measurements of stature, sitting hip breadth, the circumference of the hand, wrist, and heel ankle and strength of the hand grip for the elderly Malaysians (Shahida et al., 2015). However, the study conducted by Luna et al. (2013) shows no correlation between anthropometry value and hand grip strength. While most researchers found that the hand grip strength may be affected by anthropometry, there are still studies showing the otherwise. As a matter of fact, it seems that certain anthropometry values may affect the hand grip strength while some others might not give significant effect on the hand grip strength. Therefore, future research may emphasis on the specified anthropometry including weight, height, and hand-forearm anthropometry such as palm circumference, palm-arm length, forearm length and forearm circumference. The hand-forearms anthropometry is shown in the following Figure 2.2 and Figure 2.3.

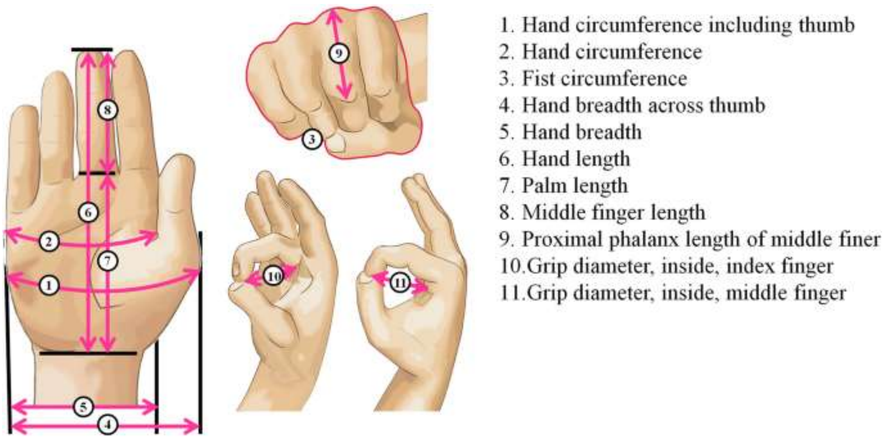


Figure 2.2: Hand Anthropometry (Rostamzadeh et al., 2021)

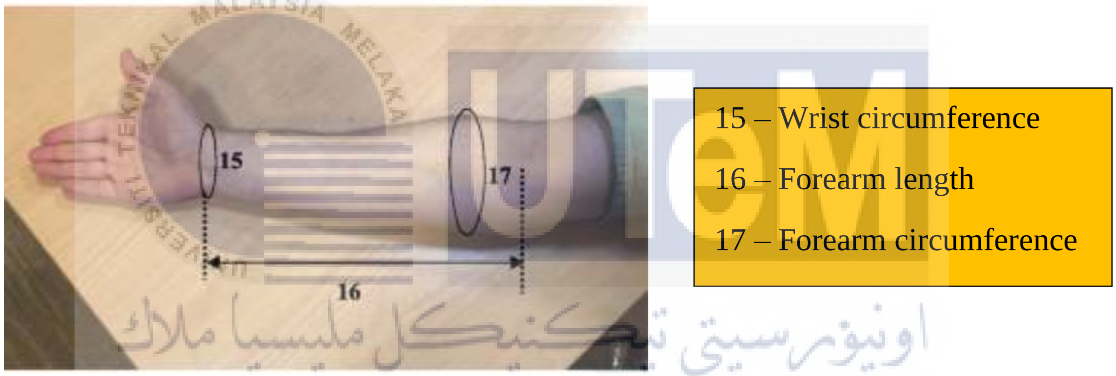


Figure 2.3: Hand-Forearm Anthropometry (Rostamzadeh et al., 2021)

The hand comprises two types of muscles which are extrinsic and intrinsic. The importance of measuring the hand and forearm anthropometry is due to the intrinsic muscles of the hand that rely on forearm muscles for their functionality. Grip strength during gripping activities is generated by the flexor muscles of the hand and forearm, while the extensors of the forearm play a role in stabilizing the wrist. Collectively, the hand, wrist, and forearm constitute an interdependent system which is crucial for the execution of manual tasks (Barlow et al., 2014 and Tyldesley & Grieve, 2009 as cited in Rostamzadeh, 2020). Therefore, future research should emphasis more on hand anthropometry as a part of measuring hand grip strength procedures, especially for the population of young female adults. This is due to the fact that there are still knowledge gaps in understanding the precise mechanisms by which hand anthropometry impacts hand grip strength and the efficacy of interventions aimed at improving hand grip strength through modifications in hand anthropometry. Future research should concentrate on these connections and investigating potential interventions to enhance hand grip strength by considering hand anthropometric measurements.

2.3.1.5 Health Status

Health status is a measure of one's well-being at a particular time and it is commonly in terms of mental and physical. Injury can be classified as the deterioration of physical health whereby it restricts the ability of a person to perform normal daily activities and hence may likely to reduce the hand grip strength. Manoharan et al. (2015) conducted an article review on hand grip strength assessment and its influencing factors, revealing that physical fatigue resulting from repetitive hand gripping poses a potential risk for occupational injuries, ultimately impacting hand grip strength. This might be due to the workers overexert the gripping beyond their limit while on the other hand extra grip effort could increase the chance of hand-arm injuries (Ramadan, 2017). As a result, reducing hand grip strength. This can be seen through the results of hand grip strength assessment conducted by Belcher (2016) to 400 patients with injured limbs, where the results show that injured hands had significantly lower maximum grip strength when compared to uninjured hands.

Apart from that, according to recent studies, mental health status can influence hand grip strength. A study from Jiang et al. (2022) used a linear mixed effect model and mediation analysis to investigate the behavioral and cognitive correlates of handgrip strength among 40000 participants in the United Kingdom. The finding shows that greater grip strength is associated with better cognitive functioning, more fulfilment in life, greater subjective well-being, and lower depression and anxiety symptoms. On the contrary, a decrease in mental well-being is anticipated to correlate with a reduction in hand grip strength.

According to the stated findings, health significantly impacts hand grip strength, with factors mental health, and physical capability associated. However, knowledge gaps need further investigation. Addressing these through studies, intervention trials, and cultural differences will help more in identifying the relationship between health status and hand grip strength.

2.3.1.6 Diet

Manoharan et al. (2015) states that nutritional status has correlation with hand grip strength. A study about the correlation between hand grip strength and eating behaviour conducted by Ding et al. (2020) whereby a self-administered questionnaire was used to assess eating habits, which included questions about breakfast consumption, snacking after dinner, and eating rate. The results show that in Chinese adults aged 25-68 years, a high frequency of breakfast consumption and a low frequency of snacking after dinner were significantly correlated with higher grip strength. This is due to eating habits that could enhance grip strength because regular breakfast consumption would result in higher nutrient intake and higher energy intake (Uzhova et al., 2018 and Yoshimura et al., 2017 as cited in Ding et al., 2020). Coincidently, the nutrient and energy intake are strongly related with muscle strength, therefore exerting higher grip strength. Current research indicates that diet plays a crucial role in influencing hand grip strength, with positive associations observed breakfast consumption. Nevertheless, there is a need for further research to delve into the underlying mechanisms, explore diverse dietary patterns, and take into account additional factors like lifestyles and anthropometry to gain a comprehensive understanding of the relationship between diet and hand grip strength.

2.3.2 Environmental

The environment to which a person is exposed to hand gripping activities may have an impact on the hand grip strength. The environmental effects that shall be discussed in this section are the time of day and ambient temperature.

2.3.2.1 Time of Day

Many studies have reported the effect of time of day on hand grip strength value and therefore Douglas et al. (2020) conducted article review that gathers the existing data on time of day and hand grip strength. Based on twenty studies, the review reported that hand grip strength value seemed to be the highest in the late afternoon which is around 4pm to 8 pm, as compared to the morning. However, most of the studies only conducted on the young and healthy males hence the specific time for other populations in terms of age ranges and gender cannot be specified.

2.3.2.2 Ambient Temperature

Ambient temperature is the air temperature of the surrounding environment. Many researchers found that there is a significant correlation between the ambient temperature and the hand grip strength. A study conducted by Cakmak & Ergul (2018) towards the professional plant trimmer to investigate the impact of various factors affecting hand grip strength of trimmers where the ambient temperature becomes one of the independent variables. The hand grip strength was measured 5 times a day in between the actual trimming activity and the ambient temperature was measured. The results showed that as the ambient temperature decreased, the hand grip strength value increased. This also indicated the trimmers perform better when the working environment was lowered down. However, the finding is in contrast with the other study conducted by Chi et al. (2012) whereby the results show that cold water reduced hand muscle strength and movement. Despite the contradictory of the findings, both studies show that there is an influence of the ambient temperature on hand grip strength.

2.3.3 Task Factor

In various settings and activities, task factors such as duration and job type may influence the hand grip strength of an individual. Therefore, the influence of the two task factors will be elaborated in this section.

2.3.3.1 Duration

The duration hands are exposed to gripping does affect hand grip strength. A study conducted by Osailan (2021) regarding smartphone uses showed that prolonged smartphone use was associated with weaker handgrip and pinch-grip. Hand grip strength as a matter for hand grip duration may be correlated to hand grip endurance as it is usually significant for activities that require repeated maximal grip and sustained submaximal grips.

Hand grip duration as a matter of the time where a person directly involved with gripping can directly affect the hand grip strength. This is common in the industry mainly for the manual workers, as they perform tasks that gripping requires a high level of hand activity for prolonged time as well as performing repetitive hand gripping. In a result, fatigue may occur, and it can affect the performance of an individual in this case particularly the worker's performance. On the other hand, the onset of occupational injury has been found to be associated with physical fatigue as a risk factor (Manoharan et al., 2015). However, there is a limited of research that focus on examining the correlation between hand grip duration and hand grip strength, especially within the population of Malaysian female young adults. This highlights the essential need for a study that concentrates on this specific population, considering the prevalence of hand gripping tasks in work settings and the potential variations in duration. Such a study could prove valuable for engineers in designing workplaces tailored to this population, particularly as their involvement in the industry increases, aiming to enhance productivity, work performance, and overall health.

2.3.3.2 Job Types

The engagement of workers in hand-gripping activities may impact their hand grip strength. Boschman et al. (2017) perform a longitudinal study that identify the relationships between work-related factors and musculoskeletal health with current and future work ability among male workers. The participants are 157 male workers of a manufacturing plant who perform several different job types and they are divided into two groups. The first group is manual workers who are welders, grinders, turners, and steel platers while the second group is office workers that consists of salesmen, managers, engineers, secretaries and administrative clerks. Regarding the job types as factor influencing hand grip strength, the results show that the manual workers possess hand grip strength slightly lower than the office workers. The weak grip strength of manual workers may be correlated to the high grip required each time to perform their jobs. Nevertheless, the longitudinal study gathered hand grip strength data in 2008 and 1997, employing various dynamometers. Considering the changes in the working environment, working methods, and tools at the engineering plant over time, the reliability of the findings may be ambiguous.

2.3.4 Hand Tools Design

Hands tools are commonly utilized for manual work and they are also associated with gripping whereby workers need to grip the tools to perform certain tasks. Exposing to hand tools for prolonged time may have impact on the hand grip strength. Thus, this section discusses several effects of tools design parameters on hand grip strength.

2.3.4.1 Handle Material

Flemmer (2016) as cited in Halim et al. (2020) provided a few properties of material that can be used to fabricate hand tools. Among the properties such that the material should have the ability to withstand slippage. This is for the purpose of ensuring secure grip between the contact area of on the handle and the hand. In junction with that, the article suggests rubber material as it is soft and can provide firm grip as well as minimizing the contact stress in the contact area on the hand, therefore optimizing hand gripping as well as the hand grip strength. On the contrary, the authors prohibit the use of materials like plastics and steels with smooth surfaces since they are low-friction materials and hence slippery.

2.3.4.2 Handle Shape

The shape of the tool handle is crucial as it is highly correlated with the grip function of the tool and may have an effect on the hand grip strength. Goodwin et al. (1998) as cited in Halim et al. (2020) demonstrated the evidence of a link between shape and grip force upon conducting a grasping testing of spherical surfaces that with radius variations from concave radius of 20 mm to convex radius of 5 mm. The results showed that greater applied grip force is correlated with the curvature being more convex. Therefore, it can be concluded that handling with concave curvature provides ease of gripping and hence optimizes the grip strength. This is due to lower grip force may be applied and muscle fatigue can be avoided.

2.3.4.3 Tool Weight

Use of heavy tools can lead to increased forces exerted by the hand, resulting in reduced grip strength (Halim et al., 2020). This is due to continuously gripping or repetitively handling of the tool which can lead to muscle fatigue. Workers in manual labor settings may be highly impacted by this scenario. The weight of a tool as well as the allocation of the load within the tool influence the way the worker holds the tool. This encompasses factors such as the requirement of one or both hands to stabilize the tool, the duration of time the worker can maintain a grip on the tool, and the level of precision with which it can be manipulated. It is advisable to restrict the weight of tools that are operated with a single hand to 1.4 kg or lower. Tools used for precision operations should have a weight of less than 1 pound, which is equivalent to 0.5 kg (James, 2005). These numbers indicate an appropriate weight for a hand tool, however, the relationship between the weight of the tool and the strength of the hand grip has not been addressed.

Summary

In conclusion, previous researchers have identified various factors that influence hand grip strength. However, despite these findings, several factors require further study due to limitations in the research that render the results inconclusive and lead to inconsistency in the findings among studies. The factors related to individuals, the environment, task-related factors, and hand tool design were discussed in the preceding literature review section, and the illustrated figure provides a visual representation of these discussed factors.

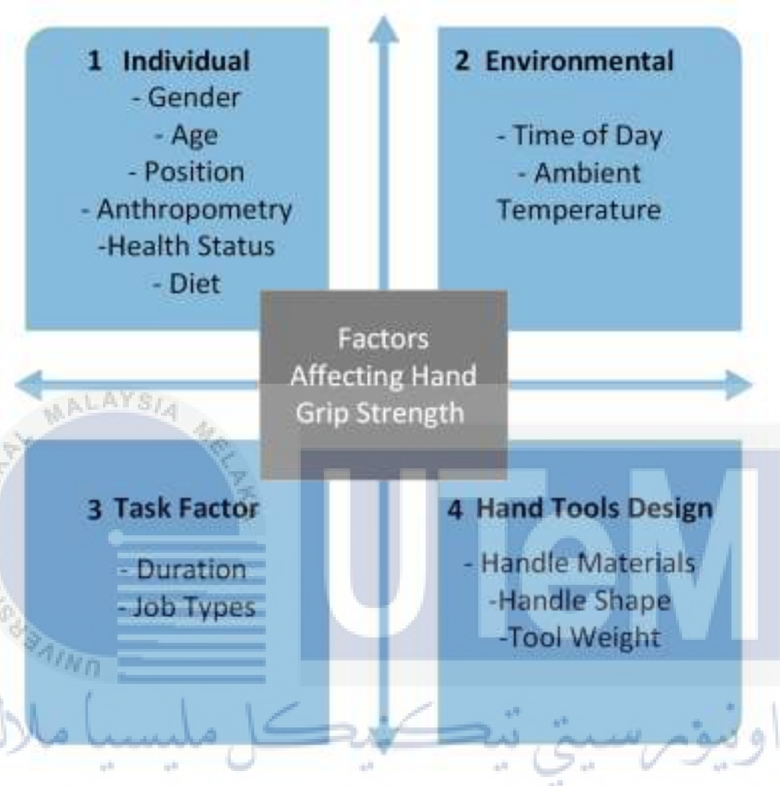


Figure 2.4: Factors Influencing Hand Grip Strength Discussed

2.4 Hand Grip Strength Measurement Tools and Procedures

Literature review in this section focuses on exploring the measurement tools to measure hand grip strength and the procedures that will serve as a basis for designing the methodology for hand grip strength testing.

2.4.1 Hand Grip Strength Measurement Tools

Hand dynamometer is a tool used to measure hand grip strength of an individual. The medical therapist usually utilizes hand dynamometer to measure the hand grip strength of patients under treatment for the purpose of assessing and tracking their recovery. Solgaard et al. (1984) as cited in Lee and Gong (2020) proposed several criteria of an ideal dynamometer which are small and portable, hand size independence, high reproducibility and comfy to the subjects. Hence, a dynamometer is said to be ideal and reliable if it possesses all the criteria. As a result, there are several types of hand dynamometer used to measure hand grip strength reviewed by the authors (Lee & Gong, 2020).

The first is the hydraulic dynamometer which is also known as Jamar hand dynamometer. The dynamometer has 2 handles where 1 handle is in curve shape which functions to put hand in place during the measurement of hand grip strength. Furthermore, it has 5 handle position to cater for various hand sizes, but the American Society of Hand Therapists (ASHT) suggested that the second handle as the standard position (MacDermid et al., 2015). It is commonly utilized due to its reliability and the enhancement in terms of the handle friction of the recent models as compared to earlier ones. Another type of dynamometer is pneumatic that has 2 variations, modified sphygmomanometer and Martin Vigorimeter. This type of dynamometer applies compressive force towards the air-filled bulb or bag, and it measures hand grip strength in millimeters of mercury (mmHg) or pounds per square inch (psi). Besides, the Modified sphygmomanometer is a low-cost option to measure the hand grip strength as it is usually an equipment to measure blood pressure (Pincus et al., 1994; Martins et al., 2015; Lee & Gong, 2020). Therefore, it has become the second most common tool used for hand grip strength measurement. The last type of dynamometer being reviewed is mechanical which is also known as Smedley hand dynamometer. The hand grip strength is measured on the basis of the amount of tension in a steel spring and displays it in kilograms or pounds. It has two handles, and the distance between them can be adjusted to fit the size of the hand. The discussed hand dynamometers are summarized in Table 2.1.

Table 2.1: Types of Available Hand Dynamometer and The Characteristics

Hand Dynamometer (Type)	Characteristics
 Jamar hand dynamometer (Hydraulic)	• Adjustable hand position • Recommended by American Society of Hand Therapists (ASHT) • High reliability & improved handle friction (compared to earlier version)
 Modified Sphygmomanometer (Pneumatic)	• Low-cost option • Commonly used in clinical settings as it is primarily used for measuring blood pressure

 Martin Vigorimeter (Pneumatic)	• Significant correlations between the measured grip strength of the dominant hand as compared to Jamar hand dynamometer (Neumann et al., 2017)
 Smedley hand dynamometer (Mechanical)	• Adjustable handles

Various tools are employed for measuring hand grip strength, with the Jamar hand dynamometer being recommended by the American Society of Hand Therapists (ASHT) as a standard tool for this purpose. The diversity in tools used by researchers poses a challenge in comparing the normal hand grip strength across different populations. However, there is a growing number of studies that aim to compare measurements of hand grip strength, facilitating the exploration of correlations and enabling comparisons between different types of hand dynamometers. Notably, the study conducted by Neumann et al. (2017) is one of the examples.

2.4.2 Hand Grip Strength Procedures

Various methods have been employed to measure hand grip strength, each with its own advantages and limitations. In their review article, Roberts et al. (2011) provide an overview of the different methods used to measure hand grip strength and discuss their reliability and validity.

2.4.2.1 Jamar Hand Dynamometer Calibration

To ensure accurate measurements and reliability, the Jamar hand dynamometer should be calibrated regularly. It is recommended that the calibration is done by professionals as they are equipped with the necessary tools and expertise to ensure proper calibration. In conjunction with that, manufacturers may offer calibration services, assigning technicians with the expertise to handle the calibration process. However, when it is not possible standard weights can be used to compare the readings of dynameter with the known weight to ensure its accuracy. Fess (1987) proposed a procedure to calibrate the Jamar hand dynamometer by utilizing an adjustable top workbench, positioning blocks, force collar, standardized test weights. Firstly, the workbench is levelled and secured, and the dynamometer is placed on the blocks. The handle posts are checked for perpendicularity. The adjustable handle is locked in position 5 and the needles are turned to "0." The weighted hook is added and recorded. The Jamar dynamometer calibration check sheet is used for all 5 handle positions, with completed columns covered with a blank sheet for consistency and data reliability. Figure 2.5 shows the setup for calibration of Jamar hand dynamometer

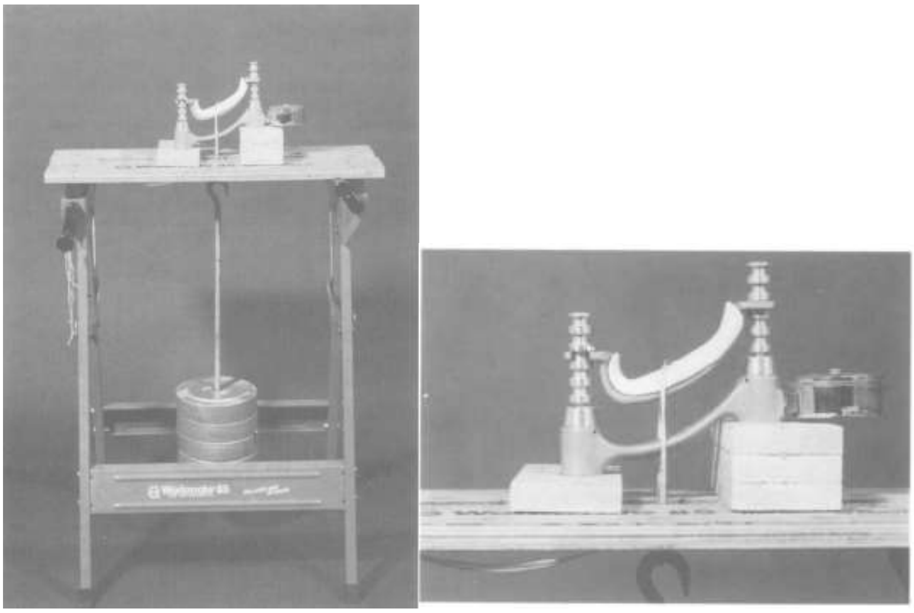


Figure 2.5: Setup The Calibration of Jamar Hand Dynamometer

2.4.2.2 Protocol and Standard

ASHT recommended measuring the hand grip strength using Jamar hand dynamometer via the second position as it is the most reliable and can provide consistent value (Roberts et al., 2011). Handle positions one and five of Jamar hand dynamometer are less reliable than others, but the number one position may be necessary for individuals with very small hands (Ruiz-Ruiz et al., 2002).

The guideline known as the 10% rule, commonly applied by therapists in the treatment of patients with hand injuries, suggests that the dominant hand typically exhibits a 10% stronger hand grip strength compared to the non-dominant hand. While this founded true for right-handed individuals among both American and Greek volunteers, it was observed that hand grip strength was equal in both hands for left-handed individuals. Similarly, a review of 10 studies noted that individuals with a dominant right hand were stronger in their right hand, whereas findings among individuals with a dominant left hand were inconclusive (Bohannon, 2003 as cited in Roberts et al., 2011). However, the decision between measuring hand grip strength in either the dominant hand or both hands, or selecting specific participants based on hand dominance depends on the specific objectives of the study.

The American Society of Hand Therapists (ASHT) advocates for standardized positioning during hand grip strength measurements: the participant should be seated with shoulders adducted and neutrally rotated, elbow flexed at 90°, forearm in a neutral position, and wrist between 0 and 30° of dorsiflexion [38]. The importance of adhering to a standardized protocol for enhanced assessment validity is emphasized by Spijkerman et al. (1991) who observed significantly different readings when subjects were allowed to assume a comfortable position as opposed to following the ASHT protocol.

Many studies either do not specify the extent of encouragement provided or report varying amounts. The diverse methods of instruction and verbal encouragement can influence the performance of the participants, thereby introducing potential measurement errors. Mathiowetz et al. (1984) as cited in Roberts et al. (2011) propose a standardized set of instructions: 'I want you to hold the handle like this and squeeze as hard as you can'. Followed by the examiner providing a demonstration and then hands the dynamometer to the subject. Once the subject is positioned correctly, the examiner prompts, 'Are you ready? Squeeze as hard as you can.' While the subject is squeezing, the examiner encourages with phrases like 'Harder!... Harder!... Relax'.

2.5 Gap in The Previous Study and The Current Study

Table 2.2 shows a list of studies from previous researchers and the gap of the studies with regard to this study have been identified.

Table 2.2: Research Gap from Previous Studies

Authors	Study	Scopes					
		HGS	HGE	Gender	Age	Various position	Population
Jaafar et al. 2023	Measure Handgrip Strength Dominant and Non-Dominant Hands of Healthy Malay Adults in Malaysia to Develop Normative Reference Values and Predicting the Factors	(/)	(x)	Both (x)	35-70 years	(x)	Malaysia (/)
Bhattacharya & Goswami, 2022	A Cross-Sectional Study of Hand Grip Strength, Endurance and Anthropometric Parameters in Healthy Young Adults	(/)	(/)	Both (x)	18-21 years	(x)	India (x)
Ashraf et al. 2020	Study The Effects of Different Testing Postures on Hand Grip Strength Among Healthy Individuals	(/)	(x)	Both (x)	18-24 years	standing, sitting, supine, side-lying, and prone	Pakistan (x)
Baxi et al. 2017	Measure Hand Grip Strength to evaluate Static and Dynamic Hand Grip Endurance	(/)	60% MVC	Both (x)	18-25 years	(x)	India (x)
Dhananjaya et al. 2017	Measure Hand Grip Strength and Hand Grip Endurance in Healthy Individual to Compare With BMI	(/)	70% MVC	Both (x)	20-45 years	(x)	India (x)
El-Sais & Mohammad, 2014	Study the Influence of Different Testing Postures on Hand Grip Strength	(/)	(x)	Male (x)	19-22 years	supine, prone, side-lying, sitting, and standing	Egypt (x)

Table 2.1: Types of available hand dynamometer and the characteristics (continue)

Authors	Study	Scopes					
		HGS	HGE	Gender	Age	Various position	Population
Hossain et al. 2014	Measure Hand Grip Strength to Perform Multiple Regression Analysis of Hand Grip Strength Factors.	(/)	(x)	Both (x)	18-65 years	(x)	Malaysia (/)
Current Study	Measure Hand Grip Strength of Female Young Adults in Different Forearm Positions During Sitting and Standing and Hand Grip Endurance For 100%, 80%, 60%, 40% And 20% MVC	(/)	100%, 80%, 60%, 40% & 20% MVC (/)	Female (/)	20-24 years (/)	neutral, pronation and supination forearm positions in sitting and standing (/)	Malaysia (/)

CHAPTER 3
METHODOLOGY

This chapter outlines methodology for this study, which includes the key elements of the methods that will be used in completion of this study. The main principle of methodology is to suggest appropriate methods, tools, and techniques to complete this research in accordance with the developed objectives. Figure 3.1 shows the flowchart of the methodology.

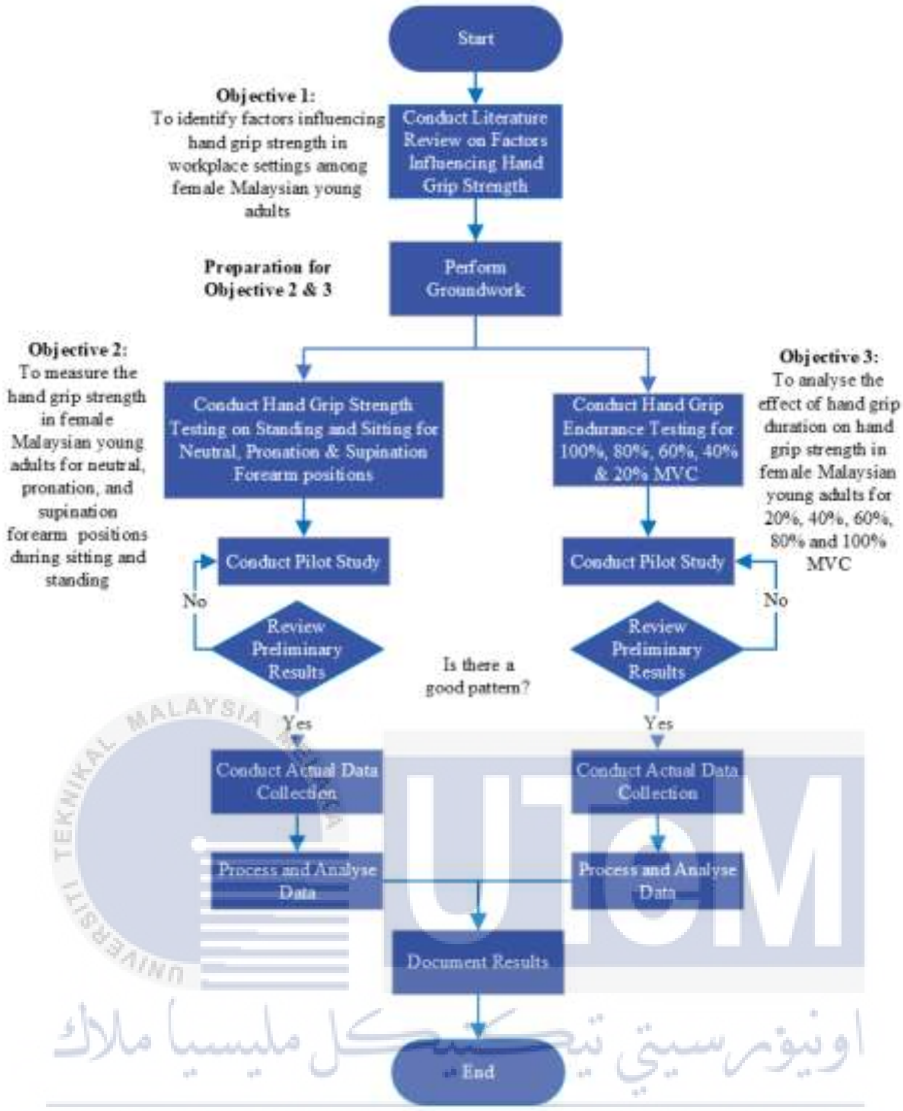


Figure 3.1: Flowchart of The Methodology

3.1 Objective 1: Conduct Literature Review on Factors Affecting Hand Grip Strength

To explore the factors affecting hand grip strength of female young adults in workplace settings, a literature review which covers was conducted. The literature review involved the reading of available materials from previous research including journals, research papers and articles from Google Scholar, ScienceDirect and ResearchGate. The review specifically considered publications from the past 10 years, while older materials were referred whenever necessary. The review focused on hand grip strength and its influencing factors, with the goal of identifying the relationship between these elements.

3.2 Perform Groundwork

The groundwork involved early-stage actions that facilitated subsequent work or progress. In this study, the groundwork involved exploring hand grip studies, with focus on determining the tool for measuring hand grip strength and getting familiarized with the tool to ensure the smooth flow of data collection process which involved experiment. This preparation was crucial for the methodology concerning objectives 2 and 3.

3.2.1 Hand Grip Strength Tool

In this study, the measurement tool of hand grip strength used was Jamar hand dynamometer as recommended by the American Society of Hand Therapist (ASHT) and the tool had been used by many researchers in Malaysia including the studies conducted by Hossain et al. (2012), Shahida et al. (2015), Lam et al. (2016) and Bani et al. (2017). Figure 3.2 show Jamar hand dynamometer.

Figure 3.2: Jamar Hand Dynamometer

To maintain precision in measurements and ensure reliability, it is essential to calibrate the Jamar hand dynamometer. The equipment for calibrating the Jamar hand dynamometer used in this study included tables of the same height, 10kg dumbbell, and a tote bag. The procedures to calibrate Jamar hand dynamometer was as follows:

1) Prior to any loading or at rest, it is essential to confirm that the gauge needle of Jamar hand dynamometer is positioned within the box marked with the number '0' but ensuring it does not touch the stopper, as illustrated in the following Figure 3.3.

Figure 3.3: Preferred Position of Gauge Needle at Rest

2) The dumbbell is weighed to ensure that the weight is 10 kg. After confirming the weight, the dumbbell is placed inside the tote bag.
3) Then, Jamar hand dynamometer is positioned with its two ends on the two tables followed by hanging the tote bag with the dumbbell on the Jamar hand dynamometer handle. The setup is as shown in Figure 3.4.

Figure 3.4: Jamar Hand Dynamometer Placement Setup on The Table

4) Then, the reading on the dynamometer scale is observed. A reading of 10 kgf on the scale indicates that the dynamometer is accurate and ready for measuring hand grip strength. In case the Jamar hand dynamometer does not display reading10 kgf, adjustments should be made accordingly. Figure 3.5 shows 10 kgf reading on Jamar hand dynamometer scale and hence the tool can be utilised to measure hand grip strength.

Figure 3.5: 10kgf Reading on Jamar Hand Dynamometer Scale

3.2.2 Design of Experiment

The design of experiment for measuring the hand grip strength was studied including the data collection procedures, the participants criteria and the participant positioning during the procedures. The criteria involved for participant selection includes age range, gender, and any other relevant factors that align with the aim of the study.

3.3 Objective 2: Conduct Hand Grip Strength Testing on Standing and Sitting for Neutral, Pronation & Supination Forearm Positions

For conducting the hand grip strength testing, repeated measures design experiment was employed in this study. A repeated measures design, also known as a within-subjects design, is a research design in which the same subjects are used for each treatment or condition in a study (Singh et al., 2013). This means that each participant is exposed to all levels of the independent variable, or conditions being studied. In other words, measurements are taken on the same participants multiple times under different conditions.

For this experiment, the maximum hand grip strength served as the dependent variable, while the independent variables (factors) were body positions and forearm positions. Both factors have 2 and 3 levels, respectively; Body position: 1) standing 2) sitting, Forearm position: 1) neutral 2) pronation 3) supination. Therefore, there were a total of 6 tests as illustrated in Table 3.1. Jamar hand dynamometer was used to measure the maximum hand grip strength of participants for standing and sitting at neutral, pronation and supination forearm positions. Furthermore, this study incorporated repetition, conducting the tests twice, and the highest recorded maximum hand grip strength between the two trials was taken into consideration. The test sequence were randomized to account for counterbalance and minimize sequence effect.

Table 3.1: Hand Grip Strength Testing Conditions

	Neutral (NFP)	Pronation (PFP)	Supination (SFP)
Sitting (DT)	DT-NFP	DT-PFP	DT-SFP
Standing (ST)	ST-NFP	ST-PFP	ST-SFP

3.3.1 Perform Pilot Study for Hand Grip Strength Testing

A pilot study is an initial investigation involving a small-scale group of participants, playing around with the designed experiment in a study. The pilot study plays a crucial role in identifying and addressing potential problems to enhance the success of the larger-scale study (In, 2017). In this particular testing, a pilot study was conducted with 20 female participants. Each of these 20 participants performed two trials of hand grip strength testing for neutral, pronation and supination forearm positions, both in sitting and standing positions as in Table 3.1. Before the hand grip strength data collection of the pilot study, participants were briefed on the study's purpose and provided with a demonstration to use the Jamar hand dynamometer. The total time consumed for the pilot study, including the data collection for each participant, was recorded as 20 minutes per participant.

3.3.2 Actual Data Collection of Hand Grip Strength

The actual data collection of hand grip strength testing was consisted of several processes including recruiting participant, participant fill the informed consent form, measuring the anthropometry and lastly performing the hand grip strength testing procedure. The processes are specified in the following sections.

3.3.2.1 Recruit Participant

Participants were recruited among female Universiti Teknikal Malaysia Melaka (UTeM) students and outsiders of aged 20-24 years old. This aligns with the study's focus on Malaysian young adult females engaged in labor participation. Since only healthy participants were considered, certain exclusion criteria were applied. This encompassed conditions such as physical impairment, heart disease, hypertension, and diabetes. The purpose was to indicate the healthy population of young female, who likely to join the labor forces.

Testing was conducted between 9 am and 5 pm, mirroring typical working hours for young women in the workplace. However, considering the hectic schedules of students, the preferred time for testing was between 5 pm and 6 pm. This timeframe aligns with peak hand grip strength, as indicated in the research findings by Douglas et al. (2020). Furthermore, participants were asked about engaging in heavy physical activity prior to data collection. If affirmative, rescheduling of the session was considered to ensure optimal measurement of hand grip strength data in order to achieve the participant's maximum capacity. Besides, the participants were also asked about their meal consumption on the day, aligning with the literature review's discussion highlighting the positive correlation between regular breakfast consumption and higher hand grip strength.

3.3.2.2 Participant fill Informed Consent Form

Prior to the testing, each participant read through and filled in an informed consent form outlining the study's objectives, procedures, and potential risks. This step ensured participants to have a clear understanding of the study and willingly provide their consent before participating.

3.3.2.3 Measure Anthropometry

As a part of the procedure, the weight and height of the participant were recorded and the hand anthropometry of the participants were measured. The hand anthropometry measurement was only considered for the dominant hand of participants, the hand they were going to perform hand grip strength testing. This was based on the assumption that individuals were more likely to perform tasks using their dominant hand, especially in a work setting. A tape measure was to measure the hand anthropometry. The hand dimensions that will be measured are specified as the following.

i. Dominance forearm length: The dominance forearm length was measured as illustrated in Figure 3.6.

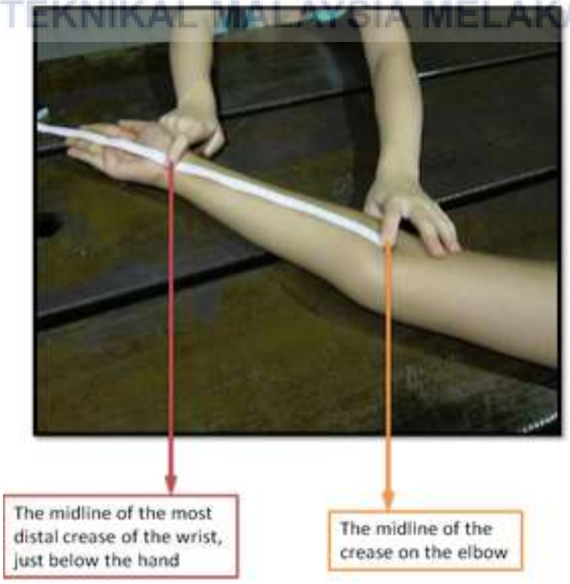


Figure 3.6: Dominance Forearm Length Measurement

ii. Dominance forearm circumference: The dominance forearm circumference was measured as illustrates in Figure 3.7. The forearm circumference should be measured at the distant of two fingers from the elbow crease.

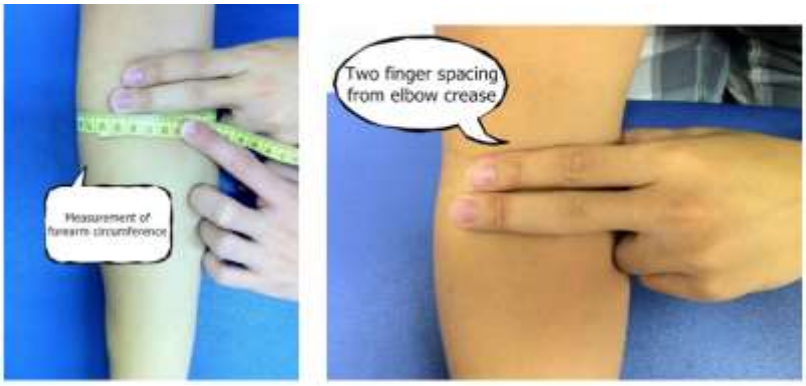


Figure 3.7: Dominance Forearm Circumference

iii. Palm circumference of dominance hand: The palm circumference was measured as per dimension A in Figure 3.8.

iv. Length of palm-wrist of the dominance hand: The length of palm-wrist was measured as per dimension G in Figure 3.8.

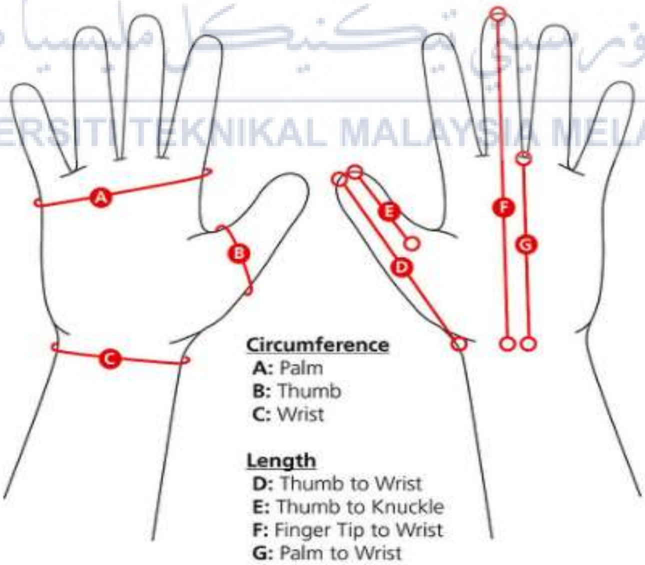


Figure 3.8: Hand Anthropometry Dimension Indicators

3.3.2.4 Hand Grip Strength Testing Procedure

Sitting Position

In the sitting position, the participant sat comfortably on a standard chair without arm support, with legs and back supported. Ensured the participant's feet were flat on the floor, and the non-dominant hand rested on the respective thigh.

Standing Position

In the standing position, participant was instructed to stand comfortably; stand straight, facing forward, with feet pointing forward and slightly apart, and the non-dominant hand hanging down by the side of body.

Figure 3.9: Standing Position

Pre-Testing

1. A card was positioned beneath the participant's armpit, ensuring that it remained in place to prevent the abduction of arm during the hand grip strength grip data measurement. This is as illustrated in Figure 3.10.

Figure 3.10: Putting A Card Beneath The Participant’s Armpit

2. Participant was instructed to grip the Jamar hand dynamometer in a comfortable manner. Participant should position the hand with the thumb around one side of the handle and the four fingers around the other side. The default position was set at the 2nd position, but the handle's position was adjusted when needed.

3. Make sure that the participant’s elbow was flex at 90° angle as in Figure 3.11.

Figure 3.11: Participant’s Elbow Flex At 90°

4. The participant was assisted in bearing the weight of the dynamometer by supporting the bottom of Jamar hand dynamometer with the researcher’s hand. This was intended to counteract the impact of gravity on the peak strength but restricting the movement must be avoided.

Figure 3.12: Supporting the Weight of Dynamometer

Testing

1. The measurement of hand grip strength involved the participant squeezing the dynamometer during the initial forearm position as per the counterbalancing. The participant was asked to squeeze the dynamometer handle gradually and avoid sudden squeezing as it may lead to a jumping needle which results in overshooting the measurement.
2. The participant was encouraged to squeeze for as long and as firmly as she could, or until the gauge needle stopped rising. Once the gauge needle stopped rising, the participant was directed to stop squeezing.
3. The measurement of hand grip strength was recorded and the participant was instructed to take a one-minute rest before proceed with the second trial.

3.3.3 Develop Excel Data System for Proccesing Data

Excel data system to store data was developed to ensure easy access and sorting of the data for data processing. Figure shows Excel datasystem that has been developed, consisting the database for pilot study of hand grip strength testing.

Demographic							Self-Reported							Measured Data of Hand Athropometry												
		Age																			SBP*NFP*NWP		SBP*PFP*NWP		SBP*SFP*NWP	
Gender 1-male; 2-female	Age group 1-20-24yo; 2-25-29yo; 3-30-34yo; 4-35-39yo	Year	Month	Age (years & months)	Race 1-Malay; 2-Chinese; 3-Indian; 4-Bumiputera; 5-Others	BirthPlace (follow the state code in national ID)	Dominant Hand 1-right; 2-left; 3-Ambidextrous	Smoking cigarette 1-Yes; 0-No	Diabetes 1-Yes; 2-No	Hypertension 1-Yes; 0-No	Heart Disease 1-Yes; 0-No	Physical Impairment 1-Yes; 0-No	Other Medical history (if any)	Weight (in kg, 2 decimal points)	Height (in meter, 2 decimal points)	BMI	Dominance forearm length (in meter, 2 decimal points)	Dominance forearm circumference (in meter, 2 decimal points)	Palm circumference of dominance hand (in meter, 2	Length of palm-wrist of dominance hand (in meter, 2	1st trial	2nd trial	1st trial	2nd trial	1st trial	2nd trial
2	1	23	9	23.75	1	11	1	0	2	0	0	0		50	1.56	20.546	0.25	0.22	0.19	0.1	20	21	17	16	21	21
2	1	22	11	22.917	1	6	1	0	2	0	0	0		43	1.47	19.899	0.23	0.2	0.17	0.1	28	30	24	24	32	33
2	1	22	7	22.583	1	14	2	0	2	0	0	0		62	1.6	24.219	0.24	0.25	0.19	0.1	37	35	36	37	39	37
2	1	22	6	22.5	1	14	2	0	2	0	0	0		110	1.65	40.404	0.25	0.28	0.2	0.11	31	30	30	29	32	32
2	1	23	5	23.417	1	14	1	0	2	0	0	0		60.8	1.5	27.022	0.23	0.25	0.18	0.09	24	25	25	24	23	21

Figure 3.13: Excel Datasystem Of Hand Grip Strength Testing

3.3.4 Analyze Data of Hand Grip Strength

Analysis of Variance (ANOVA) with two-way repeated measures was used to analyse the hand grip strength data across different body position and forearms position. It is a statistical method used to analyse the effects of two independent variables (body position and forearm position) on a dependent variable (hand grip strength) where the measurements are taken repeatedly on the same subjects, in this case the participants of hand grip strength testing.

For a two-way repeated measures ANOVA, several assumptions must be met to ensure the validity of the results. Firstly, the normality, where the dependent variable should be approximately normally distributed for each combination of the levels of the two factors, the independent variables. The Shapiro-Wilk test and Q-Q plots were used to assess the normality of data. Then, there should be no significant outliers in the data, as outliers can influence the results of the ANOVA. If significant outliers were found, they were removed from the dataset due to variation that caused by errors during the data collection. Additionally, the assumption of sphericity must be met. Sphericity relates to the equality of the variances of the differences between levels of the repeated measures factor. This assumption is specifically about the repeated measures factors. In JASP, Mauchly's Test of Sphericity was utilized to check this assumption. If sphericity was violated, corrections such as Greenhouse-Geisser or Huynh-Feldt adjustments applied to the degrees of freedom, depending on the value of ϵ. When $\epsilon < 0.75$, the first one would be used otherwise the latter correction. Finally, post-hoc tests were conducted to perform pairwise comparisons and further investigate significant effects, but only if the ANOVA indicated significant differences.

3.4 Objective 2: Conduct Hand Grip Endurance Testing for 100%, 80%, 60%, 40% & 20% MVC

In conjunction with the previous section, this section involved measuring the endurance times for 5 levels of maximal voluntary contraction (MVC). The MVC refers to the maximum hand grip strength from the previous testing where the sitting with neutral position was considered for endurance time testing. Thirty-nine participants from the 125 who participated in the previous experiment took part in this experiment. In this section, endurance time served as the dependent variable, while the independent variables were gripping of Jamar hand dynamometer for 20%, 40%, 60%, 80% and 100% MVC. Hence, there were a total of 5 tests. Prior to the testing, the participant's MVCs for were calculated 20%, 40%, 60%, 80% and 100%. Moreover, the testing employed counterbalance of MVC to avoid sequence effect.

3.4.1 Perform Pilot Study for Hand Grip Endurance Testing

The pilot study for hand grip endurance was performed to assess the reliability of conducting testing for 20%, 40%, 60%, 80% and 100% MVC. Additionally, the pilot study served the purpose of identifying the overall time consumption of the testing process. Upon performing pilot study, the decision to optimize testing time efficiency by not performing second trial was made due to very long duration consumed. However, the established standards and parameters must be strictly adhered to ensure the reliability of the collected data. For instance, participants must be provided with a minimum break time of 2 minutes to compensate for muscle fatigue. Besides, the percentage of MVCs must be accurately determined and the gripping task for each participant should be observed thoroughly.

3.4.2 Actual Data Collection of Hand Grip Endurance

The procedures of hand grip endurance testing were as follow:

1. The participant sat comfortably on a standard chair without arm support, with legs and back supported. Ensured the participant's feet were flat on the floor, and the non-dominant hand rested on the respective thigh.

2. Once the participant was ready, she was asked to slowly squeeze the Jamar hand dynamometer up to the specified MVC percentage. The participant was directed about the force she needed to exert. Simultaneously, the timer started.

3. Overtime, the participant was asked if she was still able to grip the Jamar hand dynamometer. Once the participant was no longer able to do the gripping, the timer was stop and the endurance time recorded.

4. The participant was given a 2-minute break before proceeding to the next testing condition.

3.4.3 Develop Excel Data System for Processing Data

Excel data system to store data was developed to ensure easy access and sorting of the data for data processing. The same excel data system from previous testing was used.

3.4.4 Analyze Data of Hand Grip Endurance

The analysis of hand grip endurance involved 2 analysis which were Pearson's correlation and one-way repeated measures ANOVA. All the analysis were conducted in JASP.

3.4.4.1 Pearson's Correlation

Pearson's correlation was used to examine the relationship between endurance time and MVL levels, and between endurance time across all MVC levels and anthropometry measurements. In JASP, Pearson's correlation coefficient, a standardized covariance was used to measures the strength and direction of the linear relationship between two continuous variables. Pearson's correlation coefficient (r) ranges from -1.0 to +1.0. The closer the value of r is to +1 or -1, the stronger the relationship between the two variables. An r value close to 0 indicates no relationship, r value between 0.1 and 0.3 indicates a small effect, r value between 0.3 and 0.5 represents a moderate effect, and r value greater than 0.5 demonstrates a large effect. Additionally, a positive r value means that as one variable increases, the other variable also increases, indicating a positive correlation.

Conversely, a negative r value means that as one variable increases, the other decreases, indicating an inverse or negative correlation.

3.4.4.2 One-way repeated measures ANOVA

The one-way repeated measures ANOVA is used to determine if there are statistically significant differences in means between three or more related groups, where the same participants are tested multiple times or under different conditions. In this study, this analysis was used to determine the significant difference between endurance time across 20%, 40%, 60%, 80% and 100% MVC levels. Similar to two-way repeated measures ANOVA, this analysis also required the normally distribution, no significant outliers and sphericity assumptions to be met. Lastly, post-hoc test was conducted upon ANOVA reported the significant differences among the endurance times across MVC levels to determine how endurance time at each MVC level differed from each other.

CHAPTER 4

RESULTS AND DISCUSSIONS

This chapter includes the results and discussion of the finding regarding the identification of factors influencing hand grip strength with the respect to workplace settings, followed by the data obtained from the experimental procedure of measuring hand grip strength for neutral, pronation and supination forearm positions during standing and sitting. Lastly, the data obtained from measuring the hand grip duration for 20%, 40%, 60%, 80% and 100% MVC during sitting with neutral forearm position. The findings are discussed and compared with the previous research to find correlation and similarity.

4.1 Factors Influencing Hand Grip Strength in Workplace Settings Among Female Malaysian Young Adults

In this section, the literature review findings on factors influencing hand grip strength were summarized in Table 4.1. The table lists each factor, the related findings, and the respective authors. A total of 13 factors affecting hand grip strength were identified, mainly divided into individual and workplace settings.

Based on the findings, it showed that many factors could affect hand grip strength such as gender, age and body position and the duration of hand gripping activities. Besides, individual factors such as weight, height, hand anthropometrics, diet and health status also influenced the hand grip strength of an individual. Therefore, giving conclusive evidence that hand grip strength varied among individuals. As for the workplace setting related factor, the factors included the type of job task, the ambient temperature of the work environment, time of day and as well as the design of hand tools being used.

Table 4.1: Summary of Factors Influencing Hand Grip Strength

No	Factor	Findings	Authors
1	Gender	Males have higher hand grip strength compared to females: • 35% to 40% differences • 43% differences	Eksioglu, 2016; Amaral, 2019; Mohd et al., 2019; CD, 2020; Almashaqbeh et al., 2022; Ashraf et al., 2022; Dağ and Erdoğan, 2022; Baek et al. 2023
2	Age	Hand grip strength is reduced by ageing and there is curvilinear correlation between hand grip strength and age: • Rise and peak between the ages of 30 and 39 years old then decrease gradually until 49 and followed by significant decline • Peak strength at 40 years old and gradually decreases	Carish & Kennedy, 2003 as cited in Moy et al., 2011; Eksioglu, 2016; Lim et al., 2017; CD, 2020
3	Position	Hand grip strength is affected by positions: • Among five positions (standing, sitting, supine, side lying, and prone), the highest strength is in standing and the lowest strength is in prone • Hand grip strength is higher in standing than sitting position	Barut & Demirel, 2011; Akbar & Setiati, 2018 as cited in Ashraf et al., 2022; CD, 2020; Ashraf, 2022
4	Duration	Weaker hand grip strength is associated with prolonged use of mobile phone	Osailan, 2021
5	Weight	Higher grip strength is linked to not being underweight	CD, 2020
6	Height	Higher grip strength is affected by higher height	CD, 2020
7	Hand anthropometry	Hand grip strength is influenced by hand breadth and hand circumference	Shahida et al., 2015; Eksioglu, 2016; CD, 2020
8	Health status	• Lower hand grip strength is affected by physical injury • Lower hand grip strength is linked to decrease in mental well-being	Manoharan et al., 2015; Belcher, 2016; Jiang et al., 2022
9	Diet	Hand grip strength is correlated with nutritional status: • High frequency of breakfast consumption and low frequency of snacking after dinner significantly correlated with higher grip strength	Manoharan et al., 2015; Yoshimura et al., 2017 Uzhova et al., 2018 as cited in Ding et al., 2020
10	Type of job task	Hand grip strength is affected by the type of job tasks, but there are contrary of finding among researchers: • Manual workers have slightly lower hand grip strength compared to office workers • Manual workers have 12% hand grip strength higher than office workers	Boschman, 2017; Jaafar et al., 2023
11	Temperature	Mismatched findings regarding temperature: • Hand strength is reduced by cold water • Hand grip strength increases with decreasing ambient temperature	Chi et al., 2012; Cakmak & Ergul, 2018
12	Time of day	Highest hand grip strength in the late afternoon (4pm to 8pm)	Douglas et al., 2020
13	Hand tools design	• Soft handle material provides firm grip and improve hand grip strength • Concave curvature of handle shape optimizes hand grip strength • Excessive tools weight impacts hand grip strength	Halim et al., 2020

4.2 Hand Grip Strength in Female Malaysian Young Adults for Neutral, Pronation and Supination Forearm Positions in Standing and Sitting

This section presents the finding regarding the objective 2's methodology of measuring hand grip strength of female Malaysian young adults at neutral, pronation and supination forearm positions during standing and sitting. This includes analyzing the participants' data such as demographic information, hand dominance and anthropometry, followed by the analyzing and discussion of hand grip strength data.

4.2.1 Participants' Data and Information

The participants of this study were female young adults of age 20 years old to 24 years old and did not possess the exclusion criteria which include diabetes, hypertension, and heart disease. The data and information of participants including age, ethnicity, birthplace, anthropometry as well as the hand grip strength were recorded during the data collection process by using the participant screening form. This was followed by inserting the data into the Excel spreadsheet as in Appendice D.

4.2.2 Demographic Information of Participants

The demographic information of the participants recorded for this study were age, ethnicity, and birthplace. The distributions of age of the participants are presented using pie chart in Figure 4.1. Based on Figure, the distribution is categorized by year individually from 20 years old to 24 years old. The increasing pattern can be seen in the percentage of participants of age 20 years old which is 11% (n=14), followed 16% participants (n=20) at 21 years old and 40% participants (n=50) of age 22 years old. However, the percentage of participants decreased for older ages with 24% (n=30) for participants of 23 years old and finally 9% (n=11) for participants of age 24 years old.

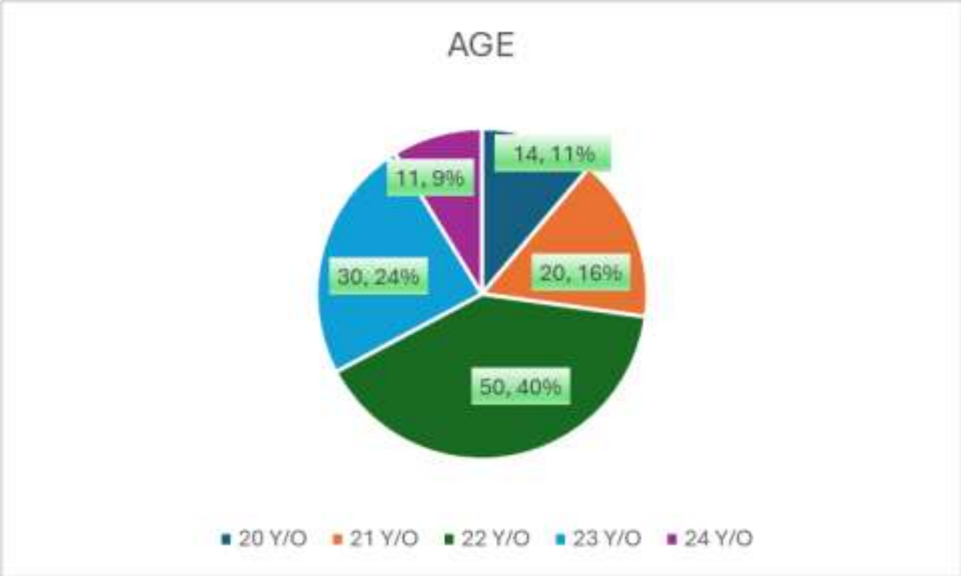


Figure 4.1: Pie Chart of Age of The Participants

The distribution of ethnicity of the participants is demonstrated in Figure 4.2. The ethnicity is classified into five categories which are Malay, Chinese, Indian, Bumiputera and others. The figure illustrates that the majority of participants were Malay, comprising 77% (n=97) of the sample. This was followed by Chinese participants, who made up 12% (n=15). The remaining categories had smaller numbers, with Indian participants at 5% (n=6), Bumiputera participants at 4% (n=5), and those classified as 'Others' at 2% (n=2). The Bumiputera participants were UTeM students from Sabah and Sarawak, while the 'Others' category included two participants of Siamese ethnicity.

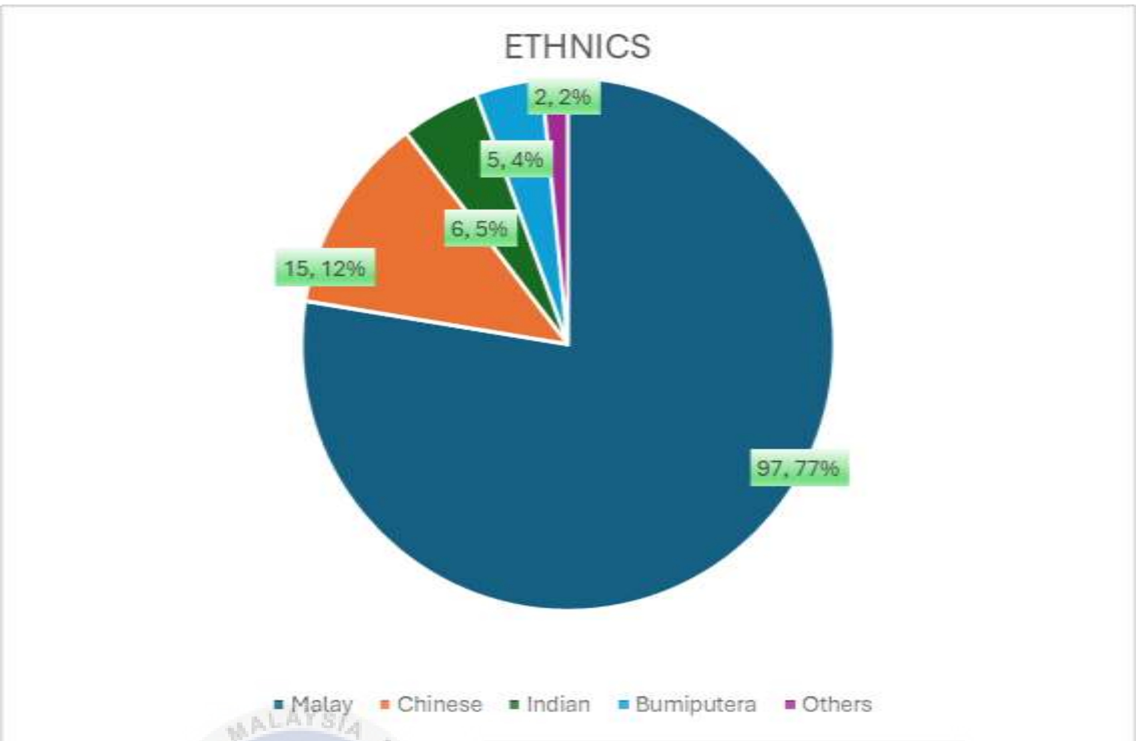


Figure 4.2: Pie Chart of Ethnicity of The Participants

The distribution and trend of the ethnicity in this study align with the population of Malaysian female young adults recorded aged 20 to 24 years old by DOSM as of 2023. According to DOSM, Malays constituted 61.27% of this population, followed by Chinese at 18.99%. However, there were contradictoriness in the distribution of Bumiputera and Indian participants. The DOSM recorded 12.95% Bumiputera and 6.09% Indian, indicating a higher proportion of Bumiputera than Indian in the general population. This variation is likely because the study was conducted among UTeM students in Peninsular Malaysia, leading to lower Bumiputera participation. The 'Others' ethnicity category constituted a minority at 0.69% in the DOSM data.

4.2.3 Hand Dominance and Anthropometry

This section presents the information of hand dominance and the mean of anthropometry measurements that had been recorded, including weight, height, BMI, forearm length, forearm circumference, palm circumference and palm-wrist length.

4.2.3.1 Hand Dominance

Figure 4.3 shows the distribution of the hand dominance data of the participants. The majority of the participants were right-handed which encompassed 86% (n=107) and only 14% participants (n=18)) were left-handed.

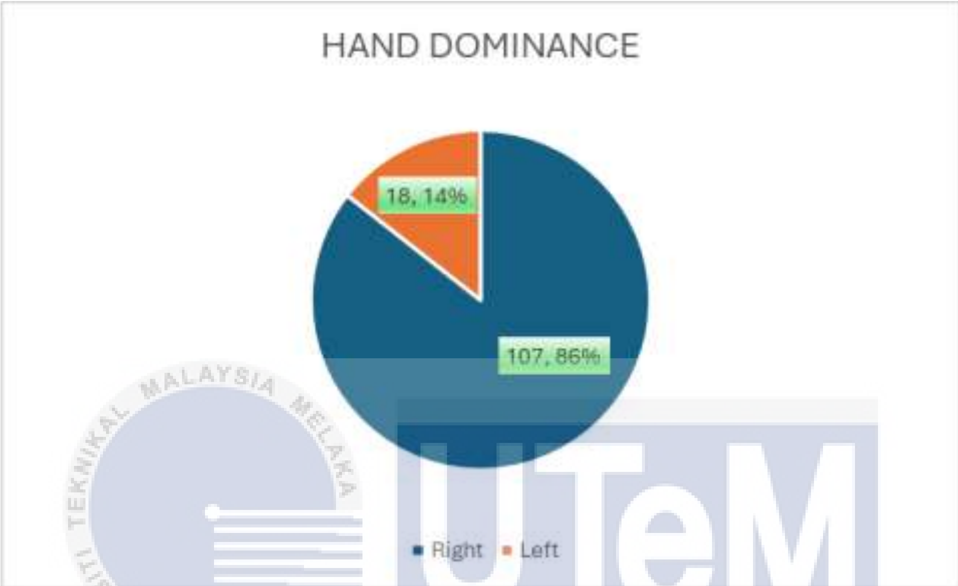


Figure 4.3: Pie Chart of Hand Dominance of The Participants

4.2.3.2 Anthropometry

Table 4.2 shows descriptive statistics of various anthropometric measurements of the participants that had been recorded during the data collection process including weight, height, Body Mass Index (BMI), forearm length and circumference, palm circumference, and palm-wrist length. The data presented are the mean, standard deviation, minimum and maximum values for each measurement.

From the results, there appears to be a wide range of values for weight (37.500 kg to 110.000 kg). This suggests a great variability in weight among the participants and hence, the standard deviation is 13.959 kg. For height, the results show low deviation based on the standard deviation value of 0.054 m with ranges 1.43 m to 1.71 m. Apart from that, the BMI of the participants shows quite high deviation with standard deviation of

5.448 kg/mm², but less than the weight. For the hand anthropometry which are forearm length, forearm circumference, palm circumference and palm-wrist length the standard deviation are low with the value of 0.014 m, 0.026 m, 0.010 m and 0.005 m respectively. The variation seems to be low due to the measurement unit of m, when considering the unit in mm the value can be regarded as notable.

Table 4.2: Descriptive Statistics of Anthropometry Measurements

	Weight (kg)	**Height (m)**	**BMI (kg/m²)**	**Forearm length (m)**	**Forearm circumference (m)**	**Palm circumference (m)**	**Palm-wrist length (m)**
Mean	57.878	1.578	23.250	0.249	0.238	0.180	0.102
Std. Deviation	13.959	0.054	5.448	0.014	0.026	0.010	0.005
Minimum	37.500	1.430	16.023	0.220	0.190	0.140	0.090
Maximum	110.000	1.710	41.207	0.290	0.320	0.210	0.120

4.2.4 Analysis of Hand Grip Strength Data

Analysis of hand grip strength data involved descriptives statistics which include the mean, standard deviation and most importantly the normality of the data. This followed by two-way repeated measures ANOVA and post-hoc test.

4.2.4.1 Descriptive Statistics of Hand Grip Strength

Table 4.3 demonstrated the results of descriptive statistics of hand grip strength data of the participants across two independent variables which are body position (level: standing and sitting) and forearm position (level: neutral, pronation and supination). Descriptive statistics were employed to summarize the data and offer a fundamental overview of its characteristics, aiding in a straightforward interpretation. Key aspects of this summary include mean and standard deviation values, which are of particular interest in understanding the data's central tendency and dispersion.

In the standing position, the mean hand grip strength for neutral, pronated, and supinated forearm positions are 23.520kgf, 22.072kgf, and 23.640kgf, respectively, with corresponding standard deviations of 5.282, 5.539, and 5.795, respectively. Notably, the highest mean hand grip strength was observed in the pronated forearm position during standing, while the lowest was recorded in the neutral forearm position. Similarly, the greatest variation was observed in the pronation forearm position, while the least variation was noted in the neutral forearm position during standing. For sitting, the mean of hand grip strength for neutral, pronation and supination forearm positions are 23.224kgf, 21.368kgf and 23.040kgf respectively with the corresponding standard deviations of 5.328, 5.124, and 5.395 respectively. The highest mean of hand grip strength during sitting was found to be in neutral forearm position and the lowest is at pronation forearm position Furthermore, the greatest deviation was observed in the supination forearm position, while the least deviation was noted in the neutral forearm position during sitting. Nevertheless, it is important to highlight that the standard deviation values for hand grip strength across all positions were not highly differed from each other. To better visualize the mean value of hand grip strength across all positions and the differences, Figure 4.4 presented the histogram of the mean values.

However, the primary highlight of the descriptive statistics results was the normal distribution of hand grip strength data across all positions. This was evidenced by the Shapiro-Wilk test's p-values where $p>0.05$, indicating normality. The p-values were 0.494, 0.108, 0.472, 0.334, 0.286 and 0.332 for standing with neutral forearm, standing with pronation forearm, standing with supination forearm, sitting with neutral forearm, sitting with pronation forearm and sitting with supination forearm, respectively. It means that the data sample is not significantly different from a normal distribution and pass the normality test. It is important to note that the data was normally distributed so the subsequent analysis which is ANOVA could proceed.

Table 4.3: Descriptive Statistics of Hand Grip Strength

	Standing, Neutral Forearm	**Standing, Pronation Forearm**	**Standing, Supination Forearm**	**Sitting, Neutral Forearm**	**Sitting, Pronation Forearm**	**Sitting, Supination Forearm**
Median	24.000	22.000	23.000	23.000	21.000	23.000
Mean	23.520	22.072	23.640	23.224	21.368	23.040
Std. Deviation	5.282	5.539	5.795	5.328	5.124	5.395
Skewness	-0.062	0.255	0.258	-0.176	-0.025	0.257
Std. Error of Skewness	0.217	0.217	0.217	0.217	0.217	0.217
Kurtosis	-0.389	-0.243	-0.187	-0.345	-0.266	-0.216
Std. Error of	0.430	0.430	0.430	0.430	0.430	0.430

Table 4.3: Descriptive Statistics of Hand Grip Strength

	Standing, Neutral Forearm	**Standing, Pronation Forearm**	**Standing, Supination Forearm**	**Sitting, Neutral Forearm**	**Sitting, Pronation Forearm**	**Sitting, Supination Forearm**
Kurtosis						
Shapiro-Wilk	0.990	0.983	0.990	0.988	0.987	0.988
P-value of Shapiro-Wilk	0.494	0.108	0.472	0.334	0.286	0.332
Minimum	11.000	8.000	10.000	8.000	8.000	12.000
Maximum	37.000	36.000	39.000	34.000	32.000	38.000

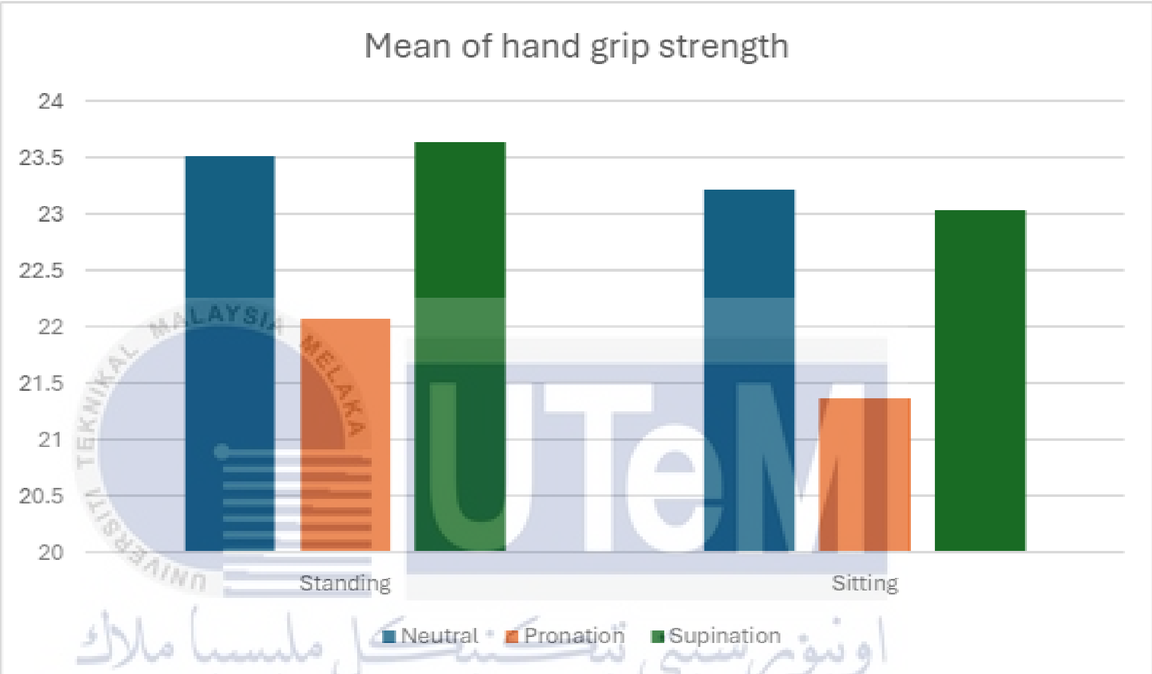


Figure 4.4: Histogram of Hand Grip Strength Mean Value for All Positions

Additionally, the normal distribution of hand grip strength data across all positions can be further illustrated using quantile-quantile (Q-Q) plots. These plots serve as graphical tools for comparing the distribution of data to an expected theoretical distribution, primarily for evaluating normality assumptions. The fundamental principle of a Q-Q plot involves plotting specific points of the data, known as quantiles, against the quantiles of the theoretical distribution. When these points align along a diagonal straight line, it indicates that the data are normally distributed.

The Q-Q plots depicting hand grip strength for all positions were displayed in Figure 4.5 through Figure 4.10, respectively. Observing these plots, the points generally align closely along the straight diagonal line for each position. This alignment suggests a strong correspondence between the theoretical distribution and the data, confirming that the data were normally distributed. This finding aligns with the earlier results of the Shapiro-Wilk normality test.

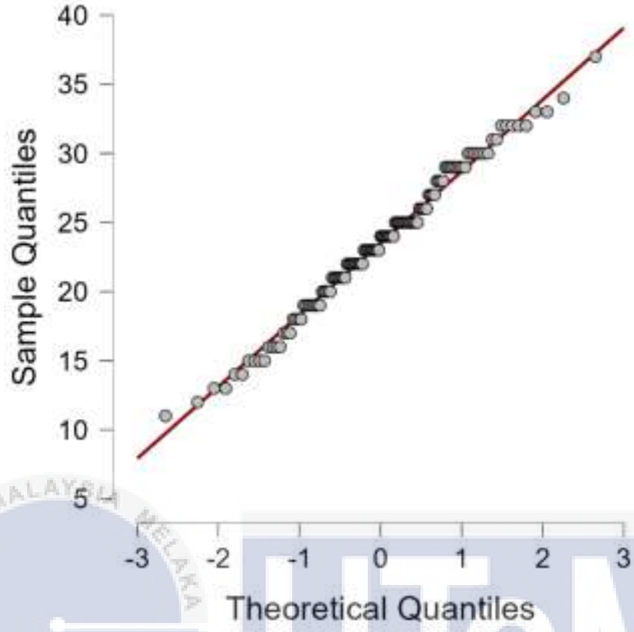


Figure 4.5: Q-Q Plot of HGS in Standing with Neutral Forearm

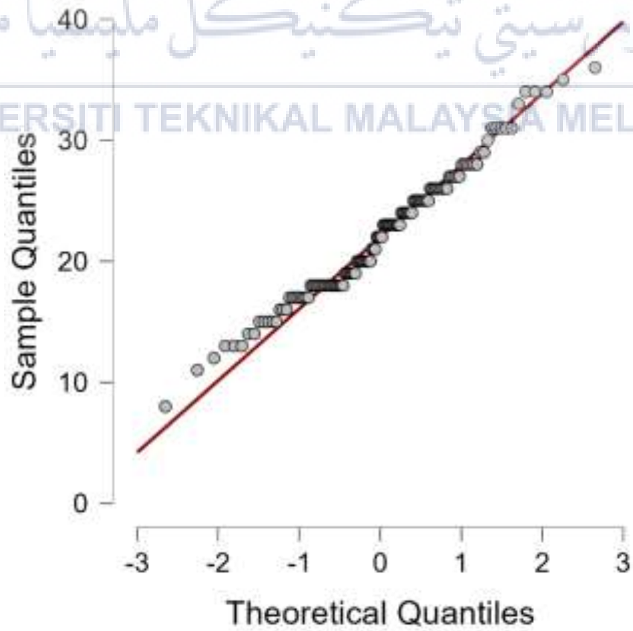


Figure 4.6: Q-Q plot of HGS in Standing with Pronation Forearm

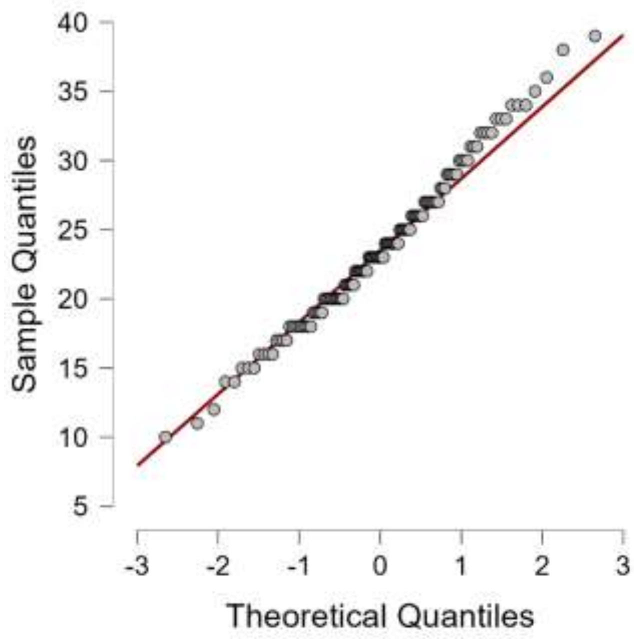


Figure 4.7: Q-Q plot of HGS in Standing with Supination Forearm

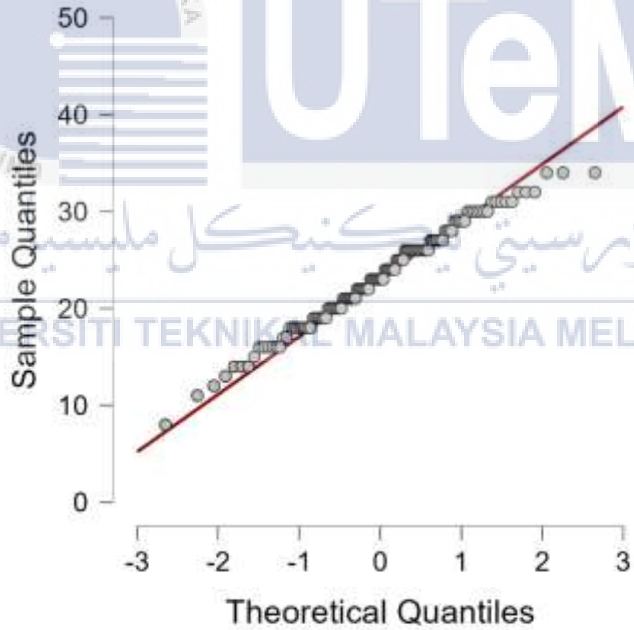


Figure 4.8: Q-Q plot of HGS in Sitting with Neutral Forearm

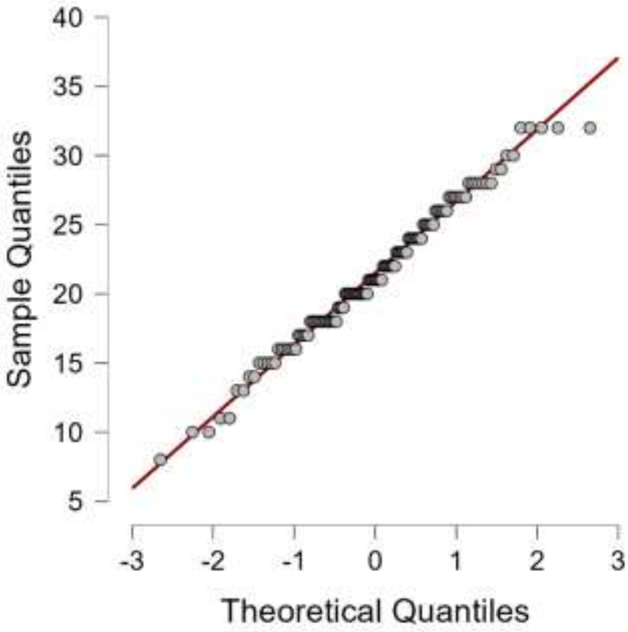


Figure 4.9: Q-Q plot of HGS in Sitting with Pronation Forearm

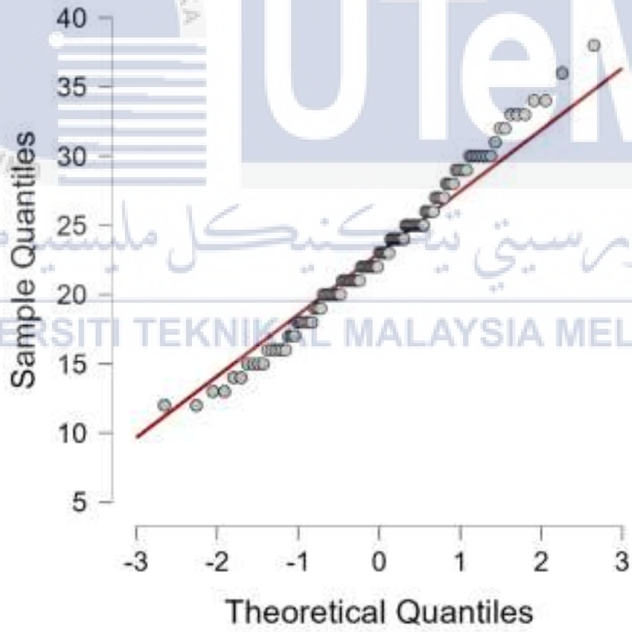


Figure 4.10: Q-Q plot of HGS in Sitting with Supination Forearm

4.2.4.2 Two-Way Repeated Measures ANOVA

Table 4.4 shows the results of two-way repeated measures ANOVA for the hand grip strength of the participants in neutral, pronation and supination forearm positions during sitting and standing respectively. The analysis was conducted using repeated measures ANOVA, which is a statistical technique used to compare means from groups where the same subjects are measured under different conditions. The results investigated the effects of independent variables which are body positions and forearm positions on the independent variable, hand grip strength.

Based on the ANOVA results, there was a significant main effect of body position, $F(1, 117) = 5.971$, $p = 0.016$, $\eta^2 = 0.013$. This indicated that the mean of hand grip strength was statistically different between standing and sitting. Apart from that, there was also a significant main effect of forearm position, $F(2, 234) = 39.252$, $p < .001$, $\eta^2 = 0.119$. Similarly, the mean value of hand grip strength was statistically different across the different forearm positions which are neutral, pronation and supination. In contrast, the interaction effect between body position and forearm position was not statistically significant, F(2[a], 234) = 0.802[a], p = 0.450[a], $\eta^2 = 0.002$. This means that the effect of body position on the dependent variable did not depend on the forearm position, and vice versa.

Table 4.4: ANOVA Within Subjects Effects

Cases	Sum of Squares	df	Mean Square	F	p	η²
Body position	53.333	1	53.333	6.737	0.011	0.014
Residuals	981.667	124	7.917			
Forearm position	446.211	2	223.105	40.630	< .001	0.116
Residuals	1361.789	248	5.491			
Body position ✻ Forearm position	5.619 [a]	2 [a]	2.809 [a]	0.709 [a]	0.493 [a]	0.001
Residuals	982.381	248	3.961			

Note. Type III Sum of Squares

[a] Mauchly's test of sphericity indicates that the assumption of sphericity is violated (p < .05).

4.2.4.3 Post-Hoc

Due to the significant main effects of both body position and forearm position, the post-hoc test was conducted to determine the specific level of factor differ from each other. Table 4.5 showed the results of post-hoc test for body position, Table 4.6 showed the results of post-hoc test for forearm position and Figure 4.11 demonstrated the descriptive plot of body position and forearm position.

For body position, the test revealed that the mean of hand grip strength for standing is significantly higher than sitting with difference of 0.5333 and p=0.011, as can be visualized through Figure 4.11. As for forearm position, the results showed that the mean of hand grip strength of neutral forearm position is significantly higher than pronation forearm position with mean difference of 1.725 and 0<0.001. However, there is no significant difference between the mean of hand grip strength for neutral forearm position and supination forearm position (p=1.000). Between supination forearm position and pronation forearm position, there is significant difference with the mean of hand grip strength in pronation forearm position is lower than supination forearm position by 1.648 and p<0.001.

Table 4.5: Post Hoc Comparisons - Body Position

		Mean Difference	**SE**	**t**	**p_{bonf}**
Standing	Sitting	0.533	0.205	2.596	0.011

Note. Results are averaged over the levels of: Forearm position

Table 4.6: Post Hoc Comparisons - Forearm Position

		Mean Difference	**SE**	**t**	**p_{bonf}**
Neutral	Pronation	1.652	0.210	7.882	< .001
	Supination	0.032	0.210	0.153	1.000
Pronation	Supination	-1.620	0.210	-7.729	< .001

Note. P-value adjusted for comparing a family of 3
Note. Results are averaged over the levels of: Body position

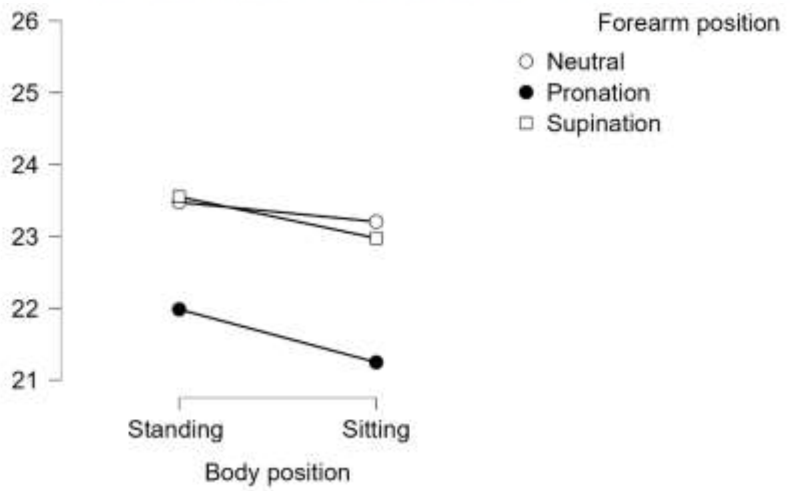


Figure 4.11: Descriptive Plot of Body Position and Forearm Position

4.2.5 Discussion of Measurement of Hand Grip Strength in Female Malaysian Young Adults for Neutral, Pronation and Supination Forearm Positions in Standing and Sitting

Based on ANOVA analysis, there is statistically difference in hand grip strength between sitting and standing with higher strength is observed in standing. This finding aligns with previous research by Xu et al. (2021), El-Sais and Mohammad (2014) and Lao (2014), which also reported significantly greater grip strength when standing compared to sitting. The higher hand grip strength in standing is due to optimal mental and physical conditions achieved in that position. When standing, there is an enhanced synergy between the muscles of the upper and lower extremities, leading to increased core engagement postural stability thus resulting in increased hand grip strength. Additionally, both cortical and peripheral areas of the brain are more effectively stimulated when in a standing position (Kong, 2014). Lstrand and Rodahl (1977) as cited in Kong (2014) attributed this effect to the continuous interaction of central commands with sensory feedback from the joints and muscles of the lower extremities in standing position. Conversely, in sitting position, sensory feedback from the muscles and joints of the lower limbs is minimal. This supports the observed difference in hand grip strength between standing and sitting.

The results also showed significantly higher hand grip strength in neutral and supination forearm positions compared to pronation. This finding aligns with the study by Fan et al. (2019). The variations in strength across different forearm positions are due to the length-tension relationship in muscle force production. Specifically, during pronation, the radius crosses over the ulna, causing the long flexor muscles to shorten (Murugan et al., 2013). This shortening leads to a reduction in hand grip strength, making it the lowest in the pronation position.

4.3 Effect of Hand Grip Duration on Hand Grip Strength in Female Malaysian Young Adults for 20%, 40%, 60%, 80% and 100% MVC

This section presents the finding regarding objective 3's methodology of conducting hand grip endurance testing for 20%, 40%, 60%, 80% and 100% MVC level.

The analysis included descriptive statistics of the endurance time data, Pearson's correlation between endurance time and MVC level, followed by a one-way repeated measures ANOVA and post hoc test. Additionally, Pearson's correlations between endurance time at each MVC level and anthropometric variables were conducted. The findings are discussed in the final subsection.

4.3.1 Descriptive Statistics of Endurance Time

Based on descriptive statistics of endurance time in Table 4.7, the mean and median of endurance time across the different MVC percentage levels differ from each other where the median and mean values for most parameters generally decrease as MVC level increases but the trend is not linear. As evident, mean and standard deviation from 20% MVC through 100% MVC were 111.889s (SD=23.172), 62.611 (SD=12.415), 39.306S (SD=7.555), 20.028s (SD=4.178) and 3.778s (SD=1.098), respectively. The trend can also be seen through the box plot presented in Figure 4.12. This suggests that the parameters were influenced by the level of muscle activation.

Table 4.7: Descriptive Statistics of Endurance Time

	20%	40%	60%	80%	100%
Mean	103.509	60.731	39.148	19.414	3.465
Std. Deviation	14.019	8.041	5.935	3.488	0.704
Shapiro-Wilk	0.964	0.978	0.964	0.981	0.944
P-value of Shapiro-Wilk	0.246	0.632	0.247	0.752	0.050
Minimum	65.910	42.040	25.000	12.000	2.220
Maximum	129.000	79.000	51.000	28.000	5.000

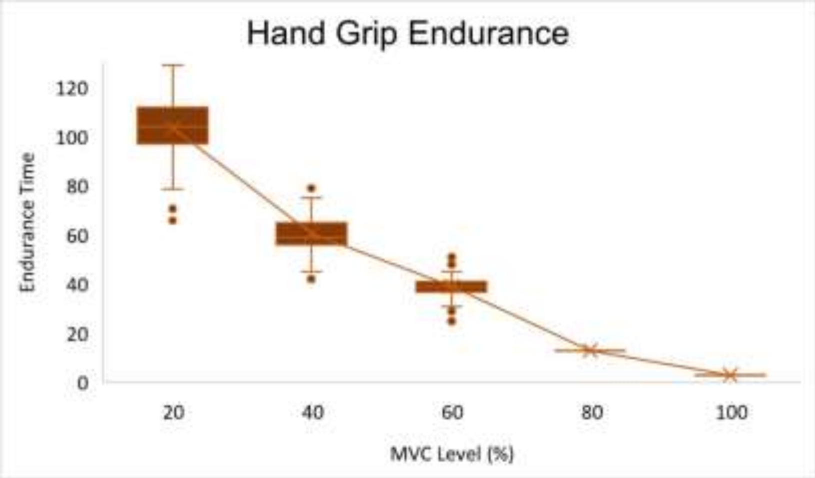


Figure 4.12: Box Plot of Hand Grip Duration

4.3.2 Pearson's Correlation between Endurance Time and MVC Level

In conjunction with the previous subsection, Pearson's correlation between endurance time and MVC level revealed a strong, significant negative correlation ($r = -0.955$, $p < 0.001$). This indicates that as the MVC level increased, the participants' endurance time decreased. Longer endurance times were associated with lighter workloads, and shorter endurance times with heavier workloads.

Table 4.8: Pearson's Correlation

Variable		Endurance Time	MVC Level
1. Endurance Time	Pearson's r	—	
	p-value	—	
2. MVC Level	Pearson's r	-0.955	—
	p-value	< .001	—

4.3.3 One-Way Repeated Measures ANOVA

The one-way repeated measures ANOVA results in Table 4.9 revealed that MVC level significantly affected hand grip strength ($p < 0.001$). This indicates that at least one MVC level had a different endurance time compared to the others and on average, endurance times were not the same across the different hand gripping activities. To examine the interactions between each MVC level, the post hoc test results are presented in the following subsection.

Mauchly's test indicated a violation of the sphericity assumption ($p < 0.05$), which requires equal variances of differences between all repeated measures. To address this, the Greenhouse-Geisser correction was applied due to $\epsilon < 0.75$, as shown in the Test of Sphericity results in Table 4.10. This adjustment is essential to ensure the validity of the p-value despite the sphericity violation.

Table 4.9: Within Subjects Effects

Cases	Sphericity Correction	Sum of Squares	df	Mean Square	F	p
Endurance time	Greenhouse-Geisser	237295.127	1.680	141225.546	1356.306	< .001
Residuals	Greenhouse-Geisser	6648.361	63.850	104.125		

Note. Type III Sum of Squares

[a] Mauchly's test of sphericity indicates that the assumption of sphericity is violated (p < .05).

Table 4.10: Test of Sphericity

	Mauchly's W	Approx. X^2	df	p-value	Greenhouse-Geisser ε	Huynh-Feldt ε	Lower Bound ε
Endurance time	0.038	119.062	9	< .001	0.420	0.437	0.250

4.3.4 Post-Hoc

Post-hoc test revealed that endurance time was significantly different between all combinations of MVC level ($p<0.001$). The highest mean difference of endurance time were found to be between 20% MVC and 100% MVC (100.044 s) and the lowest difference is between 80% MVC and 100 MVC% (15.949 s).

Table 4.11: Post Hoc Comparisons - Endurance Time

		Mean Difference	SE	t	p_{bonf}
20% MVC	40% MVC	42.778	1.498	28.563	< .001
	60% MVC	64.361	1.498	42.974	< .001
	80% MVC	84.095	1.498	56.150	< .001
	100% MVC	100.044	1.498	66.800	< .001
40% MVC	60% MVC	21.583	1.498	14.411	< .001
	80% MVC	41.317	1.498	27.587	< .001

Table 4.11: Post Hoc Comparisons - Endurance Time

		Mean Difference	SE	t	p_{bonf}
	100% MVC	57.266	1.498	38.237	< .001
60% MVC	80% MVC	19.734	1.498	13.176	< .001
	100% MVC	35.683	1.498	23.826	< .001
80% MVC	100% MVC	15.949	1.498	10.649	< .001

Note. P-value adjusted for comparing a family of 10

4.3.5 Pearson's Correlations Between Endurance Time Across All MVC Levels and Anthropometric Measurements

Based on Table 4.12, there is a weak positive correlation between weight and endurance time at 20%, 40% and 60% MVC, but the correlation is not statistically significant (p-value > 0.05). This means that people with higher weight may tend to have slightly longer endurance time at lower exertion levels, but the evidence is not very strong. There is a weak negative correlation between height and endurance time across all MVC levels. However, none of these correlations are statistically significant. So, there might be a very slight tendency for shorter people to have better grip endurance, but this is not conclusive. Body Mass Index (BMI) shows a weak positive correlation with endurance time at all MVC levels, with a slightly stronger correlation at 40% MVC (p-value = 0.037). This suggests that people with higher BMI may have a bit better grip endurance, but again, the evidence is not very strong.

There is close to zero correlation between forearm length and endurance time at all MVC levels. None of the correlations are statistically significant (p-value > 0.05). This means that forearm length is not a good predictor of grip endurance. There is a weak positive correlation between forearm circumference and endurance time at most MVC levels, with the strongest correlation at 40% MVC (p-value = 0.079). This suggests that people with larger forearms may have slightly better grip endurance, especially at lower exertion levels. There is close to zero correlation between palm circumference and endurance time at all MVC levels. None of the correlations are statistically significant (p-value > 0.05). This means that palm circumference is not a good predictor of grip endurance. There is close to zero correlation between wrist-palm length and endurance time at all MVC percentages. None of the correlations are statistically significant (p-value > 0.05). This means that wrist-palm length is not a good predictor of grip endurance.

Table 4.12: Pearson's Correlation Between Endurance Time at Each MVC Level and Anthropometric Variables

		Weight	Height	BMI	FL	FC	PC	WPL
20%	**r**	**0.247**	**-0.134**	**0.293**	**0.070**	**0.328**	**0.195**	**0.212**
	p	0.196	0.489	0.122	0.717	0.082	0.310	0.269
40%	**r**	**0.353**	**-0.079**	**0.389**	**0.097**	**0.331**	**0.142**	**0.155**
	p	0.060	0.684	0.037	0.618	0.079	0.462	0.423
60%	**r**	**0.251**	**-0.210**	**0.321**	**0.033**	**0.260**	**0.055**	**0.175**
	p	0.190	0.274	0.090	0.865	0.173	0.777	0.363
80%	**r**	**0.070**	**-0.391**	**0.176**	**-0.165**	**0.145**	**-0.026**	**-0.156**
	p	0.719	0.036	0.362	0.393	0.453	0.894	0.420
100%	**r**	**0.103**	**-0.077**	**0.102**	**0.028**	**0.008**	**-0.099**	**0.109**
	p	0.595	0.691	0.597	0.885	0.969	0.609	0.573

4.3.5 Discussion of The Effect of Hand Grip Duration on Hand Grip Strength in Female Malaysian Young Adults for 20%, 40%, 60%, 80% and 100% MVC

A clear downward trend in endurance time as the MVC level increases can be observed from the hand grip endurance testing, based on Pearson's correlation and the box plots. These outcomes are consistent with the study by Yamaji et al. (2006), which examined force reduction for target values of 100%, 75%, and 50% MVC over 6 minutes. In the study, participants exhibited lower endurance times at high MVC levels (75% and 100%) and longer sustained times at 50% MVC and below. The shorter endurance times at high MVC levels were due to sustained gripping with higher contraction levels, which imposed greater pain. In other words, participants could not sustain higher force for a long duration due to muscle fatigue, reducing their ability to produce force and continue the gripping task. This study also demonstrated that there was significant difference of endurance time between different MVC level of hang grip strength. This means that the endurance time of an individual at 20%, 40%, 60%, 80% and 100% MVC levels were varied from each other. This finding is in line with the study conducted by Demura & Nakada (2010).

The correlations between endurance time and anthropometric measurements in this study show weak correlations with grip endurance at different exertion levels. Forearm circumference seems to have the most consistent but weak, positive correlation with endurance time. However, none of these correlations are strong enough to make conclusive predictions about grip endurance based on these anthropometric measurements alone. Similarly, Balaji and Poornima (2017) found that forearm circumference has strongest correlation with endurance time, (r=0.543, p=0.001) & (r=0.587, p=0.001) for clerk and teaching staff group, respectively. However, Bhattacharjya & Goswami (2022) showed that height has a positive correlation with endurance (r=0.438, p=0.001). Additionally, Alam et al. (2022) demonstrated that palm length is the best predictor of endurance (r=0.541, p<0.001), followed by palm circumference (r=0.497, p<0.001), forearm length (r=0.413, p<0.001) and weight (r=0.313, p<0.001). These studies provide different outcomes that do not conclusively identify which anthropometry measurements affect grip endurance. This inconsistency might be due to the small sample and the different populations involved.

CHAPTER 5

CONCLUSION AND RECOMMENDATIONS

This chapter concludes the findings of this study in relation to the objectives. Additionally, recommendations for future research are provided, followed by life-long learning and finally the chapter discusses sustainability impact of this study.

5.1 Conclusion

Hand grip strength is influenced by various factors, including individual and environmental factors. Additionally, workplace setting factors such as the type of work tasks, temperature, time of day, and design of hand tools can also impact hand grip strength. Apart from that, hand grip strength testing performed suggested that both body position and forearm position significantly affect the measured outcome. The results showed that hand grip strength is significantly higher in standing compared to sitting, and neutral and supination forearm positions yield significantly higher hand grip strength than pronation forearm position. This information can be useful in fields like occupational ergonomics, where body and forearm positions impact work performance. This knowledge can be used to design working environments and tools to maximize biomechanical abilities. Finally, the hand grip endurance testing demonstrated that endurance time decreases as the MVC level increases due to faster muscle fatigue at higher contraction intensities. The recorded endurance time can contribute to designing ergonomic solutions, training programs, and optimizing work tasks to improve grip strength endurance and overall performance.

5.2 Recommendations

For specific workplace settings, it is essential to conduct a comprehensive analysis to identify the key factors that significantly influence hand grip strength under various conditions, as the findings from this study are generalized and might not be applicable to every workplace. Understanding these factors can help engineers create targeted interventions to improve hand grip strength. For example, analysing specific work tasks and evaluating the positions involved to identify optimal body positions can enhance hand grip strength. Implementing these optimal positions can improve work performance and reduce the risk of work-related musculoskeletal disorders. Additionally, to gain deeper insights into the relationship between hand grip endurance and hand grip strength, participants should be categorized according to their Body Mass Index (BMI) (underweight, normal, overweight). This approach will provide more valuable data on how BMI influences hand grip strength and endurance, as lower endurance times are prevalent among obese individuals and are associated with work-related musculoskeletal disorders, as noted by Pajoutan et al. (2017).

5.3 Sustainability Impacts

The findings of this study can contribute to improving workplace ergonomics by designing layouts and working positions that have less impact on health, directly promoting good health and well-being, which aligns with the essence of SDG 3. By reducing the risk of injuries and promoting sustainable work practices, these findings can help advance the goal of ensuring healthy lives and promoting well-being for all.

5.4 Long-Life Learning

The life-long learning achieved throughout this study is the importance of hand grip strength study for ergonomics especially in workplace, acknowledging the various factors contributing to it. Understanding the optimal body positions and the impact of gripping duration on hand grip strength leading to improved work performance and reduced risk of injuries. On top of that, acknowledging that there is necessity for continuous research to identify and address specific factors influencing hand grip strength in various workplace settings, ensuring that ergonomic practices evolve with new insights.

REFERENCES

Alam, M., Ahmad, I., Samad, A., Khan, M., & Ali, A. (2022). Grip strength and endurance: Influences of anthropometric characteristics, posture, and gender. *Muscles, Ligaments and Tendons Journal*, *12*(02).

Almashaqbeh, S. F., Al-Momani, S., Khader, A., Qananwah, Q., Marabeh, S., Maabreh, R., & Abdullah, K. (2022). The Effect of Gender and Arm Anatomical Position on the Hand Grip Strength and Fatigue Resistance during Sustained Maximal Handgrip Effort. *Journal of Biomedical Physics & Engineering*, *12*(2), 171.

Amaral, C. A., Amaral, T. L. M., Monteiro, G. T. R., Vasconcellos, M. T. L., & Portela, M. C. (2019). Hand grip strength: Reference values for adults and elderly people of Rio Branco, Acre, Brazil. *PloS one*, *14*(1), e0211452.

Ashraf, S., Kiran, Q., Malik, A., Mubashar, H., Subhani, A. H., Ahmed, S., & Ahmed, S. (2022). Effects of Different Testing Postures on Hand Grip Strength among Healthy Individuals. *Pakistan BioMedical Journal*, 164-167.

Baek, K., Park, J. T., Hong, J., & Kwak, K. (2023). Hand grip strength for the working-age population in South Korea: Development of an estimation and evaluation model. *International Journal of Industrial Ergonomics*, *94*, 103398.

Balaji, P. A., & Poornima, S. (2017). Correlation of BMI and Hand Anthropometry with Hand Grip plus Endurance for 1/3rd of Tmax among Staff of Teaching Institute at Bengaluru, India. *International Journal of Physiology, Nutrition and Physical Education*, 12(1), 204–208.

Bani, N. A., Noor, N. M., Aris, S. A. M., Muhtazaruddin, M. N., Kaidi, H. M., Abd Jalil, S. Z., ... & Mas' ud, A. A. (2017, November). A preliminary study on the hand grip and pinch strength among adults in an indigenous people community in royal belum

Forest, Malaysia. In *TENCON 2017-2017 IEEE Region 10 Conference* (pp. 2099-2103). IEEE.

Belcher, H. J. C. R. (2017). The assessment of grip strength after upper limb injuries in medico-legal practice. *Medico-Legal Journal*, *85*(1), 23-32.

BhattacharJya, J., & GoSwami, B. (2022). Hand Grip Muscle Strength, Endurance and Anthropometric Parameters in Healthy Young Adults: A Cross-sectional Study. *Journal of Clinical & Diagnostic Research*, *16*(9).

Boschman, J. S., Noor, A., Lundström, R., Nilsson, T., Sluiter, J. K., & Hagberg, M. (2017). Relationships between work-related factors and musculoskeletal health with current and future work ability among male workers. *International Archives of Occupational and Environmental Health*, *90*, 517-526.

Çakmak, B., & Ergül, E. (2018). Interactions of personal and occupational risk factors on hand grip strength of winter pruners. *International Journal of Industrial Ergonomics*, *67*, 192-200.

CD, M. A., Norashiken, O., & Salleh, A. F. (2020). Investigation On Young Adult Hand Grip Strength. *Malaysian Journal of Public Health Medicine*, *20*(Special1), 45-50. Nurul Shahida, M. S., Siti Zawiah, M. D., & Case, K. (2015). The relationship between anthropometry and hand grip strength among elderly Malaysians. *International Journal of Industrial Ergonomics*, *50*, 17–25.

Chi, C. F., Shih, Y. C., & Chen, W. L. (2012). Effect of cold immersion on grip force, EMG, and thermal discomfort. *International Journal of Industrial Ergonomics*, *42*(1), 113-121.ed

Dağ, F., & Erdoğan, A. T. (2020). Gender and age differences in absolute and relative handgrip strength of the Turkish population aged 8–27 years. *Hand Surgery and Rehabilitation*, *39*(6), 556-563.

Daruis, D. D., Khamis, N. A., Halim, I., Umar, R. Z., & Mohamed, M. S. (2019). 2H1-3 Malaysian Young Adult Female Hand Grip Strength. *Ergonomics*, *55*(Supplement), 2H1-3.

Das, A., & Dutta, M. (2015). Correlation between body mass index and handgrip strength and handgrip endurance among young healthy adults. *Journal of Evidence based Medicine and Healthcare*, *2*(27), 3995-4001.

Demura, S., & Nakada, M. (2010). Muscle endurance measurment using a progressive workload and a constant workload by maximal voluntary contraction. *Electron Health*, *2*(11), 1255-1259.

Ding, L., Yin, J., Zhang, W., Wu, Z., & Chen, S. (2020). Relationships Between Eating Behaviors and Hand Grip Strength Among Chinese Adults: A Population-Based Cross-Sectional Study. *Risk Management and Healthcare Policy*, 1245-1252.

Douglas, C. M., Hesketh, S. J., & Esser, K. A. (2021). Time of day and Muscle Strength: A circadian output? *Physiology*, *36*(1), 44–51.

Ekşioğlu, M. (2016). Normative static grip strength of population of Turkey, effects of various factors and a comparison with international norms. *Applied ergonomics*, *52*, 8-17.

El-Sais, W. M., & Mohammad, W. S. (2014). Influence of different testing postures on hand grip strength. *European Scientific Journal*, *10*(36).

Fan, S., Cepek, J., Symonette, C., Ross, D., Chinchalkar, S., & Grant, A. (2019). Variation of grip strength and wrist range of motion with forearm rotation in healthy young volunteers aged 23 to 30. *Journal of Hand and Microsurgery*, *11*(02), 088-093.

Goldberg, S. B., Flook, L., Hirshberg, M. J., Findley, D., Kesebir, P., Schaefer, S. M., & Davidson, R. J. (2017, July 27). *Getting a grip on the handgrip task: Handgrip duration correlates with neuroticism but not conscientiousness*. Frontiers.

Halim, I., Radin Umar, R. Z., Syed Mohamed, M. S., Ahmad, N., Saptari, A., & Padmanathan, V. (2019). The influence of hand tool design on Hand Grip Strength: A Review. *International Journal of Integrated Engineering*, *11*(6).

Hossain, M. G., Zyroul, R., Pereira, B. P., & Kamarul, T. (2012). Multiple regression analysis of factors influencing dominant hand grip strength in an adult Malaysian population. *Journal of Hand Surgery (European Volume)*, *37*(1), 65-70.

In, J. (2017). Introduction of a pilot study. *Korean journal of anesthesiology*, *70*(6), 601-605.

Indira, E., & Rajeswari, M. (2015). Correlation of hand grip strength with anthropometric variables and quantifying hand grip strength in children of age 3-5.5 years with Martin Vigorimeter in Indian population. *International Journal of Physiotherapy and Research*, *3*, 1006-11.

Jaafar, M. H., Ismail, R., Ismail, N. H., Md Isa, Z., Mohd Tamil, A., Mat Nasir, N., ... & Yusof, K. H. (2023). Normative reference values and predicting factors of handgrip strength for dominant and non-dominant hands among healthy Malay adults in Malaysia. BMC musculoskeletal disorders, 24(1), 74.

Jiang, R., Westwater, M. L., Noble, S., Rosenblatt, M., Dai, W., Qi, S., Sui, J., Calhoun, V. D., & Scheinost, D. (2022). Associations between grip strength, brain structure, and mental health in > 40,000 participants from the UK Biobank. *BMC Medicine*, *20*(1).

Kamarul, T., Ahmad, T. S., & Loh, W. Y. C. (2006). Hand grip strength in the adult Malaysian population. *Journal of Orthopaedic Surgery*, *14*(2), 172-177.

Keevil, V., Razali, R. M., Chin, A. V., Jameson, K., Sayer, A. A., & Roberts, H. (2013). Grip strength in a cohort of older medical inpatients in Malaysia: a pilot study to describe the range, determinants and association with length of hospital stay. *Archives of gerontology and geriatrics*, *56*(1), 155-159.

Khan, A. A., Khan, Z., & Mukarram, M. (2013). Effect of elbow flection on grip strength in vertical and horizontal directions. *Journal of human ergology*, *42*(1_2), 13-22.din

Koley, S., & Yadav, M. K. (2009). An association of hand grip strength with some anthropometric variables in Indian cricket players. *Facta Universitatis: Series Physical Education & Sport*, *7*(2).

Kong, Y. K. (2014). The effects of co-ordinating postures with shoulder and elbow flexion angles on maximum grip strength and upper-limb muscle activity in standing and sitting postures. *International Journal of Occupational Safety and Ergonomics*, *20*(4), 595-606.

Kovarik, M., Joskova, V., Patkova, A., Koblizek, V., Zadak, Z., & Hronek, M. (2017). Hand grip endurance test relates to clinical state and prognosis in COPD patients better than 6-minute walk test distance. *International Journal of Chronic Obstructive Pulmonary Disease*, *Volume 12*, 3429–3435.

Lam, N. W., Goh, H. T., Kamaruzzaman, S. B., Chin, A. V., Poi, P. J. H., & Tan, M. P. (2016). Normative data for hand grip strength and key pinch strength, stratified by age and gender for a multiethnic Asian population. *Singapore medical journal*, *57*(10), 578.

Lee, J.-A., & Sechachalam, S. (2016). The effect of wrist position on grip endurance and grip strength. *The Journal of Hand Surgery*, *41*(10). https://doi.org/10.1016/j.jhsa.2016.07.100

Lee, S. H., & Gong, H. S. (2020). Measurement and interpretation of handgrip strength for research on sarcopenia and osteoporosis. *Journal of bone metabolism*, *27*(2), 85.

Lee, S. Y. (2021). Handgrip strength: An irreplaceable indicator of muscle function. *Annals of Rehabilitation Medicine*, *45*(3), 167-169.

Leyk, D., Gorges, W., Ridder, D., Wunderlich, M., Rüther, T., Sievert, A., & Eßfeld, D. (2007). Hand-grip strength of young men, women and highly trained female athletes. *European journal of applied physiology*, *99*, 415-421.

MacDermid, J., Solomon, G., & Valdes, K. (Eds.). (2015). *Clinical assessment recommendations*. American Society of Hand Therapists.

Mahadi, M., Bani, N. A., Nazmi, N., Usman, S., Rahman, S. A. S. A., & Noor, N. M. (2022, July). Effect of body postures on gripping force classification using a multimodal system of Electromyography and Handgrip strength measurement.

In *2022 4th International Conference on Smart Sensors and Application (ICSSA)* (pp. 138-143). IEEE.

Manoharan, V. S., Sundaram, S. G., & Jason, J. I. (2015). Factors affecting hand grip strength and its evaluation: A systemic review. *International Journal of Physiotherapy and Research*, *3*(6), 1288–1293.

Martins, J. C., Aguiar, L. T., Lara, E. M., Teixeira-Salmela, L. F., & Faria, C. D. (2015). Assessment of grip strength with the modified sphygmomanometer test: association between upper limb global strength and motor function. *Brazilian journal of physical therapy*, *19*, 498-506.

Mehta, R. K., & Cavuoto, L. A. (2015). The effects of obesity, age, and relative workload levels on Handgrip Endurance. *Applied Ergonomics*, *46*, 91–95.

Modarres, M. (2006). *Risk analysis in engineering: techniques, tools, and trends*. CRC press.

Moy, F. M., Chang, E. W. H., & Kee, K. W. (2011). Predictors of handgrip strength among the free living elderly in rural Pahang, Malaysia. *Iranian Journal of Public Health*, *40*(4), 44.

Murugan, S., Patel, D., Prajapati, K., Ghoghari, M., & Patel, P. (2013). Grip strength changes in relation to different body postures, elbow and forearm positions. *Int J Physiother Res*, *1*(4), 116-121.

Neumann, S., Kwisda, S., Krettek, C., & Gaulke, R. (2017). Comparison of the grip strength using the Martin-Vigorimeter and the JAMAR-dynamometer: establishment of normal values. *in vivo*, *31*(5), 917-924.

Oyewole, S. A. (2014). Enhancing ergonomic safety effectiveness of repetitive job activities: Prediction of muscle fatigue in dominant and nondominant arms of Industrial Workers. *Human Factors and Ergonomics in Manufacturing & Service Industries*, *24*(6), 585–600.

Pajoutan, M., Cavuoto, L. A., & Mehta, R. K. (2017). Testing the efficacy of existing force-endurance models to account for the prevalence of obesity in the workforce. *Journal of Occupational and Environmental Hygiene*, *14*(10), 786-792.

Ramadan, M. Z. (2017). The effects of industrial protective gloves and hand skin temperatures on hand grip strength and discomfort rating. *International journal of environmental research and public health*, *14*(12), 1506.

Roberts, H. C., Denison, H. J., Martin, H. J., Patel, H. P., Syddall, H., Cooper, C., & Sayer, A. A. (2011). A review of the measurement of grip strength in clinical and epidemiological studies: Towards a standardised approach. *Age and Ageing*, *40*(4), 423–429.

Rostamzadeh, S., Saremi, M., & Fereshteh, T. (2020). Maximum handgrip strength as a function of type of work and hand-forearm dimensions. *Work*, *65*(3), 679-687.

Rostamzadeh, S., Saremi, M., Vosoughi, S., Bradtmiller, B., Janani, L., Farshad, A. A., & Taheri, F. (2021). Analysis of hand-forearm anthropometric components in assessing handgrip and pinch strengths of school-aged children and adolescents: a partial least squares (PLS) approach. *BMC pediatrics*, *21*, 1-12.

Ruiz-Ruiz, J., Mesa, J. L., Gutiérrez, A., & Castillo, M. J. (2002). Hand size influences optimal grip span in women but not in men. *The Journal of hand surgery*, *27*(5), 897-901.

Shahida, M. N., Zawiah, M. S., & Case, K. (2015). The relationship between anthropometry and hand grip strength among elderly Malaysians. *International Journal of Industrial Ergonomics*, *50*, 17-25.

Shivers, C. L., Mirka, G. A., & Kaber, D. B. (2002). Effect of grip span on lateral pinch grip strength. *Human Factors: The Journal of the Human Factors and Ergonomics Society*, *44*(4), 569–577.

Spijkerman, D. C., Snijders, C. J., Stijnen, T., & Lankhorst, G. J. (1991). Standardization of grip strength measurements. Effects on repeatability and peak force. *Journal of Rehabilitation Medicine*, *23*(4), 203-206.

Stoklasek, P., Mizera, A., Manas, M., & Manas, D. (2016). Improvement of handle grip using reverse engineering, CAE and rapid prototyping. *MATEC Web of Conferences*, *76*, 02029.

Xu, Z. Y., Gao, D. F., Xu, K., Zhou, Z. Q., & Guo, Y. K. (2021). The effect of posture on maximum grip strength measurements. *Journal of Clinical Densitometry*, *24*(4), 638-644.

Yusof, A., & Shalahim, N. S. M. (2021). Prevalence of Musculoskeletal Discomfort Among Workers in a Medical Manufacturing Facility. *International Journal of Automotive and Mechanical Engineering*, *18*(2), 8687-8694.

APPENDICE A

Gantt Chart of FYP 1

ACTIVITIES	W1	W2	W3	W4	W5	W6	W7	W8	W9	W10	W11	W12	W13	W14	W15
Submission of FYP Title															
Introduction															
Discuss detail about the project															
Background Study															
Finding the Problem Statements															
Objectives															
Methodology															
1st Objective – Conduct a literature review															
2nd Objective															
a. Calibration of Jamar Hand Dynamometer															
b. Pilot Study															
c. Actual Data Collection															
3rd Objective – Data Collection for duration															
a. Design of Experiment															
b. Pilot Study															
c. Actual Data Collection															
Submission/Important Deadline for FYP 1															
Logbook															
Poster Presentation															
Final Report															
FYP 1 Write-up															
Draft of Introduction															

Draft of Literature Review															
Draft of Methodology															
Draft of Poster Presentation															
Draft of FYP 1 Report															

APPENDICE B

Gantt Chart of FYP 2

ACTIVITIES	W15	W16	W17	W18	W19	W20	W21	W22	W23	W24	W25	W26	W27	W28
Result of the Experiment (Collecting Data)														
Project Discussion (Analyse the data)														
Presentation of FYP 2														

APPENDICE C

INFORMED CONSENT FORM

I am ______________________________, student ID ____________________ and IC no. ______________________ agreed to participate in this experiment. The purpose of this form is to state clearly the terms of my participation in this experiment.

1. I confirmed that I have fully understood the overall procedures of this experiment through the briefing from the researcher.
2. I understand that my participation is voluntary and I am willing to take the risk while doing this experiment.
3. I understand that all information I provide for this experiment will be treated confidentially.
4. I understand that I have the right to withdrawn from this experiment if I feel uncomfortable during the execution of experiment.

By signing below, you acknowledge that you have been informed about and consent to be a participant in the study described above. Should you have any question about the study or any other matter related to your participation in this experiment, or if you experience a experiment related injury as a result of this study, you may call **Dr. Isa bin Halim at 012 5142756** or email at **isa@utem.edu.my**

____

Signature of subject

Date: ______________

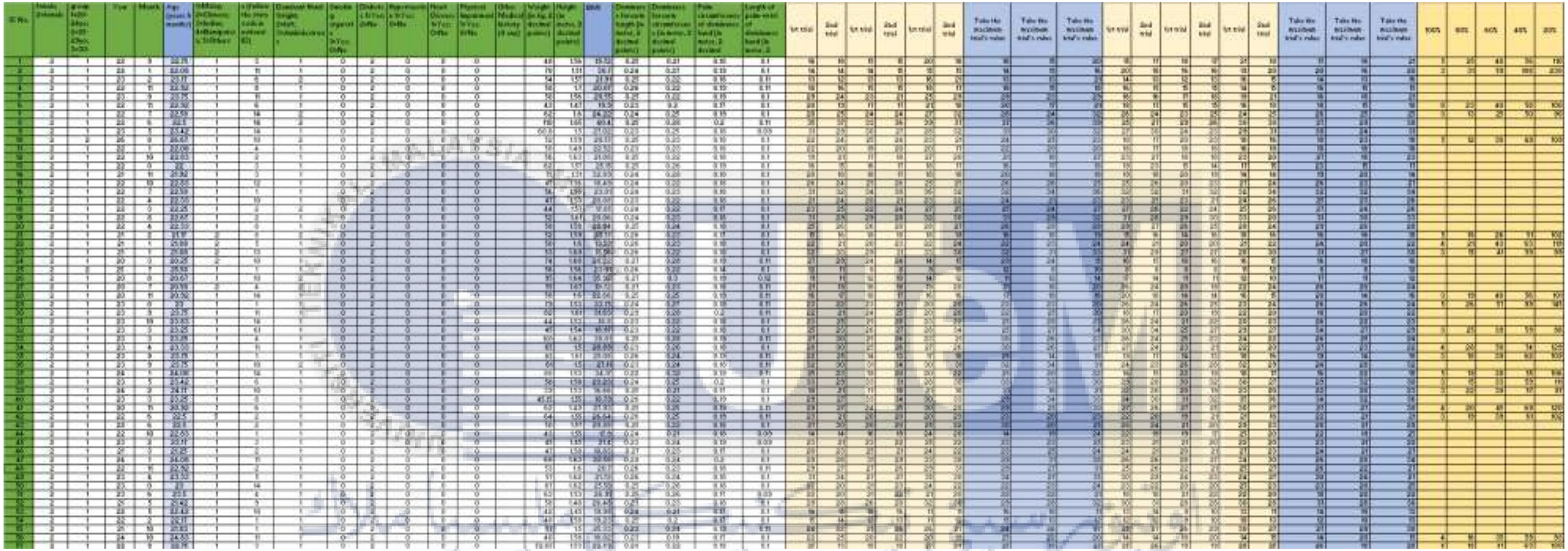
____

Signature of researcher

Date: ______________

APPENDICE D

Excel Spreadsheet



Excel Spreadsheet (Cont)