ENHANCING HAND GRIP STRENGTH IN ADULT FEMALE THROUGH ERGONOMIC GLOVE DESIGN

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

by

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DECLARATION

I hereby, declared this report entitled "Enhancing Hand Grip Strength In Adult Females Through Ergonomic Glove Design" is the result of my own research except as cited in references.

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Date : 11 JULY 2024

APPROVAL

This report is submitted to the Faculty of Industrial and Manufacturing and Engineering of Universiti Teknikal Malaysia Melaka as a partial fulfilment of the requirement for Degree of Bachelor Manufacturing Engineering (Hons).
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………………………...................................

(Dr Isa bin Halim)

ABSTRAK

Kekuatan cengkaman tangan adalah elemen penting dalam kehidupan seharian, dan mempengaruhi pelbagai aktiviti di industri. Jurutera telah mencipta sarung tangan sedia ada tetapi tidak merujuk kepada kriteria anatomi tangan menyebabkan sarung tangan tidak sesuai untuk dipakai oleh pekerja. Pekerja digalakkan memakai sarung tangan semasa menjalankan tugas elektrik bagi mematuhi keperluan peralatan perlindungan diri. Terdapat kekurangan penyelidikan yang komprehensif tentang data kekuatan cengkaman tangan untuk orang dewasa dan wanita warga Malaysia. Selain itu, kajian terdahulu tidak mengkaji secara specifik bagaimana posisi badan, orientasi lengan, dan postur pergelangan tangan mempengaruhi kekuatan cengkaman tangan di kalangan wanita dewasa warga Malaysia. Objektif kajian ini adalah untuk membangun set data normatif dan merumuskan model regresi untuk meramal kekuatan cengkaman tangan berdasarkan umur, berat, tinggi, panjang lengan bawah, lilitan lengan bawah, lilitan tapak tangan, dan panjang tapak tangan. Kajian ini juga merekabentuk sarung tangan yang ergonomik untuk pekerja wanita Malaysia bagi meningkatkan keupayaan mencengkam semasa tugas pemasangan palam elektrik. Data kekuatan cengkaman tangan dikumpul dalam kalangan 126 wanita dewasa di Malaysia. Eksperimen ini berkait dengan faktor kedudukan badan dan lengan bawah sebagai pembolehubah bebas, dan daya cengkaman sebagai pembolehubah bersandar. Antropometri tangan diukur menggunakan pita pengukur dan angkup Vernier. Simulasi model regresi menggunakan perisian Program Statistik Hebat Jeffreys (JASP). Pemilihan konsep reka bentuk dengan menggunakan kaedah penyaringan konsep, penggunaan fungsi kualiti, dan penilaian konsep. Akhir sekali, prototaip sarung tangan telah dicipta menggunakan mesin jahit manual. Prototaip sarung tangan diuji menggunakan instrumen tork pergelangan tangan, alat geseran mekanikal, kekuatan tegangan, dan temubual untuk menilai kekuatan cengkaman tangan. Kajian ini menghasilkan set data normatif kekuatan cengakaman tangan dan prototaip sarung tangan konsep B dipilih yang ergonomik untuk meningkatkan produktiviti kerja dalam pekerjaan pemasangan palam soket elektrik.

ABSTRACT

Hand grip strength is a crucial element of daily life, influencing various activities and overall well-being. The engineers who designed the existing gloves did not consider the criteria of hand anatomy and hand grip strength. This made the gloves unsuitable for workers to wear. Workers are encouraged to wear hand gloves during electrical tasks, complying with personal protective equipment requirements. There was a lack of comprehensive research on hand grip strength for adults and females, which made it difficult to apply hand grip data in designing hand gloves. Published studies have not thoroughly investigated the relationship between hand grip strength and factors such as body position, forearm orientation, and wrist position in adult females. The objectives of this study were to establish a normative dataset for hand grip strength in adult females from Malaysia and formulate a regression model predicting hand grip strength based on independent and dependent variables. The study developed ergonomic hand gloves for female operators, enhancing gripping capabilities during electric plug assembly tasks, using hand grip strength assessments among 126 Malaysian adult females. This study employed a full-factorial experimental design with body and forearm positions as independent variables, and grip force as the dependent variable. Also, hand anthropometry was measured using measuring tape and a Vernier caliper. Jeffreys's Amazing Statistics Program (JASP) software was used to develop a regression model to predict hand grip strength. The design and selection of the best design concept were developed by using screening, quality function deployment (QFD), and scoring. Lastly, a glove prototype was created using a sewing machine, and an engineering test was conducted to assess factors affecting hand grip strength using wrist torque, tensile strength, mechanical friction, and user interviews. The expected outcomes of this study were a normative dataset of hand grip force and a functional prototype of hand gloves for enhancing user comfort levels and work productivity in electric plug assembly tasks.

DEDICATION

Only

my beloved and appreciated to my parents,

my adored sister and brother, Nor Wahidah and Sulaiman

for giving me moral support, money, cooperation, encouragement and also understandings

Thank You So Much & Love You All Forever

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In the name of ALLAH, the most gracious, the most merciful, with the highest praise to Allah that I manage to complete this final year project successfully without difficulty.

I want to extend my heartfelt appreciation to Dr. Isa bin Halim, my supervisor, for his continuous support throughout this project. His guidance, valuable advice, and constructive criticism played a crucial role in the successful completion of the project. Whenever I encountered challenges, Dr. Isa showed unwavering dedication by offering me valuable information and insightful comments to help me overcome obstacles.

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Moreover, I extend my gratitude to the assistant engineers who actively participated in this project, offering valuable information, and providing the necessary facilities to ensure its successful completion. I am thankful and profoundly indebted to all my friends who played both direct and indirect roles in this project. Their ideas and support were invaluable, especially during challenging moments.

Finally, I want to express my heartfelt appreciation to my parents for their unwavering moral and financial support throughout this project. Their constant motivation and advice encouraged me to persevere, enabling me to complete the project on schedule.

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LIST OF ABBREVIATIONS

ASHT	-	American Society of Hand Therapists
BMI	-	body mass index
COF	-	Coefficient of Friction
CRs	-	customer requirements
EMG	-	Electromyography
GTAW	-	gas tungsten Arc welding
GUI	-	graphical user interface
HGS	-	Hand grip strength
HOQ	-	House of Quality
NASA	-	National Aeronautics and Space Administration
PDCs	-	product design characteristics
PPE	-	personal protective equipment
QFD	-	Quality Function Deployment
RPE	-	Rate of Perceived Exertion
RPF	-	Rating of Perceived Fatigue
SHAP	-	Southampton Hand Assessment Procedure
SMAW	-	shielded metal arc welding
SOP	-	Standard operation procedure
WHO	-	World Health Organization's
SNP	-	Standing Neutral Position
SPP	-	Standing Pronation
SSP	-	Standing Supination
DNP	-	Sitting Neutral
DPP	-	Sitting Pronation
DSP	-	Sitting Supination

LIST OF SYMBOLS

cm	-	Centimetre
kg	-	Kilograms
lbf	-	pounds of force
m	-	Metre
mm	-	Millimetre
mmHg	-	millimeter of mercury
N	-	Newton of force
psi0(lb/in^2)	-	pounds per square inch

CHAPTER 1

INTRODUCTION

This chapter introduces the study, covering the background, problem statements, objectives, scope, and significance of the study. The primary focus of this study is to enhance the grip strength of adult females through the design of ergonomic hand gloves for tasks involving the assembly of electric plugs. The problem statement outlines the current challenges faced by female workers who either wear inadequate gloves or work without gloves when performing their tasks. This chapter also underscores the primary aim of this study, which is to develop a prototype of an ergonomic glove designed specifically for females. Furthermore, it presents the scope and limitations of the study.

1.1 Background of Study

The industry in Malaysia continue to increase grow demand from the domestic and international markets for rubber gloves for medical, healthcare, and personal protection Mandy (Mok & Man, 2021). Workers are encouraged to wear gloves during work in industry manufacturing based on the rules of personal protective equipment (PPE). It is important to prevent any injuries when working. The function of gloves is various types used depending on the industry and tasks being performed. Some examples of industries and typical uses of gloves are healthcare and medical, food service, chemical and laboratory, construction, and manufacturing, automotive etc. Each industry has specific made-up materials. Most gloves are common made-up materials from rubber such as natural rubber, leather, textile materials etc. The selection of material depends on the specific applications such as protection against chemicals, heat, cold, cuts, or for medical or general-purpose use.

Figure 1.1: Example of application grinding process and materials gloves (Bachute, 2019).

In this era of globalization, there has been innovation in the range of ergonomic products available, both those intended for general use and for specialist applications. Good ergonomic products have become highly marketable, and demand is increasing. The aim of ergonomic glove design is to allow comfortable movement of fingers and wrists, fit, and functionality while reducing the risk of hand injuries and health problems associated with prolonged glove use. In addition, gloves with grips help prevent repetitive-type injuries such as tendonitis by requiring less force from the fingers to do the task. Grip strength refers to the ability of an individual's hand and forearm muscles to generate force and maintain a firm hold on an object. It is a key component of hand strength and is essential for various everyday activities and occupational tasks. Grip strength can be measured using various tools and instruments, including Jamar dynamometers. Enhancing grip strength is important for hand health, functional capacity, and well-being. Moreover, ergonomic glove designs can be considerate of materials, lightweight, etc.

Furthermore, the anatomy of the hand and wrist is a complicated network of bones, muscles, nerves, connective tissue, and blood vessels. It helps to do everything throughout the day that involves touching, holding, grasping, or using something with fingers. The wrist of the hand is the joint at the end of the forearm. It is the hinge between the arm and hand, while the hand begins where the wrist ends and includes the palm, fingers, and thumb. Thus, the structure of the hand and wrist allows movement, flex, and rotation of the wrist joint, as well as the use of the hand to grab and touch objects. From the journal, hand grip strength showed that Malaysian adult males had greater grip strength than adult females (Hossain et al., 2011). Following research, it was found that females and males have different hand sizes and shapes. According to a comprehensive study of the proportions of the human body by the National Aeronautics and Space Administration (NASA), the average adult female hand size is 6.8 inches in length, 3.1 inches in breadth, and 7.0 inches in circumference.

WOMEN'S SIZES

Size	Inch	CM
XS	6	15
S	6.5	17
M	7	18
L	7.5	19
XL	8	20

Figure 1.2: Anatomy hand and common size of female gloves (Team, 2018).

Based on the overall considerations, redesigning ergonomic hand gloves is necessary to achieve future improvement of this PPE. Many researchers and studies were conducted to reduce the risk of hand injuries during the assembly of electric plugs. However, the impact of glove ergonomic design such as limited size and shape. As well as the recent hand glove was designed and manufactured by foreign countries such as Japan and China; hence, the anthropometric data applied in the glove design were based on their populations.

The aim of this study is to develop a prototype of an ergonomic hand glove that enhances the gripping abilities of female operators in Malaysia, particularly those involved in assembling electric plugs. This case study focuses on the grip strength of adult female hands through ergonomic glove design, considering that many females are employed as operators in the semiconductor and electric products sectors. For instance, female operators are often responsible for assembling electric plugs. The potential benefits of this study include the establishment of a normative dataset for hand grip strength as a reference for designers, the creation of a regression model that correlates hand anthropometry with human grip strength, and the development of hand gloves designed for female operators, which can improve hand comfort and work efficiency.

1.2 Problem statement

(1) Many researchers have collected data on hand grip strength, noting its dependence on various factors, including body size and shape, age, gender, occupation, social status, ethnicity, lifestyle, and other socio-demographic variables (Hossain et al., 2011). However, there is a notable gap in the collection of data pertaining to the hand grip strength of adult females in relation to the movement of the hand with different body, forearm, and wrist positions. This gap hinders our ability to understand the relationship between hand grip strength

and neutral, supination, pronation forearm positions in both standing and sitting positions.

(2) Another main issues to solve in this study are: female operators often struggle to grip electrical and electronic products due to their various shapes and sizes, which can be exacerbated by ill-fitting gloves; oversized gloves designed primarily for men make it uncomfortable and difficult for female operators to perform their tasks; and the use of non-breathable glove materials like polyester can lead to discomfort and excessive sweating, especially during extended wear, and gloves with poor grip materials can hinder the handling of delicate instruments. Figure 1.2.1 shows the ergonomics issues faced by a female user.

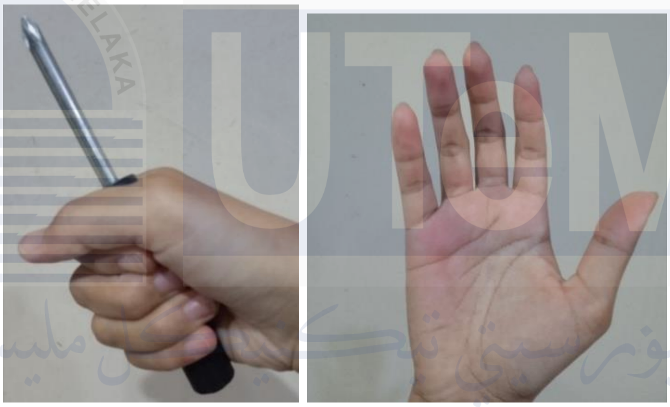


Figure 1.2: A female user experienced contact stress while donning an existing glove, causing redness on her hand palm.

Figure 1.3: Female assembly part of plugs.

Based on the difficulties faced on the female operator, a design prototype of ergonomic hand gloves to improve female workers comfort and productive work.

1.3 Objectives

In providing the solution for the above-mentioned problems, this study aims to achieve the following objectives:

- To measure and establish normative dataset of hand grip strength for adults female Malaysian.
- To formulate a regression model that predicts the hand grip strength based on body position, neutral, supination, pronation forearm position, with standing and sitting position.
- To develop a prototype of ergonomic hand gloves that enhances the ability of Malaysian female operators to perform gripping tasks in electric plug socket assembly.

1.4 Relationship Between Problem Statement and Objectives

A problem statement is an explanation of an issue or problem that must be addressed right away to improve the situation. The goal purpose of the project was to address the problem state. Table 1.1 below shows the relationship between the problem statement and the objectives of the study.

Table 1.1: Relationship between problem statement and objectives of the study.

Problem statements	Objectives
Many researchers have collected data on hand grip strength, noting its dependence on various factors, including body size and shape, age, gender, occupation, social status, ethnicity, lifestyle, and other socio-demographic variables (Hossain et al., 2011). However, there is a notable gap in the collection of data pertaining to the hand grip strength of adult females in relation to the movement of the hand with different body, forearm, and wrist positions. This gap hinders our ability to understand the relationship between hand grip strength	To measure and establish normative dataset of hand grip strength for adults female Malaysian.
	To formulate a regression model that predicts the hand grip strength based on body position, neutral, pronation, supination forearm position

and forearm and wrist positions in both standing and sitting positions.	with standing and sitting position.
Female operator does assembly product or equipment of electronic, and electric are uncomfortable wearing recent of hand gloves because of unsuitable size, felt sweaty etc. Mostly of female did not wear hand gloves that affect their hand grip strength during working like feel sick and scratched skin on palm of hand because of have contact stress between palm hand and handle tool.	To develop a prototype of an ergonomic hand gloves that enhances the ability of Malaysian female operator to perform gripping tasks in electric plugs assembly.

1.5 Scope of Study

This study discusses the consideration of hand grip strength in ergonomic glove design to improve subjective comfort and work productivity. There are several scopes listed to ensure the objectives of the study can be achieved.

The first goal of the study is to measure the grip strength of adult female hands using a Jamar Dynamometer. In this section, the participants for the experiment are adults who are female Malaysians and between the ages of 20 and 39. Only healthy participants without any injuries or illnesses will be considered in this project. These data are taken among the participants when the wrist is in vertical, supination, and pronation positions while standing and sitting while gripping the Jamar hand dynamometer. The subjects can be lecturers, staff, students at UTeM, and foreigners. The experimental session should take place between 8:00 a.m. and 5:00 p.m. only. The venue of the experimental session can be the laboratory or any comfortable room, i.e., room temperature, with no extreme temperature conditions. Based on the data collected, we will be finding the normative dataset of hand strength for adults females.

The second objective of the study is to formulate a regression model to observe the relationship between hand grip strength and independence variables based on the data experiment collected using Minitab software. Thus, creating the equation for a multiple regression model such as hand grip force (kg) = constant + a body position + b forearm position + c wrist position + d gender + e ethnic.

The last objective of the study is to focus on hand glove design for female operator-assembled electric plugs. Following the recent glove design, we will consider hand anthropometry, materials, and size in this project. The new design of ergonomic gloves will be fabricated into a prototype that can improve hand grip strength, comfort level, and productivity in the assembly process.

1.6 Significance of Study

This study holds great significance as it aims to enhance the grip strength of adult females working in tasks such as electric plug assembly by developing ergonomic gloves tailored to their needs. This not only improves their workplace health and safety but also enhances work efficiency. Additionally, the creation of a normative dataset and a predictive model for hand grip strength contributes to gender-specific ergonomic design, knowledge transfer, and future research opportunities, benefiting both Malaysian and broader populations. In essence, this research combines practical improvements for female workers with valuable insights and resources for the field of ergonomics and product design.

1.7 Summary

This chapter revolves around the core objective of enhancing grip strength in adult females through the development of ergonomic glove design. The study is conducted with a specific focus on Malaysian adult females engaged in gripping tasks, particularly in the assembly of electric plugs. The project's objectives are threefold:

1) Normative dataset of hand grip strength - The study seeks to measure and establish a normative dataset of hand grip strength for adult females in Malaysia. By gathering this data, the project aims to provide a benchmark reference for future research and design endeavors.
2) Regression model of hand grip strength - A regression model will be formulated to predict hand grip strength, considering variables such as body position, neutral, supination, pronation forearm position, considering both standing and sitting positions. This predictive model will offer insights into how these factors influence grip strength, contributing to a deeper understanding of the subject.

3) Ergonomic glove design - The central focus of this research is the development of a prototype for ergonomic hand gloves tailored to enhance the gripping abilities of Malaysian female operators engaged in electric plug assembly. The objective here is to improve the efficiency and comfort of these female workers in their tasks, ultimately benefiting their overall work performance.

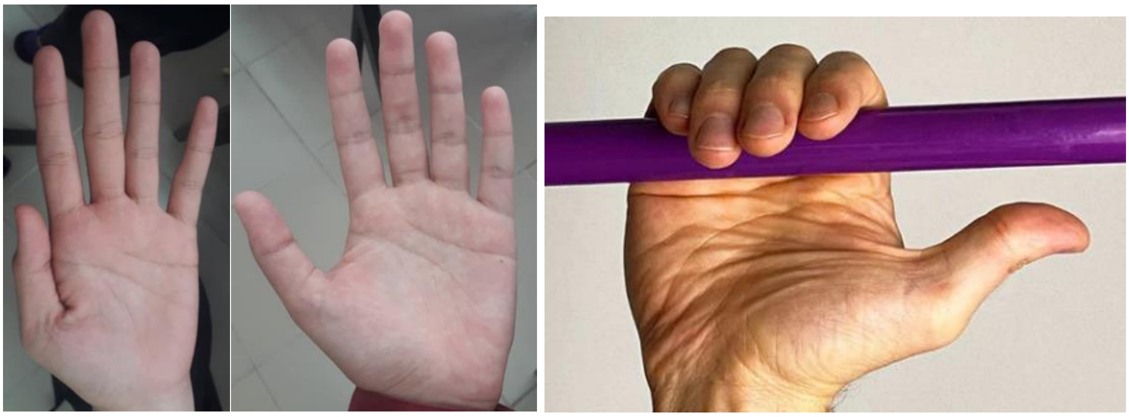
CHAPTER 2

LITERATURE REVIEW

This chapter provides a comprehensive study of pertinent materials, encompassing the analysis, synthesis, and evaluation of the literature relevant to the study. It includes definitions related to key terms, explores theoretical and foundational aspects of the existing body of knowledge, outlines experimental procedures, and utilizes past research as a point of reference for the present study. All information presented is sourced from reputable outlets, such as books, credible online resources, journal articles, and conferences. The organization of these sources aligns with the objectives of the study.

2.1 An overview of hand grip strength

Grip strength measures how much hand force can pull, push, suspend, grasp, or hold an object against resistance (Huerta Ojeda et al., 2021). Commonly, grip strength measures how strong the forearm muscles are and the maximum force they can produce. It's a useful indicator to check the upper body and overall strength (Beyer et al., 2018). Research that demonstrates a cross-sectional connection between grip strength and the strength of other muscle actions in both healthy individuals and adults with pathology most directly supports the use of grip strength as a biomarker for current health status (Bohannon, 2019). Figure 2.1 (a)-(c) shows male, and female, hand gripping objects.



(a) (b) (c)

Figure 2.1(a): The hand of a male; (b) The hand of a female; (c) Hand grip object (*Hand Grip Exercise Benefits for Health and Performance*, n.d.).

The human hand is skilled at precisely guiding its movements due to its beautiful shape and sensitive nature. The study of similar measurements related to the human hand, including hand length, palm length, thumb length, thumb breadth, index finger length, and hand breadth, is also known as hand anthropometry (Chandra et al. 2011; Hall et al. 2007).

Hand grip strength (HGS) is linked to various important health outcomes and is an improved factor in assessing disability. It is also connected to the ability to carry out daily activities (Nybo et al., 2001). Moreover, it measures hand grip strength by using a dynamometer to quantify the static force exerted by the hand.

2.1.1 Analysis of literature on factors affecting hand grip strength

There are many factors affecting hand grip strength following past research. Factors affecting hand grip strength are posture, time, hand circumference, individual, smoking and alcohol consumption, grip force, handle orientation, health issues, hand tools design, type of hand grip, and environmental and occupational.

2.1.1.1 Posture

The position of the human body has a significant effect on hand grip strength. (Teraoka, 1979) has investigated the grip strength of 2014 subjects in standing, sitting, and supine (lying on the back) positions. The grip strength in a standing position is stronger than sitting position and the grip strength in a sitting position is stronger than supine position for both males and females.

1. In a previous investigation, researchers explored the potential differences in grip strengths when measured in supine and sitting positions. The results indicated that grip strengths were comparable in both positions (Richards, 1997). However, it was observed that hand grip strength was notably greater when sitting with the elbow unsupported compared to when in bed or sitting with the elbow supported (Hillman et al. 2005). The study found that hand grip strength was significantly higher in sitting with the elbow unsupported than in bed and sitting with the elbow supported Another research study showed that grip strength is higher in standing and sitting with the elbow is extended. Based on the physiological basis, muscles will increase during activity in the standing position while muscles more relaxed during sitting. Hand grip strength is higher in standing position than in sitting because of arm is unsupported and muscles must be forced approach by biomechanical (El-Sais & Mohammad, 2014). Figure 2.2 (a)-(c) shows different positions such as sitting posture, supine posture, and standing posture.

(a) (b) (c)

Figure 2.2 (a): Sitting posture; (b): Supine posture; (c): Standing posture (El-Sais & Mohammad, 2014).

2.1.1.2 Time

All measurements were obtained by two observers at the same time of the day between 10:00 am and 12:00 am (Incel, et al., 2002). Participants were approached in the evening between 5:00 pm and 8:00 pm. Grip strength performed at various times has a diurnal variation. Martin stated that the variation in grip strength of the individual, grip is greater between 6.00 am to 9.00 am and decreased grip strength between 8.00 pm to 4.00 am. To specific study variables isometric muscle strength at a different time of the day that indicating that maximal isometric muscle strength is highest in the late afternoon compared to the morning.

The observed differences in muscle strength throughout the day indicate that the changes in skeletal muscle function can be considered as a circadian response. Previous research conducted on the same group of individuals showed a consistent and significant increase of approximately 5-6% in grip strength during the evening compared to the morning. In contrast, the current study found reduced muscular power and strength in the early morning hours.

2.1.1.3 Individual (gender, age, and handedness)

Measurements commonly taken for individuals include weight, height, and body mass index (BMI), which is calculated by dividing weight in kilograms by the square of height in meters (kg/m2). The individual factor of hand grip strength is influenced by gender, age, and handedness. Researchers have found that the average hand grip strength of adult males and females is generally higher in the right hand compared to the left hand, regardless of the posture. Additionally, individuals who are right-hand dominant tend to have higher hand grip strength than those who are left-hand dominant.

Thus, the dominant or non-dominant hand gender is an important affect factor in measuring hand grip strength (Manoharan et al., 2015). A researcher proved that male subjects showed greater grip strength than female counterparts. Due to low muscle mass and high-fat mass in females lead to decreased grip strength compared to males. A researcher stated that females are 40-60% weaker in upper limbs and 25-30% weaker in lower limbs compared to males (Shephard, 2000). (Ashraf et al., 2022) stated males have more muscle bulk and are more fit than males.

Following the (Kamarul, 2019), hand grip strength reduces when age increases. The strongest hand grip strength is in the right-hand dominant group of age 25 – 35 years whereas the left-hand dominant group of age between 35 – 44 years. However, most of the researchers considered that right-hand grip strength is comparatively stronger than left hand of any age (Incel et al., 2002).

2.1.1.4 Health status

The sum of literature investigated the relationships between hand grip strength and various health statuses such as depression, cognitive function, suicidal ideation, cardiovascular disease, osteoporotic factors, multimorbidity, and mortality has increased exponentially in recent years. Consequently, the number of systematic literature reviews that included meta-analysis has also increased (Soysal et al., 2020). The research revealed a correlation between depression and decreased grip strength, indicating that individuals experiencing depression may engage in fewer physical activities, resulting in reduced muscle strength. Moreover, the lack of motivation among depressed individuals may lead to an incomplete grip on the handle, ultimately leading to weaker grip strength measurements. (Liu et al., 2022).

Moreover, handgrip strength is affected as people age and experience a decline in their neurological and muscular systems, which results in decreased force. This is because handgrip strength is one of the diagnostic criteria used to diagnose sarcopenia. Sarcopenia is a skeletal muscle disease that can impair an elderly person's general quality of life and, if ignored, result in frailty. According to data from the Federal National Health Institutes, 5% of senior Americans had insufficient grip strength, compared to 19% of older adults. In the meantime, research conducted in Asia revealed that weak grip strength was also typical among the elderly, including those in hospitals in Indonesia (43.8%) and Korea (32%) (Kim et al., 2019).

2.1.1.5 Smoking and alcohol consumption

In the previous study, the analysis of some groups of smokers showed that the hand grip strength of current smokers' weakness compared to non-smokers which contrasts with this study on the relationship between grip strength and smoking (Kim et al., 2020). The effect of grip strength is easy-to-get fatigue for smokers (Saud et al., 2014). This factor has also been investigated by Japanese researchers on the male. The research proved that there was a negative correlation between cigarette 15 smoking and hand grip strength among Japanese men (Saito, et al., 2012).

Alcohol is a drug that may cause users to become addicted to it. Alcohol consumption is an important lifestyle factor for a variety of health problems. A few research information has shown a relationship between alcohol use and hand grip strength in the Japanese population. This relationship between grip strength and alcohol reduced muscle strength (Kawamoto et al., 2018). Next The effects of alcohol change depending on the individual, the situation, and the amount consumed. Although most individuals drink for relaxation, up to four drinks a day may be beneficial to your heart. However, alcohol has many negative effects and kills over 100,000 people in the US each year. Alcohol misuse can have a short-term negative impact on motor skills and performance among fitness-focused individuals as well as a long-term negative impact on physical capacities, including muscular degeneration and weakening (Vengata Subramani Manoharan et al., 2015).

2.1.1.6 Hand circumference

Hand circumference is an efficient and practical variable for commonly predicting MGS since its measurement is easy to perform (Li et al., 2010). Measurements of the forearm and hand were the most accurate factors for measuring hand grip strength compared to height and weight (Rice et al., 1998; Nicolay and Walker, 2005). According to previous researchers, forearm circumference was the most accurate index of hand grip strength (Kallman et al., 1990). Recent research found that hand circumference was measured by hand grip strength for men but not for men (Anakwe et al., 2007).

Hand circumference can be used to measure the hand grip strength that was an associated body size factor that influences grip strength. Furthermore, if men have larger hands compared to women the dominant hand is significantly larger than the non-dominant hand (Hopkins, 2000).

Some of the disorders will be a weakness in the hand grip strength associated with discomfort, instability, or casting that is related to reduced hand muscle use and relative atrophy. In comparison with this healthy group, there might be a corresponding difference in forearm circumference of more than 2 cm for several disorders (Anakwe et al., 2007). Figure 2.3 shows measuring the hand circumference.

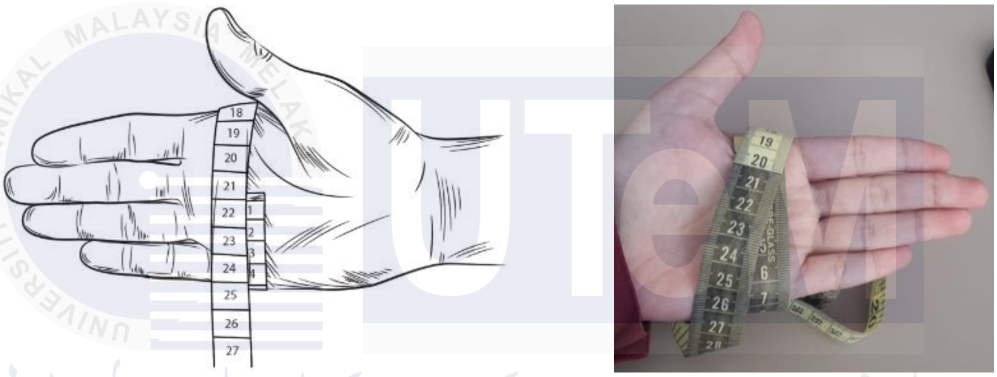
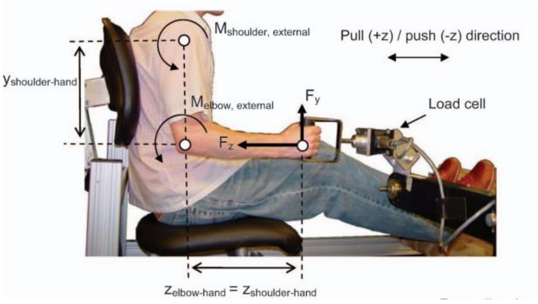


Figure 2.3: Measuring the hand circumference (*How to Measure Glove Sizes Correctly*, n.d.)

2.1.1.7 Handle orientation

Handle orientation is the angular position measured from the horizontal plane to the handle axis. It refers to the angle from the horizontal plane to the handle axis. Proper angulation, typically between 70° and 80°, is crucial in designing hand tools to keep the wrist in a natural position. If the handle is not correctly oriented, it can result in uncomfortable wrist or hand positions, diminishing grip strength and potentially compressing nerves and blood vessels. A recent study emphasized that handling orientation affects grip strength when using tools (Halim et al., 2019). Figure 2.4 (a) - (b)shows handles and postures used in the study on the handles were adjusted to the vertically rested elbow height.



(a) (b)

Figure 2.4 (a): Handle orientation (Halim et al., 2019); (b): Postures used in the study: All handles were adjusted to the vertically rested elbow height (Seo et al., 2010).

Past research often used commercially available hand dynamometers to measure grip force. However, grip span, handle diameter, and handle shape significantly impact grip force production, making it challenging to create accurate predictive models and generalize results to tools with varying handle shapes. The complexity of grip force capacity calls for improved measurement accuracy in research. From an ergonomics requirement, understanding how the location and orientation of the workpiece and hand-tool interface affect power grip capacity is crucial for evaluating hand-tool use or designing workstations. Estimating grip capacity can be challenging due to the numerous joint angle combinations and degrees of freedom. In ergonomics practice, it is essential to design the job to match the worker's capacity. Therefore, when designing tasks or workstations, evaluating how factors like workspace dimensions, handle type, hand gloves, and handle orientation influence the worker's physical ability to grip a tool handle is a recommended approach.

2.1.1.8 Hand-handle friction: handle material and gloves

The friction coefficient between the hand and handle plays a role in determining the maximum pull/push forces for both parallel and perpendicular handles. Factors like handle materials and gloves affect the friction coefficient and, consequently, impact pull/push strength. For instance, wearing rubber gloves increased jar lid opening capability, while cotton gloves decreased it compared to bare hands (Nagashima & Konz, 1986). This occurs due to alterations in the friction between the hand and the object when gloves are worn, impacting both friction force and maximum torque. The present research investigates the correlation between friction in the hand-handle interaction and the maximum force applied in pulling or pushing. Specifically, it scrutinizes the impact of two frequently utilized handle materials on maximum pull/push forces, along with examining the association between glove friction and maximum pull force across three prevalent glove conditions for parallel handles. Figure 2.5 shows hand handling fiction with gloves.

Figure 2.5: Hand handle fiction with gloves. (*Redirect Notice*, 2023)

2.1.1.9 Environmental

Hand grip strength in humans was associated with environmental factors. For example, time of day, altitude, oxygen level, and temperature are considered to affect grip strength (Maridaki, 2006). Next, the two primary sources of energy for muscles are glucose and oxygen. Hand grip strength will decrease in response to a drop in oxygen and an increase in carbon dioxide (Consolazio et al., 1947). The Myocardial Volume Oxygen (MVO2) index was affected differently before and after surgery depending on the peripheral strength of the muscles in the upper limb (HGS dominant and non-dominant). The low oxygen level in Chronic obstructive pulmonary disease (COPD) patients resulted in decreased lung function, static hyperinflation, lower HGS, and a 6-minute walking distance (6MWD) when compared to the controls on both tests. Air pollution is linked to various health issues, but its impact on hand-grip strength, a measure of muscle strength and health status, is largely unknown. Higher altitudes can indirectly impact hand grip strength. Researchers have studied grip strength changes at various altitudes. These found that grip strength begins to decrease between 4000 and 7000 meters, with a sharp drop from 7000 to 9000 meters (Ruff & Strughold, 1942). Thus, environmental factors influence HGS in good conditions.

2.1.1.10 Occupational

In certain occupations, workers are exposed to hazardous elements including agriculture some of these substances are known to be damaging to the nervous system and can affect muscle strength. Measurement of hand-grip strength may be useful for detecting neurotoxic exposure. In addition, the strength of handgrip can be affected by one's occupation, with manual workers generally having a stronger grip compared to non-manual workers. It is important to identify the most accurate indicators of handgrip strength based on various physical characteristics, and also determine how physical and sporting activities can impact hand strength. (Charles et al., 2006).

Occupational factors can influence hand grip strength in individuals. The scientific explanation for this phenomenon involves the concept of specific adaptations to imposed demands (SAID) and the principle of use-dependent plasticity. Hand grip strength is heavily dependent on the muscles of the forearm, particularly the muscles responsible for finger flexion and extension. Individuals engaged in occupations that require repetitive gripping, lifting, or fine motor skills may experience specific adaptations in these muscles over time (Roby-Brami et al., 2021).

The SAID principle suggests that the human body adapts specifically to the demands placed upon it. In the context of occupational activities, consistent use of hand muscles in a particular way can lead to hypertrophy (increased muscle size) and enhanced neuromuscular coordination, resulting in improved grip strength for tasks commonly performed in that occupation (Voight et al., 2013).

Occupations that involve frequent and intense hand use, such as manual labor, construction work, or jobs that require manipulating tools, can contribute to the development of greater hand grip strength. The repetitive nature of these activities may lead to increased muscle strength and endurance (Gangopadhyay, 2022).

Occupational tasks often require precise control and coordination of hand muscles. Over time, individuals may develop improved neuromuscular coordination, which can enhance their ability to generate force during gripping activities (Singh et al., 2018). Long-term occupational demands can also lead to adaptive changes in connective tissues, such as tendons and ligaments, supporting the hand and forearm muscles. These changes may contribute to increased stability and strength during gripping tasks (Woo et al., 1980).

Some occupations involve unique and specialized movements that can result in job-specific training effects. For instance, musicians, athletes, or individuals in professions that require precise hand movements may develop hand grip strength that is specific to the demands of their tasks (Gorniak et al., 2018). Conversely, sedentary, or desk-bound occupations may lead to deconditioning of the hand muscles over time. Lack of regular use and engagement in activities that challenge grip strength may result in decreased muscular strength and endurance (Le Roux et al., 2021).

It is important to note that individual variations, genetics, and overall health also play roles in determining hand grip strength. While occupational factors can influence grip strength, they are just one component of a complex interplay of factors affecting muscular function. Figure 2.6 shows the application of hand grip strength for different types of occupations.

Figure 2.6: Application of hand grip strength for different types of occupations.

2.1.2 Synthesis of literature on methodologies to measure hand grip strength

2.1.2.1 Sample size of participants

Sample size determination is important in survey research to ensure the representativeness of the sample and the general findings. The researcher discussed sample size determination in survey research by highlighting the importance of considering factors such as desired precision, confidence level, and population variables (Adam, 2020). Most of the research studies used sampling techniques because they could reduce cost and time while getting better results. 1. The rationale behind choosing sampling methods lies in the fact that a study, no matter how well-executed, may fail to identify significant effects if the sample size is insufficient. Similar, if the sample size is excessively large, the study may become more intricate and potentially introduce inaccuracies in the findings (Singh & Masuku, 2014). Moreover, if you take a larger sample size, you should increase the cost of the study. Thus, the sample size is an essential variable in any scientific research. Sathian (2010) highlights the complexity of determining sample size, requiring the collaboration of a specialist with extensive scientific knowledge in medical statistics.

Sampling techniques have three methods sample size calculator, G-Power analysis, and sample size table. The first method is a sample size calculator to compute the minimum number of necessary samples to meet the desired statistical constraints. Evans et al. (2000) defined sample size as the number of observations in a sample. Sample size can be calculated using the formula published by the National Education Association:

$S = X^2NP(1 - P) / [d^2(N - 1) + X^2P(1 - P)]$

S = required sample size

X^2 = the table value of chi-square for 1° of freedom at desired confidence level (3.841)

N = the population size

P = The population proportion (assumed to be 0.50 since would provide the maximum sample size)

d = the degree of accuracy expressed as a proportion (0.05).

Furthermore, the sample size calculator used automatically calculated the sample size via the website. To determine the appropriate sample size, factors such as precision, confidence, and variability in the measured variables must be considered alongside the study's objective and population size (Miaoulis and Michener, 1976). The following text provides an overview of the G-Power analysis, which involves the calculation of sample size and power. This analysis utilizes a user-friendly graphical user interface (GUI). The G-Power software is designed to facilitate the calculation of sample size and power for different statistical methods, including F, t, $\chi 2$, Z, and exact tests. It can be downloaded at no cost from the website www.psycho.uni-duesseldorf.de/abteilungen/aap/gpower3 (Kang, 2021). Besides that, use the sample size table if you do not need the calculation shown in Figure 2.7.

Table for Determining Sample Size from a Given Population

N	*S*	*N*	*S*	*N*	*S*
10	10	220	140	1200	291
15	14	230	144	1300	297
20	19	240	148	1400	302
25	24	250	152	1500	306
30	28	260	155	1600	310
35	32	270	159	1700	313
40	36	280	162	1800	317
45	40	290	165	1900	320
50	44	300	169	2000	322
55	48	320	175	2200	327
60	52	340	181	2400	331
65	56	360	186	2600	335
70	59	380	191	2800	338
75	63	400	196	3000	341
80	66	420	201	3500	346
85	70	440	205	4000	351
90	73	460	210	4500	354
95	76	480	214	5000	357
100	80	500	217	6000	361
110	86	550	226	7000	364
120	92	600	234	8000	367
130	97	650	242	9000	368
140	103	700	248	10000	370
150	108	750	254	15000	375
160	113	800	260	20000	377
170	118	850	265	30000	379
180	123	900	269	40000	380
190	127	950	274	50000	381
200	132	1000	278	75000	382
210	136	1100	285	1000000	384

Note.—*N* is population size.
S is sample size.

Figure 2.7: Sample size table (Krejcie & Morgan, 1970).

2.1.2.2 Hand Anthropometry

Previous researchers have analysed comparisons on the anthropometric dimensions of locals compared with those of different populations. Taha et al. (2009) studied the measures of Malaysian and Saudi Arabian males with an age range of 20 – 30 years. These measure the number of anthropometric dimensions between different countries including eye height, elbow height, and height shoulder. A comparison of population Malaysian and Dutch was the largest with a value of 84 mm (Leong et al., 2011).

The patients' anthropometric dimensions were assessed using standard anthropometric equipment, including the TTM Martin's Human Body Measuring Kit, a sliding caliper, a weighing scale, and a plastic measuring tape. To measure sitting posture, an adjustable chair was used to accommodate different heights based on the subjects' preferences. The anthropometric set allowed for the measurement of straight lines, curves, circumferences, and thickness, while sliding and spreading Varnier callipers were used to measure the breadths and depths of body parts. Body circumference was determined using the measuring tape. A total of 38 body dimensions were measured on each subject, following the standardized procedure outlined by Pheasant (1986). To ensure consistency, the same person conducted all anthropometric measurements for every participant, having received training on measuring techniques and device use. Prior to actual measurements, several trial runs were conducted in the lab to ensure the subjects' full understanding of the method (Nurul Shahida et al., 2015). Figure 2.8 illustrates the measurement of hand-forearm anthropometric dimensions.

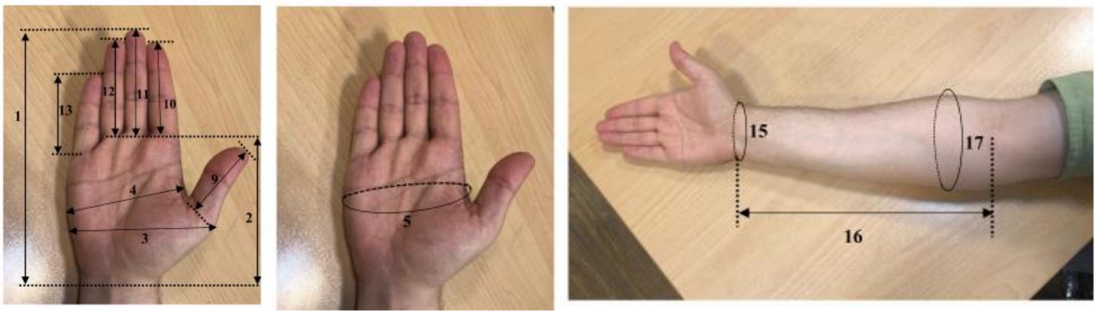


Figure 2.8: Measuring the hand-forearm anthropometric (Rostamzadeh et al., 2021).

The research assessed four different measurements of the hand, including overall length, middle finger length, hand width, and wrist thickness. To determine the complete hand length, the distance from the tip of the middle finger to the midpoint of the distal wrist crease was measured. The length of the middle finger was measured from its tip to the crease of the metacarpophalangeal joint. Hand width was calculated by dividing the distance between the radial side of the second metacarpal joint and the ulnar side of the fifth metacarpal joint. Wrist thickness was determined by measuring the sagittal diameter at the proximal wrist crease (Wen et al., 2020).

2.1.2.3 Type of hand grip

The hand is considered a remarkable human device since it can be used in many ways for gripping any object (Elyasdin, 2012). The concept that hand grip strength is formed up of five basic movements which are crushing, pinching, supporting, power, and precision grip posture (Rodriguez et al., n.d.).

A crush grip posture is defined by a robust and forceful hand and finger position, frequently employed for tightly grasping or applying substantial pressure to an object. This grip entails a powerful closure of the hand, utilizing both the fingers and palm to exert force. It is often linked to actions like gripping, squeezing, or securely holding objects, activating the muscles in the hand and forearm to generate strength. The term "crush grip" emphasizes the concept of exerting force as if one is intensely crushing or squeezing something. The ability to clench your hand into a fist is known as a crushing grip, whereas the length of time you can hold onto something with your hand is defined as support strength. Figure 2.8: A crush grip posture (Nerd Fitness, 2019).; Figure 2.9 shows the crush grip posture, pinch grip posture, and power grip posture.

Figure 2.9: A crush grip posture (Nerd Fitness, 2019), pinch grip posture, and power grip posture.

Grip force was assessed using a grip dynamometer comprising two parallel bars connected to a force gauge. The dynamometer, with a width of 3.84 cm, allowed subjects to align their 3rd metacarpophalangeal joint with the center of the device during flexion/extension force application. The average grip span was 4.25 cm, and the handle circumference averaged 13.5 cm. Participants were directed to maintain a power grip posture on the dynamometer, ensuring that the fingers remained in this position, rather than flattening the hand, even during wrist exertions with minimal grip effort.

2.1.2.4 Hand grip measurement

Measuring hand grip strength commonly uses a Jamar dynamometer, a device designed specifically for this purpose. Handgrip dynamometers come with different tension-providing features such as hydraulic, pneumatic, and spring, and provide various configurations including electronic digital and gauge readings (Handgrip Dynamometer for Grip Strength Testing | Baseline, Jamar, Camry, Smedley, n.d.). The Jamar dynamometer is the standard tool used by 80% of occupational therapy clinics and schools in the United States to evaluate grip strength. The Jamar is equipped with numerous beneficial functionalities that aid in routine screening and evaluating hand-related diseases and injuries. It has a maximum grip force of 200 pounds (90 kg) and can measure grip force in both pounds and kilograms. Additionally, the Jamar incorporates a peak-hold needle that retains the highest reading until it is manually reset. Figure 2.10 (a) and (b) Jamar Plus Digital Hand Dynamometer and Baseline Digital Smedley Spring Hand Dynamometer.

(a) (b)

Figure 2.10 (a): Jamar Plus Digital Hand Dynamometer; (b): Baseline Digital Smedley Spring Hand Dynamometer

There are different types of hand dynamometers, including hydraulic, pneumatic, and digital varieties. Among them, the hydraulic hand dynamometer is the most used for measuring hand grip strength. The Jamar hydraulic hand dynamometer is widely regarded as the gold standard in literature (Shiratori et al., 2014) and has been recommended by previous studies as the best tool for this purpose (Kirkpatrick, 1956; Mathiowetz et al., 1984). Key features with different hand dynamometers are shown in Table 2.1, based on the previous studies by Smith, J. A., & Doe, R. B. (2020), Brown, T. C., & Green, P. L. (2019), and National Institute of Health, (2018).

Table 2.1: Key features of hand dynamometers.

Instrument types	Hydraulic	Pneumatic	Mechanical	Strain
Measures	Grip strength	Grip pressure	Grip strength	Grip strength
Operation mechanism	A scaled hydraulic system that enables grip strength to be read off a gauge dial.	The compression of an air-filled compartment, e.g. bag or bulb	The amount of tension produced in the spring	The variation in electrical resistance of a length of wire due to the strain applied to it.
Example of instrument	Jamar	Martin Vigorimeter	Harpenden dynamometer	Isometric Strength Testing Unit
Units	kilogram (kg) or pounds of force (lbf)	millimeter of mercury (mmHg) or pounds per square inch (psi0(lb/in^2)	kilogram (kg) or pounds of force (lbf)	Newton of force (N)
Advantages	Portable, economical, large amount of data available	Gentler on weak or painful joints.	No evidence for superiority is presented in the literature	Are not subject to leaks (of oil/water/air), which can compromise accuracy
Limitations	Can cause stress on weak joints. Can develop slow leaks and hysteresis.	Grip pressure measurement depends on surface area and can be affected by hand size.	Grip force measurements are not very reproducible due to difficulties in replicating the grip position and device calibration.	Can be expensive and heavy.

2.1.2.5 Hand grip measurement procedures

Hand grip strength measurement procedure should follow the standard guidelines that had been by the world. This since a standard protocol can improve the measurement of hand grip strength and allow the data to be significantly applied across study populations (Roberts et al., 2011). The most effective protocols for assessing hand grip strength are the American Society of Hand Therapists (ASHT) and the Southampton Hand Assessment Procedure (SHAP).

The American Society of Hand Therapists (ASHT) is an organization comprised of hand therapy professionals who are dedicated to improving clinical standards, research, education, and advocacy in the field of hand and upper extremity treatment. Established in 1977, ASHT consists of various members such as occupational and physical therapists, physician extenders, surgeons, researchers, and administrators. The aim of ASHT is to foster and strengthen the community of professionals who are committed to providing exceptional hand and upper extremity therapy. ASHT is an organization that provides the standard procedures and basic guidelines for four techniques which are range of motion, grip and pinch strength, volume, and coordination and dexterity (Fess & Moran, 1981). ASHT protocol provides the standard measurement of hand grip strength.

1. Ensure the elbow is at a 90-degree angle, aligning the forearm with the thumb pointing upward.
2. Adjust the participant's wrist to be straight, with the hand either pointing forward or slightly bent outward.
3. With one hand, support the hand dynamometer, and with the other hand, rotate the red peak hold needle clockwise.
4. Ask the participant to squeeze the hand dynamometer handle as strongly as possible and maintain the grip for about 3 seconds.
5. Instruct the participant to stop and take a rest.
6. Record the maximum hand grip strength.
7. Repeat the steps for measuring hand grip strength with the replacement of the other hand.

Southampton Hand Assessment Procedure (SHAP) is a procedure used for assessing prosthetic, impaired, and normal hand functionality (Light et al., 2002). Because the SHAP provides a general functioning assessment as well as a comprehensive evaluation of the functionality of prehensile grips (spherical, tripod, power, lateral, tip, and extension), clinicians and researchers currently prefer to use it. The time taken to complete each job contributes to the calculation of SHAP scores (Vasluian et al., 2014). Therefore, many researchers preferred to use SHAP as the protocol for the measurement of hand grip strength.

1. Adjust the participant's forearm on the chair's arm so the wrist is over the end.

2. Demonstrate proper use of the dynamometer for the highest score.

3. Position the right hand with the thumb on one side of the handle.

4. Rest the dynamometer on the palm to support it.

5. Encourage squeezing until the needle stops rising.

6. Rest after the needle stops.

7. Record grip strength and rest period, then repeat for the left hand.

8. Take three readings for each hand.

9. Use the highest score for analysis.

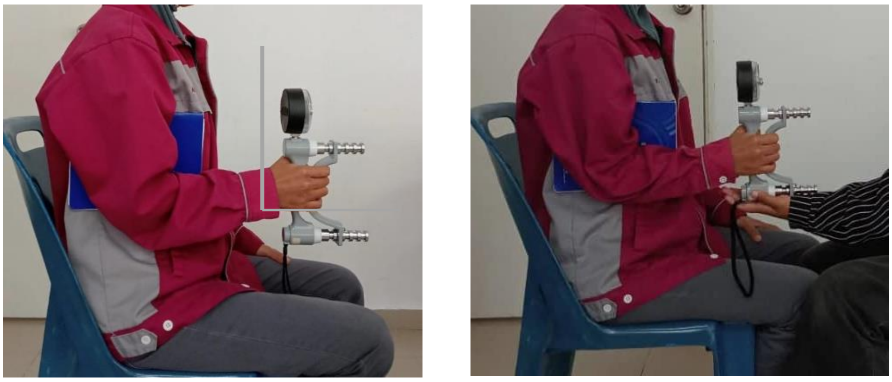


Figure 2.11: Left AHST (90-degree angle of elbow posture) and right SHAP (Support the weight of the hand dynamometer) protocol.

2.1.2.6 The importance of hand grip data

Data on hand grip strength are important and have a lot of uses in several kinds of industries. Hand grip strength is a useful indicator of potential declines in physical mobility, cognitive status, health-related quality of life, general physical function, and mortality risk. Commonly upper body strength can be achieved by an effective review of hand grip strength data. Previous research proved that there is a correlation between grip strength and surgical results in rotator cuff tears (Yasuo et al., 2005). It also means that the hand grip data is important for determining the capability of people's hands who have undergone the surgery. Besides that, many studies also certify that hand grip strength data is useful in determining the physical capability in surgical, lifestyle disease, and middle to late-life subjects (Shea, n.d.). As a result, hand grip strength is correlated with total body strength, therefore it is useful in the design of handle tools for any objects. A previous investigation identified a relationship between hand grip strength and the effect of surgery on an injured hand. Because it's affordable and connected to daily activities, researchers use grip strength to assess upper extremity function and outcomes after treating diseases or injuries (Lee & Gong, 2022). Therefore, hand grip strength data assists in the design of hand gloves because it correlates with entire body strength.

2.1.3 Evaluation of literature on hand grip strength arm different populations

Hand grip strength is an important indicator of physical health and functional capacity. Studies show that grip strength declines with age and is generally higher in men than women. Ethnicity and health conditions can also affect grip strength. Populations with chronic conditions such as arthritis, neurological disorders, and sarcopenia often exhibit lower grip strength, which can predict functional decline and mortality. However, methodological inconsistencies across studies can hinder cross-population comparisons. Despite this, grip strength remains a valuable tool for assessing health and predicting future risks. Future research should focus on standardizing measurement techniques, exploring deeper links between grip strength and specific health conditions, and tailoring interventions to optimize grip strength across different populations. Evaluation of literature on hand grip strength arms different populations as shown in Table 2.2. Based on Table 2.2, the dominant hand has strong hand grip strength compared to the non-dominant hand in the population of other countries.

Table 2.2: Study of population on the hand grip strength.

Authors	Studies	Population and Gender	Key finding
(Faris Almashaqbeh, 2022)	Study how different anatomical postures affect maximum handgrip strength and fatigue resistance in healthy adult turkeys during maximum handgrip effort at varying levels of grip force.	These are adult Turkish individuals, females, and males.	The average maximum hand strength for males was 48.6 kg, whereas females had an average maximum hand strength of 32.9 kg for their dominant hand. Females were found to have handgrip strength that was 67.7% of the strength observed in males
(Wiśniowska-Szurlej et al., 2021)	The objective of our research was to establish the standard values of hand grip strength (HGS) and identify the factors associated with it among elderly individuals residing in Southeastern Poland.	The population of older adults in Poland.	The study consisted of 405 elderly participants, of which 271 were women and 134 were men. The average handgrip strength (HGS) was 19.98 kg, with women averaging 16.91 kg and men averaging 26.19 kg. The study found that 50.18% of women and 55.22% of men had low handgrip strength.
(Zaccagni et al., 2020)	The objective of this study is to provide original mean handgrip strength (HGS) values derived from healthy young persons in Italy, categorized by gender.	Young Italian females and males.	The HGS mean values of the dominant hand obtained in our study for young healthy Italian adults were 45.7 ± 8.2 kg for males and 28.9 ± 4.7 kg for females. The right hand was stronger than the left hand.

	These values can serve as a benchmark for similar populations.		
(Daruis et al., 2019)	This study aims to assess the impact of forearm postures, specifically vertical (neutral), pronation, and supination, on hand grip strength in Malaysian females.	Malaysian females.	Among the 200 female participants aged 19 to 24 years, 85% (170 individuals) exhibited right-hand dominance, while 15% (30 individuals) demonstrated left-hand dominance. The supination wrist position yielded the highest average grip strength for both hands, whereas the pronation position resulted in the lowest mean grip strength (pronation < neutral < supination).

2.2 Development of a regression model for forecasting hand grip strength

2.2.1 Definition of Regression Statistics

Regression statistics is a statistical technique used in various fields, including finance and investing, to examine the relationship between a dependent variable and a set of independent variables. It allows researchers to determine the strength and nature of this relationship. By collecting data on relevant factors and employing regression analysis, researchers can quantify the direct influence of one variable on another. For instance, they can assess the impact of price increases on demand or changes in the money supply on inflation. Additionally, researchers often assess the "statistical significance" of these relationships, which indicates the level of confidence in the similarity between the observed and calculated relationships (Alan O. Sykes,1993). Thus, the purpose of regression statistics is to identify future values and understand the strength and direction of relationships. This deepens our knowledge in diverse fields and helps us make informed decisions based on genuine variable connections.

In the literature review, the development of regression models for forecasting hand grip strength is explored with a focus on understanding the multifaceted factors influencing grip strength prediction. In ergonomics research, regression models have been used to predict various types of human strengths (Chaffin and Andersson, 1994). Previous research aimed to develop regression equations to forecast handgrip strength in individuals spanning a broad age spectrum by incorporating anthropometric, demographic, and related strength (pinch) variables. Despite being less straightforward and expeditious to measure compared to anthropometric factors, pinch variables have gained prevalence in ergonomics studies, primarily due to their correlation with cumulative trauma disorders resulting from manual labor. The anticipation is that these derived equations will prove beneficial in clinical and ergonomic contexts (Imrhan & Mandahawt, 2010). Since many factors can influence strength measurements, achieving high accuracy and dependability in direct measurements may not be simple or quick (Caldwell et al., 1974). Therefore, handgrip strength prediction from easily measured data, including anthropometric characteristics, may be used instead of direct measurement.

Numerous studies have explored the impact of demographic features and anthropometric measures on hand grip strength, investigating correlations between hand dimensions and maximal grip strength, as well as exploring the influence of handle grip span and user hand dimensions on maximum grip strength (Lee et al., 2009). Various predictive models have been developed for different purposes, such as predicting grip strength (Taha & Nazaruddin, 2005), estimating hand length and grip strength (Huntington et al., 2000), assessing peak pinch strength (Eksioglu et al., 1996), estimating grip strength and endurance (Nicolay & Walker, 2005), and predicting grip strength (Wu et al., 2009). Additionally, regression analysis has been employed to estimate grip strength by using strength measurements other than body dimensions (Didomenico & Nussbaum, 2003) and (Dubrowski & Carnahan, 2004). Furthermore, a non-linear statistical approach has been applied to predict strength based on the age parameter (A.I.M. Voorbij & L.P.A. Steenbekkers, 2001).

As an alternative approach, the prediction of handgrip strength from easily measurable variables, such as anthropometric factors, may offer a viable solution. Recently, Vaz et al. (2002) introduced regression equations to predict the grip strength of the non-dominant hand in individuals aged 5-67 in India, including anthropometric and demographic predictor variables. An example of the formula and equation to develop the regression model as shown in Table 2.3.

Table 2.3: Past studies of the regression equation.

Studies	Regression Equation	References
Nakandala et al., 2019	(1) DHGS= -9.37 + (2.734 D.H. Breadth) + (0.472 D.H. Span) (2) DHGS= 2.99 + (1.250 D.F. Girth)	DHGS= Dominant Hand Grip Strength D.H= Dominant Hand D.F= Dominant Forearm
(Lopes et al., 2018)	$HSD_{kg} = -15.490 + (10.787 \times Gender_{male=1;female=0}) + (0.558 \times Forearm\ circumference) + (1.763 \times Hand\ Length)$ $HSND_{kg} = -9.887 + (12.832 \times Gender_{male=1;female=0}) + (2.028 \times Hand\ length)$	HSD: handgrip strength in dominant hand; HSND: handgrip strength in nondominant hands.
Nurul Shahida et al., 2015	Hand grip strength = - 724.770 + 0.303 (A1) + 3.270(A2) – 5.950(A3) + 1.756(A4) + 1.453(A5) + 2.908(A6) + 4.396(A7) – 1.136(A8) + 2.267(A9) + 2.164(A10)	A1 Stature; A2 Eye height, standing; A3 Shoulder height, standing; A4 Span; A5 Elbow span; A6 Sitting height; A7 Eye height, sitting; A8 Shoulder height, sitting; A9 Arm reach upward

2.2.2 Analysis of literature on a regression model with different body position

There is an analysis of the literature on the regression models with different body positions following past research. The analysis of the regression models includes the type of regression model, variable selection, data table collection based on different body positions, and regression results.

2.2.2.1 Type of regression model

Regression models have many types including linear regression, multiple regression, polynomial regression, poison regression, and others. Each model has independence and dependence variables will be related to hand grip strength. The main goal of regression analysis is to understand the strength and nature of the relationship between the dependent variable and the independent variables. There are several types of regression models, each suited for different types of data and scenarios. Past research study where linear regression analysis was conducted to ascertain the association between anthropometric dimensions and hand grip strength in the elderly population of Malaysia. The previously acquired data on hand grip strength and anthropometric measurements were employed in constructing the regression model. The dependent variable in the model was hand grip strength, while gender and 18 anthropometric dimensions served as the independent variables. The selection of anthropometric dimensions was contingent upon a correlation coefficient (r) exceeding 0.5, indicating a robust correlation, as evaluated at a significance level of 0.05 in a two-tailed test (Nurul Shahida et al., 2015).

Next, a multiple regression coefficient was calculated to evaluate the impact of anthropometric measurements on hand grip strength. The obtained regression coefficient indicated a positive association between grip strength and both height and BMI for both genders. These findings align with those of Mitsionis et al. (2009), who similarly observed a positive correlation between the dominant hand grip strength in Greek adults and body height for both sexes, as well as a positive association with BMI in women. A negative correlation was found between age and grip strength, indicating that grip strength weakens with age. This inverse relationship between age and hand grip strength has also been documented in studies involving Greek, Indian, Chinese, and Caucasian adults (Wu et al., 2009).

2.2.2.2 Model specification and variable selection

The research used distinct analyses for males and females. Paired t-tests were performed to explore disparities in grip strength between the right and left hands. Subsequently, multiple regression analysis was employed to investigate the average correlation between grip strength, age, and body measurements. To ensure the reliability of ANOVA analyses, the randomness, normality, and homogeneity of group variances were evaluated using non-parametric Kolmogorov-Smirnov tests, normal probability plots, and Levene's tests, respectively. Statistical significance was established at $p < 0.05$, and the findings are presented as mean standard deviation (Kamarul et al., 2006).

The demographic attributes of the study participants and variations in handgrip strength based on demographic characteristics and mental health status were examined through appropriate statistical tests, including the t-test and $\chi 2$ test. Subsequently, logistic regression analysis was conducted to ascertain the relationship between handgrip strength and the participants' mental health, utilizing odds ratios and 95% confidence intervals. This analysis was adjusted for clinically relevant demographic characteristics. Specifically, Model 1 was adjusted for age and gender, Model 2 included adjustments for age, gender, education, marital status, living arrangements, body mass index (BMI), economic status, place of residence, occupation, smoking habits, alcohol consumption, and physical activity. Model 3 incorporated adjustments for hypertension and diabetes mellitus (DM) in addition to the variables considered in Model 2. A significance level of $P < .05$ was applied for all statistical tests (Kwak & Kim, 2022).

2.2.2.3 Data table regression data based on different body positions

In the study, it was discovered that girls exhibited a significant increase in right handgrip strength when tested in anatomical position ($p<0.05$). However, there were no notable differences in left grip strength for girls, as well as in both hands of boys and the entire study group, when tested in the two different positions ($p>0.05$). These findings suggest that only the right handgrip strength of girls showed a significant increase in anatomical position ($p>0.05$) when comparing the two testing positions.

Our research showed that boys had higher grip strength values for both hands when the elbow was flexed, while girls had higher grip strength values with the elbow extended for both hands. The only significant difference we observed was in the right-hand grip strength values of girls (Barut, 2012). Results comparison of right and left handgrip strength values in two different positions as shown in Table 2.4.

Table 2.4: Comparison of right and left handgrip strength values in two different positions.

	Right handgrip strength (Kgf) (Anatomical position) Mean ± SD	**Right handgrip strength (Kgf) (Elbow flexion) Mean ± SD**	**Left handgrip strength (Kgf) (Anatomical position) Mean ± SD**	**Left handgrip strength (Kgf) (Elbow flexion) Mean ± SD**
Girls (n = 213)	19.59 ± 5.64	19.00 ± 4.76	18.98 ± 4.81	18.96 ± 4.85
Boys (n = 333)	23.16 ± 9.55	23.36 ± 9.93	22.73 ± 9.43	22.89 ± 9.80
Total (n = 546)	21.77 ± 8.42	21.65 ± 8.57	21.26 ± 8.15	21.36 ± 8.45

The reproducibility of the results was evaluated using the Intraclass Correlation Coefficient (ICC 2,1). The interpretation of the ICC results was based on the Landis and Koch classification, which categorizes the values as follows: almost perfect agreement (0.81-1.00), considerable agreement (0.61-0.80), moderate agreement (0.42-0.60), fair agreement (0.21-0.40), low agreement (0.00-0.20), and poor agreement (< 0). In addition, confidence intervals were calculated using a 95% confidence level for concordance (Vargas-Pinilla & Rodríguez-Grande, 2021).

2.2.3 Synthesis of literature on elements of regression statistics

Researchers have conducted a thorough investigation into the relationship between hand grip strength and factors such as age, gender, height, and body mass index. The studies show that accurately predicting hand grip strength is complex due to multiple factors that can influence these measurements. Researchers commonly use regression analysis to determine the impact of these variables. Model specification, including the choice of functional forms and consideration of interaction terms, is important for these analyses.

The researchers tested several models using subsets of anthropometric and demographic variables that are commonly used as predictors of sub-M. They included continuous variables like age (in years), body mass (in kilograms), body height (in meters), and BMI (in kg/m²), as well as a discontinuous variable for sex (male=1). The forward stepwise method was used to enter these variables in the model and adjust the R^2 value as a criterion for either entry or removal of the variables (Santos Neves et al., n.d.). Therefore, to avoid selecting variables that may not be relevant to our study, we chose to use the forward stepwise method for automated variable selection. This method was carefully selected based on our study aims and previous research conducted by Novaes et al. (2009) and Schlüssel et al. (2008), as recommended by Sun, Shook, and Kay (1996).

The study studied demographic profiles, including age, sex, and grip strength, using descriptive analysis. It presented mean, standard deviation, and coefficient of variation for hand grip strength. The researchers also examined correlations between handgrip strength and independent variables like age, height, weight, and BMI using Pearson Product-moment correlation. All determinants of hand grip strength were analyzed using a stepwise multiple regression model. Moreover, variable selection methods such as stepwise regression, and ridge regression are essential in identifying the most influential predictors. The synthesis emphasizes the importance of these statistical approaches in uncovering the determinants of hand grip strength in diverse populations and suggests avenues for future research and methodological improvements.

2.2.4 Evaluation of literature on using software

Evaluation of the literature on hand grip strength involves using regression analysis software to systematically import, clean, and preprocess data. The process involves fitting a model, evaluating its fit, validating it through cross-validation or hold-out validation, and interpreting and reporting the findings. The software used such as R, Python, or SPSS, is contingent upon specific study objectives, with each alternative providing unique benefits. Researchers can evaluate the quality and extract insights from a literature regression on hand grip strength by following these steps and using suitable software tools. They should customize their approach to match their research aims and the features of the data. Previous researchers used software to predict hand grip strength by manipulating independent and dependent variables, as shown in Table 2.5.

Table 2.5: The software will be utilized by previous researchers.

Studies	Software	Test	Key findings
(Zhou et al.,2021)	SPSS version 21.0	The study used mean ± standard deviation for continuous variables and frequency or percentage for categorical variables, with sample size calculated based on recorded numbers and reference to an earlier study.	Handgrip strength (HS) has been identified as a risk factor for all-cause mortality and cardiovascular diseases. However, the factors that influence HS and the mechanisms that contribute to this correlation are still uncertain. To address this, we conducted a prospective, cross-sectional study to explore the factors related to HS and investigate the underlying mechanism behind its risk-predictive value.
(Abdullatif et al., 2021)	GraphPad Prism software (version 5.0)	The study used descriptive statistics to analyze the differences in grip strength among different groups, and Pearson's correlation coefficient test to measure the strength of the relationship between hand grip and BMI/blood pressure, using one-way and repeated ANOVA and Tukey's tests.	The researcher was to investigate the influence of handedness, gender, ethnicity, and Body Mass Index (BMI) on hand grip strength, as well as the acute effect of grip strength testing on blood pressure in young adults.
(Samad et al., 2019)	Minitab	In this study, we compared hand grip strength with age, height, weight, and handbreadth. We used linear regression analysis and the Pearson correlation	The researcher demonstrated that it is not possible to conclude a significant relationship between hand grip strength and anthropometric measures, except for weight.

		coefficient to measure the degree of dependence between hand grip strength and the other parameters.	
(La & Potvin, 2016)	MATLAB	The study created artificial neural networks using Matlab's Neural Network toolbox. To compare multiple regression and ANN models, Pearson's correlation, explained variance, and root mean square differences were evaluated between model predictions and development and validation datasets.	The researcher suggested that artificial neural networks (ANNs) are a more accurate and robust alternative to regression approaches. Therefore, they should be used more often in biomechanics and ergonomics evaluations.

2.3 Design and develop ergonomic hand gloves

2.3.1 Analysis of literature on hand gloves design

There is an analysis of the literature on hand glove design including material selection, size and shape of hand gloves, application of hand gloves in industry, the development process of hand gloves, the survey on User Needs, House of Quality (HOQ), user experience, focus group, design software.

2.3.1.1 Hand gloves design

Hand gloves are designed to protect hands from hazards such as sharp objects, chemicals, heat, cold, biocontamination, radioactive contamination, and electric shock (Griffin, 2011). Proguard hand gloves also enable users to work more efficiently and comfortably, reducing fatigue while feeling safe. Furthermore, there are instances where gloves are required to safeguard the items being handled rather than the individual handling them. Additionally, gloves are frequently utilized to provide protection to the hands when working with manual tools, preventing injuries (Claudon, 2006).

Hand and finger injuries are reported to be more prevalent in occupational settings compared to other types of injuries, making up around 30% of all injuries (Oleske & Hahn, 1992). Nevertheless, the utilization of protective gloves has been found to effectively decrease the associated risks by approximately 60% (Sorock, 2004). Thus, personal protective equipment is designed in a variety of forms to protect the hand part of the body against risks associated with equipment use (González, 2005). The study of the comfort equipment of protection such as gloves in industrial work zones. consequently, it is necessary to analyze and explore the standard of comfort provided by protective gloves according to the characteristics of the materials that were made. This may allow us to determine the quantity to which these gloves can be considered suitable for use, thus improving hand protection, and reducing the risk of injuries.

The study's results showed that the behavior of wearing gloves harmed hand performance (Johnson & Sleeper, 1986). Bensel (1993) identified that when glove thickness is increased, there can be a decrease in manual dexterity because it requires more time to do tasks. Therefore, hand gloves are designed not may to protect the hand but also to help the worker reduce the maximum grip strength (Wells, 2016).

2.3.1.2 Material selection

The researcher studied the effective fit of gloves on the hand performance whereby the dimensions of gloves and hand, and the selection of gloves material. Developing an understanding of the impact of glove fit on different hand functions would provide important data for glove design. Gloves can be manufactured using many materials that are suited to certain purposes (Yu et al., 2019). Different types of gloves, including disposable medical gloves and chemical protective gloves, are typically made from rubber materials like natural rubber (latex), nitrile rubber, chloroprene rubber, or butyl rubber. However, assembly gloves, which provide protection against mechanical impact, may also incorporate a layer of natural or synthetic rubber. In the production of rubber products, accelerators are commonly utilized to expedite the manufacturing process (Yu et al., 2019).

Table 2.6: Types of Gloves, Occupational Safety and Health Administration (OSHA).

Material selection in gloves	Types of gloves	Characteristics
Cotton or fabric	Fabric gloves 	Fabric gloves are generally used to improve grip when handling slippery objects. It also helps insulate hands from mild heat or cold.
Polyvinyl chloride (PVC) Polyvinyl alcohol Polyethylene Natural rubber latex	Chemically Resistant Gloves	Blending or laminating these materials can enhance their performance, providing users with protection against the

Nitrile		potentially harmful chemical effects commonly found in pharmaceutical and industrial applications.
Thermoplastic rubber	Anti impact gloves 	Protect users from crushing, pinching, cutting, and puncture hazards that make up most of the serious hand injuries.
Goatskin Cowhide	Leather gloves 	Leather gloves, used for welding, resist sparks, moderate heat, and minimize cuts. However, not suitable for chemicals due to chemical absorption.
Rubber	Electrical insulating gloves 	Protect electrical engineers from shock while working on live electrical equipment.

2.3.1.3 Size and shape of hand gloves

Features of gloves affected have been studied, such as the material used and thickness of gloves. 1. The impact of these characteristics on user dexterity, strength, and overall performance is evident. Additionally, the fitting of the gloves to hand dimensions is another design feature that influences performance. Typically, glove size is determined by considering two main hand dimensions: hand length and hand circumference. The researcher focused on these dimensions to determine the key attributes for glove sizing (Kwon et al., 2009). A past study identified the coverage rate of a glove-sizing system and used these two aspects (Lee et al., 2015). Manufacturers commonly use two measurements such as hand length, hand circumference, and hand breadth (Lee et al., 2015). Hand length and breadth are the most used dimensions to make gloves (Jee and Yun, 2016). Therefore, Glove sizes have typically been determined based on the length and width of hands. To improve accuracy in sizing, it's important to also consider variations in the shapes of palms and fingers (Vergara et al., 2019). Hand dimensions refer to the measurements of various parts of the hand, including the palm length (1), middle finger length (2), little finger length (3), ring finger length (4), hand length (5), index finger length (6), thumb finger length (7), minimum handbreadth (8), and maximum handbreadth (9). These measurements are used in hand anthropometric studies to understand the physical characteristics and proportions of the hand as shown in Figure 2.12.

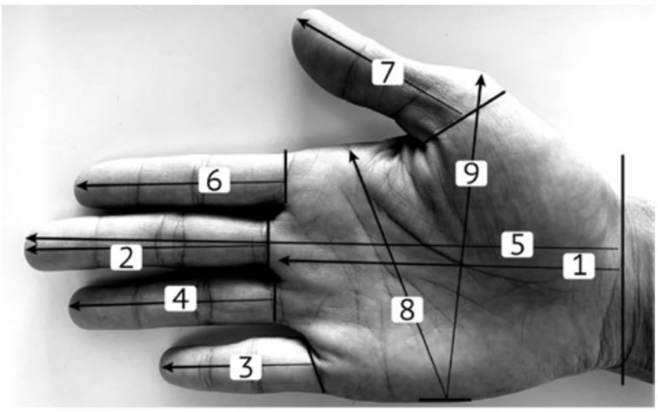


Figure 2.12: Hand dimensions (Ahmad Zahudi et al., 2023).

Wrap your hand with the tape at one point below the knuckles excluding thumb.

Circumference (mm)	Size
152 - 178	XS or 6
178 - 203	S or 7
203 - 229	M or 8
229 - 254	L or 9
254 - 279	XL or 10
279 ++	XXL or 11

Measure distance between the bottom of your palm or wrist to the top of the tip of your middle finger.

Length (inch)	Size
6 - 7	XS
7 - 8	S
8 - 9	M
9 - 10	L
10 - 11	XL
11 - 12	XXL

* 1 inch = 25.4mm

(a)

(b)

Figure 2.13: (a) Gloves Sizing & Length Chart; (b) hand length and hand circumference (Hsiao et al., 2015).

2.3.1.4 Application of hand gloves in industry

Industrial hand gloves provide protective apparel for factory workers, offering cut-slash and thermal protection against rough objects, sparks, heat, and heavy-duty blows. Individuals could wear knitted gloves to safeguard their hands and palms from injuries that may occur when plucking okra. These gloves provide both comfort and excellent absorption, as shown by Padma and Khateeja Sulthana in their 2017 study. When evaluating the effectiveness of knitted gloves with protective attributes, it is important to compare them to bare hands or conventional methods that are typically associated with occupational dangers. Existing literature suggests that there is a lack of knowledge concerning the prevention of hand and finger injuries during the process of harvesting okra (V Daivashiromani et al., 2020). Therefore, the purpose of the study was to evaluate the effects of knitted, and rubber gloves in reducing occupational injuries during okra plucking. Vegetable picking exposed agricultural workers to significant health risks, including cuts and wounds on their hands, hardened skin, itching, blisters, and abrasions. To study this issue, protective hand gloves were created and produced (Vastrad & Kotur, 2012). Agriculture workers wore gloves as shown in Figure 2.14.

Figure 2.14: Agriculture workers wear knitted gloves; Farm women and men engaged in bhedi plucking (Vastrad & Kotur, 2012).

Two primary categories of medical gloves employed in healthcare are sterile and non-sterile gloves. As per the World Health Organization's (WHO) guidelines from 2009 regarding medical glove usage, sterile gloves are predominantly utilized in surgical procedures, whereas non-sterile gloves are primarily employed in activities involving contact with blood, body fluids, secretions, and skin. While non-sterile gloves are not intended for surgical procedures, there are instances where sterile gloves may be used for non-surgical procedures (Jamal et al., 2021). In addition, it is important to note that gloves used for gas tungsten Arc welding (GTAW) and low-amperage applications must possess heat resistance and be of sufficient length to cover the hand, wrist, and lower forearm. These gloves should be designed to fit either over or under the jacket sleeve, ensuring maximum comfort for the wearer. On the other hand, for higher-amperage GMAW, shielded metal arc welding (SMAW), and air carbon arc cutting, it is crucial to have thick leather-insulated gloves that offer both melt-through and cut resistance. Manufacturers often provide split-grain leather for enhanced protection and softer-grain leather for increased comfort. Typically, heavy insulation is located on the back of the gloves to provide heat protection. It is worth mentioning that select manufacturers also offer curved GMAW and GTAW gloves. Notably, both medical workers and welders utilize the gloves depicted in Figure 2.15.

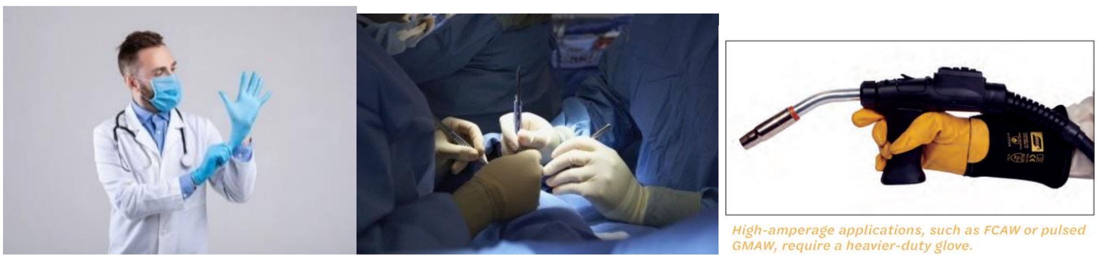


Figure 2.15: Sterile and nonsterile gloves medical and leather gloves.

2.3.1.5 Survey on User Needs

Surveys are a systematic approach used to gather, analyze, and interpret data from a subset of individuals to create a numerical representation of a larger population. Survey research is one of the three main techniques for collecting primary data, alongside direct measurement, and observation (Wiley,2009). Depending on the purpose of the survey, data can be presented in a variety of formats and defined according to design such as prospective or retrospective or data type obtained (Real LM, 2005). Survey information can be collected in a variety of ways including face-to-face interviews, online interviews, and most self-administered questionnaires (A, 2009).

To develop a survey or questionnaire, researchers must consider scaling methods, response options, scales, Likert scale alternatives, reliability, validity, response rate, preferred scale points, item readability, Likert scales, and advantages of visual analog response scales. There must also be consideration of the impact of midpoint response, Likert scales, and the optimal number of response options, as well as the best time to endorse the midpoint response in a survey (Taherdoost, 2018). Survey research has evolved into a rigorous approach, involving scientifically tested strategies for representative sample inclusion, distribution, and follow-up to ensure high-quality outcomes, encompassing various research aims, sampling strategies, data collection instruments, and administration methods (Brant et al., 2015).

2.3.4.6 House of Quality (HoQ)

House of Qualify (HoQ) is a component of Quality Function Deployment (QFD), which is an iterative process utilized in the planning process (Ertugrul Karasak and Dursun, 2014). HoQ prioritizes requirements such as product design characteristics (PDCs) based on customer requirements (CRs). There are interrelationships between PDCs and CRs, and the planning process is represented by a process map within HoQ (Shahin et al., 2018). The model used in this research classifies quality attributes into three main categories: one-dimensional and attractive dimensions (Madzik, 2018). Additionally, HoQ is depicted as a diagram resembling a house with five walls, with the left wall emphasizing customer acquisition (Mujalda & Singh Verma, 2006).

Quality Function Deployment (QFD) is a methodology used to develop a design that meets the consumer's requirements. It involves translating the consumer's demands into specific design targets and quality assurance points employed during production. QFD can be viewed as a systematic approach in which the input and feedback from consumers are highly regarded and integrated throughout the entire process of manufacturing and service delivery. QFD, also known as Quality Function Deployment, was invented by Yoji Akao in Japan in 1966. However, its first practical use took place in 1972 at Mitsubishi's Kobe shipyard, maybe influenced by the guidelines of Deming. Then, other Japanese corporations, especially Toyota and its suppliers, adopted and developed this previously mentioned technology (Mujalda & Singh Verma, 2015).

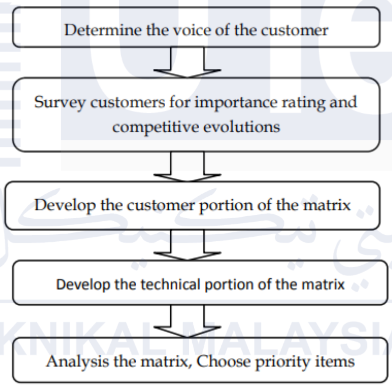


Figure 2.16: Flowchart of QFD process (Mujalda & Singh Verma, 2015).

The House of Quality (HoQ) is a diagram that establishes a connection between the demands of the customer and the engineering requirements or design variables. It is based on the well-established Quality Function Deployment (QFD) method in early stages of product development (Masao & Yoji, 2017). The matrix in the diagram allows for the identification of consumer requirements and their impact on design variables. It also includes a roof that indicates trade-offs between different design variables. Additionally, there is often an extra column that serves as a benchmark for evaluating how competitors address customer demands. Weights can be added below the matrix to highlight the importance of engineering needs and the corresponding time and effort required (Chen et al., 2017).

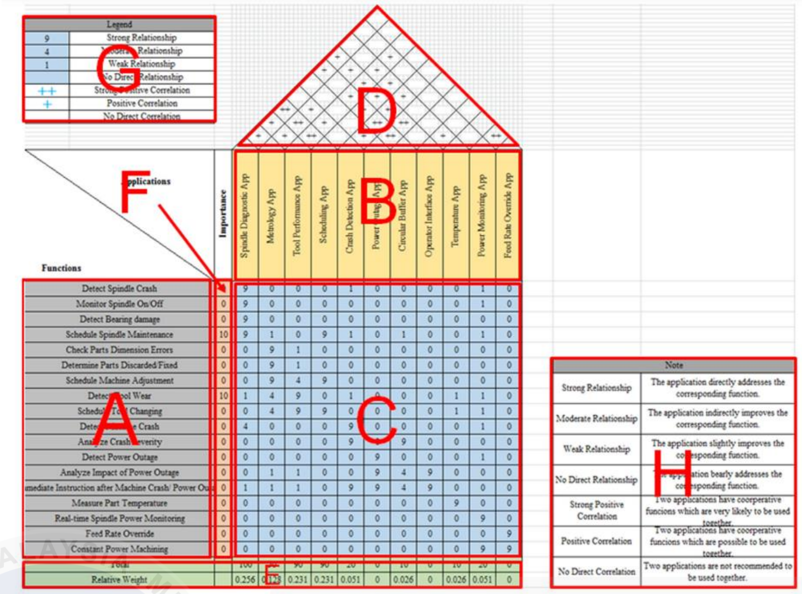


Figure 2.17: Dynamic HoQ Diagram for Manufacturing Apps (Chen et al., 2017).

2.3.1.7 Concept screening method

The concept screening method is an approach employed by designers to ensure that designs are generated from a limited set of concepts, incorporating the advantages of each. This method employs both quantitative and qualitative measures to identify the most relevant concept by assigning data to a reference concept, ensuring that the final design meets critical customer requirements (Pugh, 1996). In other words, the concept screening method aims to eliminate weaker product concepts and select the best one. The concept screening matrix utilizes a rating process, where three symbols are used to compare concepts: "better than" (+), "same as" (0), and "worse than" (-). All concepts are rated based on their comparison to the reference concept. The concept screening method is shown in Figure 2.18.

SELECTION CRITERIA	A	B	C	D	E	F	G	REF.
	CONCEPT VARIANTS							
Ease of Handling	0	0	–	0	0	–	–	0
Ease of Use	0	–	–	0	0	+	0	0
Number Readability	0	0	+	0	+	0	+	0
Dose Metering	+	+	+	+	+	0	+	0
Load Handling	0	0	0	0	0	+	0	0
Manufacturing Ease	+	–	–	0	0	–	0	0
Portability	+	+	–	–	0	–	–	0
PLUSES	3	2	2	1	2	2	2	
SAMES	4	3	1	5	5	2	3	
MINUSES	0	2	4	1	0	3	2	
NET	3	0	–2	0	2	–1	0	
RANK	1	3	7	5	2	6	4	
CONTINUE?	Yes	Yes	No	No	Yes	No	Yes	

Figure 2.18: Concept screening method (Product Design & Development Concept Selection, 2017).

Pugh decision matrix is a measure of conceptual selection (Black et al., 2021). Evaluation criteria are summarized from the order of the technical descriptors and the essential needs in QFD. The following processes are carried out, as shown in Figure 2.21.

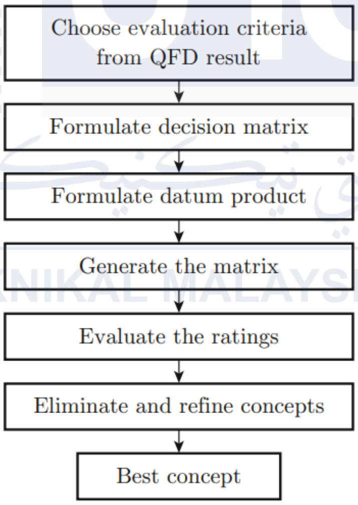


Figure 2.19: Flow chart of Pugh decision matrix.

2.3.1.8 User experience

Company questionnaires are commonly used to evaluate the user experience of products and services. These questionnaires serve as a quantitative technique to measure the user experience. Various UX questionnaires exist in the literature, including the Visual

Aesthetics of Websites Inventory (VisAWI), the Standardized User Experience Percentile Rank Questionnaire (SUPR-Q), and the User Experience Questionnaire (UEQ). One of the main objectives of using a UX questionnaire is to gather insights and recommendations for product development and improvement.

User experience is an approach used by researchers, practitioners, and designers who need to create a new and improved product, system, or service. User experience is the perception of a human while they are interfacing with a system (Gube, 2010). In the previous few years, there is a famous remark mentioning that the user experience has served as an established part of research in design (Hassenzahl & Tractinsky, 2006). It is also viewed as a rising study subject that delivers both researchers and practitioners a big quantity of profit in product design and development (Partala & Saari, 2015). Ordinarily, it is a realization of the consideration of capabilities for the products function.

The question of measuring user experience arises due to subjective evaluations, with different levels of expertise affecting how easy or complex a product is perceived by different individuals (Schrepp et al., 2017). Therefore, surveys are a straightforward technique for collecting such user feedback (Schrepp et al., 2014). The research can be distributed rather efficiently to larger groups of people, especially if they exist as online questionnaires. In addition, studying the numerical data from such questions is quite standardized and thus efficient as well.

2.3.1.9 Focus group

A focus group is a research technique that involves a small group of individuals coming together in a controlled environment to respond to inquiries. The selection of participants is based on specific demographic criteria, and the questions asked aim to gather additional information about a particular subject (George, 2021). Various definitions of focus groups can be found in literature, but common characteristics such as structured discussions (Kitzinger, 1994), collective engagement (Powell et al., 1996), social dynamics (Goss & Leinbach, 1996), and interaction (Kitzinger, 1995) highlight the valuable contribution of focus groups to social research. The primary objective of focus group research is to capture participants' opinions, emotions, beliefs, experiences, and reactions in a way that cannot be achieved through alternative methods like observation, individual interviews, or surveys. These sentiments, emotions, and beliefs are more likely to be revealed through social gatherings and interactions.

Focus groups elicit a multiplicity of views and emotional processes within a group context, allowing researchers to gain more information in a shorter period. They are useful when power differences exist, language and culture are of interest, or consensus on a topic is sought (Morgan, 1997). This researcher discusses focus group research, highlighting its benefits of interaction and group dynamics. Despite practical considerations and time constraints, participants find it rewarding and empowering. Focus group research offers a unique perspective for social researchers seeking a different approach to their field (Gibbs, 1997). Therefore, the flow of focus group conversations can be taken successfully. The study focuses on validating a method by evaluating YouTube and WhatsApp, focusing on confidence and scale consistency for each scale (Hinderks et al., 2019).

2.3.1.10 Design software and simulation

Design software acts like a digital paintbrush, allowing you to create, edit, and visualize anything from logos to 3D models and websites. From simple drawing tools to advanced animation features, it empowers graphic designers, engineers, architects, and anyone else who wants to bring their creative visions to life. There are several kinds of design software, such as SOLIDWORKS, AUTOCAD, and CATIA. In between this design software, SOLIDWORKS is a 3-dimensional mechanical design software package that is most popular and familiar to the designer. It is developed for producing innovative products with high quality, and of time and money compared to other CAD software packages. Moreover, the researcher studies comparing software design models are crucial in model-centric tasks, identifying commonalities and differences, and identifying conflicting changes as relevant models are executed by different teams (Morgan, 1997). Previous research has pointed out that evaluating similarity remains an error-prone and time-consuming task (Thaler et al., 2016). Regardless, researchers and those working in industries still need to choose from among several methodologies in literature the one that best matches their goals. However, this choice is not straightforward for two reasons (Gonçales et al., 2019).

2.3.1.11 Development processes of hand gloves

The prototype process of gloves has several methodologies that have been employed to incorporate conductive materials into textile structures, such as coating or printing directly onto the textile surface (Li et al. 2020; Uzun et al. 2019). To create the stitching pattern with conductive thread with a sewing machine (Shin et al. 2018) and develop the knitted machine to textiles with functional yarns (Fan et al. 2020; Wu et al. 2018). The researcher used the seamless digital knitting machine (15 gauge; 60-cm width; Shima Seiki SWG041N2, Wakayama, Japan) was improved to fabricate the knitted glove (Song et al., 2021). There is knitting software to adjust the shape and design options of measurement gloves. Testing the knitted sensor gloves used a strain testing machine (Teraleader, Daejeon, Korea) to measure resistance and characteristics. The strain testing equipment features an integrated linear elongation function, allowing direct sample characterization under tension using the built-in testing bed (Song et al., 2021). Thus, the digital knitting machine was used to fabricate seamless glove sensors for both human and robotic hands, as detailed in the "Fabrication of a smart glove using CAD/CAM" section.

(a) (b)

Figure 2.20: (a) Digital knitting machine (Davis, 2018); (b) a universal strain testing machine for textile sensors.

In addition, simple smart gloves often use glued or sewn electronic parts, which can feel bulky and limit hand movement. These are often used for entertainment, like virtual reality or music control. Higher-tech gloves use stretchy fabrics, embedded components, and advanced printing to be lighter and more comfortable. The main problem with most gloves is their stiffness and bulky electronics, which limit the user's ability to feel and move naturally (Dipietro et al., 2008). This research explores affordable ways to make comfortable smart gloves for measuring forces in manual therapy (Baribina et al., 2019). This research aims to explore cost-effective technological solutions for creating comfortable smart gloves for measuring load forces in manual therapy. The researcher used the sewing machine to make the glove sensor that maintains elasticity and thickness, a more complex and time-consuming method than gluing. However, the finished gloves still maintain their textile properties, including flexible seams, sewn conductive lines, unlimited hand, and finger movements, and a comfortable fit as shown in Figure 2.23.

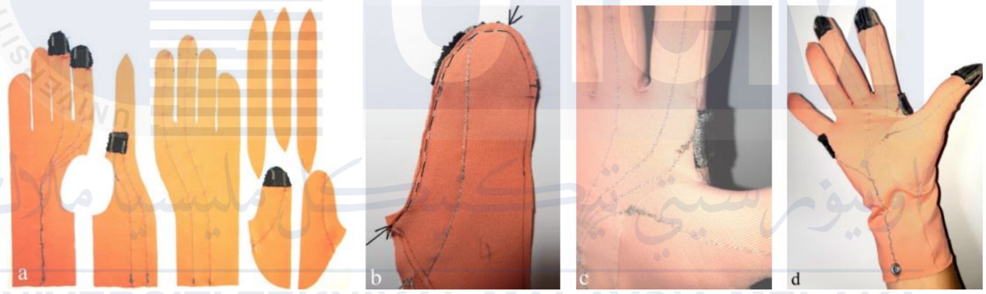


Figure 2.21: Fabrication of the data glove using a sewing machine.

2.3.1.12 Electromyography (EMG)

Electromyography (EMG) provides data on the activity of muscles (Cifrek et al., 2009). As a result, EMG devices find application across several study disciplines, including biomedicine, ergonomics, physiotherapy, and sports performance assessments. It proves significant in observing muscle action during tasks by analyzing differences in the electrical signal (Toro et al., 2019). Furthermore, this technology has the potential to contribute to other studies (Olmeda et al., 2018). The researcher's study aims to examine the variations in the intricate structure of the EMG signal resulting from the hand posture. These hand postures measure actions whereby 'Thumb up,' 'Extension of index and middle, flexion of the others,' 'Flexion of ring and little finger, extension of the others,' 'Thumb opposing base of little finger,' 'Abduction of all fingers,' 'Fingers flexed together in a fist,' 'Pointing index,' and 'Adduction of extended fingers.' This study used fractal analysis to explore the complexity of the EMG signal. The fractal dimension serves as a metric for process complexity, with higher values indicating a more intricate process (Namazi, 2019). For example, EMG as shown in Figure 2.24. Moreover, this kind of technology can be used to improve other studies.

Figure 2.24: DELSYS Trigno wireless EMG measurement instrument (Choi & Lee, 2015).

2.3.2 Synthesis of literature on the combination of material gloves

Hand gloves provide an important part in a wide range of applications. This literature review aims to synthesize research findings on a combination of materials and hand gloves in different industries. Gloves are commonly designed using a combination of materials to enhance their performance, comfort, and protective attributes. The choice of material depends on its specific application and the risks involved. Table 2.7 shows Combinations of materials to improve the protection of gloves.

Table 2.7: Combinations of material gloves.

Studies	Materials	Methods/process	Protective properties	Key findings	Application
(Irfan et al., 2022)	carding waste of para-aramid fibers, knitted polyester fabric	Flats of the carding machine, cutting machine, Sewing machine	Increase cut resistance, abrasion resistance, tear-resistance, and heat resistance.	The study suggests that high-performance fiber waste can be utilized as a cost-control and environmentally friendly strategy in the creation of protective textiles.	Resistance gloves
(Lovato et al., 2023)	Natural rubber and acrylonitrile butadiene rubber Gloves Coated with Gardine Solution	Dipping process	• Comfortable, good fitting and feeling for hands. • High elasticity and ability to adapt to shapes. • High tear strength. • Waterproof. • Resistance to various chemicals.	To scale laboratory knowledge to industry, consider production ease and profitability. Including performance-enhancing materials directly into rubber formulations or using an extra dipping process may be most economically appealing. Optimizing manufacturing parameters is crucial for safe gloves.	Medical gloves

(Yu & Sukigara, 2022)	• chloroprene rubber and spacer fabric • memory foam	• Compression tester (KES-G5, Kato Tech Co., Ltd., Japan) with a flat circular indenter that has a surface area of 2 cm2EMG	• protect the hands from external impacts, anti-vibration gloves	A systematic study is recommended to analyze the impact of placement, shape, thickness, and assembly method on hand performance of vibration isolation materials.	screw driving task.

2.3.3 Evaluation of literature on applications ergonomics hand gloves

Ergonomics hand gloves play a crucial role in ensuring the safety and well-being of workers in various industries, including the electrical sector. These gloves are designed to provide protection, comfort, and enhance performance during work activities. This literature review aims to explore the research findings related to ergonomics hand gloves for the electrical sector and identify knowledge gaps for potential future research directions.

Dianat et al. (2012) conducted a literature review to evaluate gloves about their effects on hand performance capabilities. The study stated the importance of considering hand performance capabilities when evaluating gloves. The impact of gloves on hand performance can help in designing more effective and ergonomic gloves for workers in the electrical sector.

The researcher introduced a wearable tactile device that employs mechanical and electrical stimulation to provide fingertip interaction with the virtual environment (Yem and Kajimoto, 2017). The study mainly studied technological applications, but the results indicate the possibility of employing comparable tactile devices in the electrical industry. These devices can offer tactile feedback and enhance the skill and precision of hand motions, resulting in improved performance and safety.

In addition, investigation into the ergonomics of women's gloves in surgery (Sutton et al., 2014). Although the study focused on surgical procedures, it emphasized the importance of considering ergonomic factors, including the design of gloves, to improve performance and reduce the risk of musculoskeletal disorders. Therefore, can be extended to the electrical sector where workers also face ergonomic challenges, and the design of hand gloves can play a significant role in minimizing the risk of injuries.

2.3.3.1 Comfort Questionnaire for Hand Gloves (CQH)

Hand gloves provide an important function in several industries, including healthcare, robotics, and rehabilitation. The design and evaluation of hand gloves are important to ensure optimal performance and user comfort. To evaluate the comfort of gloves, questionnaires have become a common method that is used in the assessment of subjective ratings. In the CQH, the questions are developed to be “satisfactory” (Yes), “unsatisfactory” (No), and “not applicable” (NA) in terms of satisfying the design feature given by that item (Dababneh et al., 2004). Another research similarly scored the questionnaire on a 7-point scale, where 1 was worst and 7 was best to evaluate the comfortable range (Jung & Hallbeck, 2000). However, it is accurately impossible to assume the level of comfort of hand gloves.

2.3.3.2 Rate of Perceived Exertion (RPE)

RPE scale is an easy way to determine the comfort level of ergonomic hand gloves. During a self-paced exercise, the rating of perceived exertion (RPE) and the level of effort are extremely important in determining and modifying the intensity of the activity (Abbiss et al., 2015). The Borg 6 to 20 RPE scale was initially developed by Gunnar Borg and is referred to as the original Borg scale (Morishita et al., 2019). Resting activity with minimal effort is represented by a score of 6, while intensive exercise is represented by a score of 20, as depicted in Figure 2.13. The Borg Rating of Perceived Exertion (RPE) technique gauges the intensity of physical activity by evaluating the bodily sensations experienced by individuals. The Borg CR-10 scale, which is an adaptation of the original Borg 6-20 RPE scale, consists of 12 categories with values ranging from 0 to 10 (0 representing nothing at all and 10 representing maximal exertion). This scale, as shown in Figure 2.23, has been utilized to measure the intensity load of cycle-ergometer exercise (Machin et al., 2011) and assess the intensity of various aerobic activities performed by elderly individuals (Morishita et al., 2019). Put simply, RPE can be used to assess and analyze the emotions and experiences of a person. While RPE is commonly seen as a subjective assessment, it remains the simplest method for gauging human perceptions and is widely recognized. This range enables the determination of both the physical strength level and the rate of human sensation. Typically, it is utilized to assess the participant's heart rate, breathing rate, and muscle tiredness following exercise.

Rating	Descriptor
6	No exertion at all
7	Extremely light
8	
9	Very light
10	
11	Light
12	
13	Somewhat difficult
14	
15	Difficult (heavy)
16	
17	Very difficult
18	
19	Extremely difficult
20	Maximal exertion

Rating	Descriptor
0	Rest
1	Very, very easy
2	Easy
3	Moderate
4	Somewhat difficult
5	Difficult
6	–
7	Very difficult
8	–
9	–
10	Maximal

Figure 2.23: Borg 6-20 RPE scale and Borg CR-scale (Morishita et al., 2019).

Furthermore, in the context of tasks that induce fatigue, there has been limited exploration of the connection between muscle fatigue and ratings of perceived fatigue (RPF), as opposed to exertion or discomfort. A recent study by a researcher conducted a series of experiments aimed at creating and validating a modified Rating of Perceived Fatigue (RPF) scale Micklewright et al. (2017). The fatigue levels of individuals were measured using the Borg CR 10 scale, which ranged from 0 (no fatigue) to 10 (complete fatigue and exhaustion). During the recovery phase after the cycling task, Ratings of Perceived Fatigue (RPF) consistently correlated with systemic physiological markers of muscle fatigue, unlike Ratings of Perceived Exertion (RPE), which returned to baseline quickly during rest. However, a limitation of this study was the lack of investigation into the relationship between RPF and a localized measure of muscle fatigue, such as a decline in maximal voluntary contraction strength (MVC). Muscle fatigue, which involves a temporary reduction in MVC during or after prolonged efforts, is influenced by both central and peripheral factors. Therefore, in order to establish RPF as an indicator of immediate muscle fatigue in workplace or performance settings, its association with objective measures needs to be demonstrated. The display scale for perceived fatigue (RPF) can be found in Table 2.8.

Table 2.8: Rating of Perceived Fatigue (RPF) scale (Whittaker et al., 2019).

Rating of Perceived Fatigue (RPF) Scale		
Completely Rested	0	No fatigue
	0.5	Very light fatigue
	1	Light fatigue
	2	Fairly fatigued
	3	Moderately fatigued
	4	Fatigued
50 % rested	5	Very fatigued

	6	
	7	Nearly exhausted
	8	
	9	
Completely fatigued	10	Absolutely exhausted

2.3.3.4 Coefficient of Friction Fixture

The previous study conducted evaluations, both objective and subjective, to investigate the impact of gloves on hand strength, contact forces during manual work with hand tools, and hand tactility and discomfort. The main objective was to determine the most suitable glove designs for glovebox operation. The study focused on assessing various glove properties such as thickness, friction coefficient, and pliability, as well as their interactions, to improve safety and health in work environments that involve glovebox tasks (Sung, 2014).

In contrast, another researcher stated that further research is needed to understand the effects of gloves on pinch strength (Dianat et al., 2012). The study by Hur et al. (2012) found that the low static coefficient of friction on the glove surface increased the required grip force. Batra et al. (1994) demonstrated a strong association between grip strength and the coefficient of static friction. In addition, Tsaousidis and Freivalds (1998) stated that improved glove pliability reduced tactile information and increased force exertions.

Therefore, it is essential to understand the glove attributes that influence hand performance, as they can serve as design requirements for currently available and potential glove materials. However, the study found no correlation between static friction coefficients and grip strength, possibly due to similar coefficients across different glove materials and thicknesses.

The Coefficient of Friction (COF) is a critical factor in determining the grip performance between hand gloves and hand tools. The COF represents the resistance between two surfaces as they slide against each other. For gloves and tools, it dictates how well the gloves grip the tools during tasks. Factors like surface material, wetness, and surface finish influence grip. Medical gloves, for instance, require specific COF for safety and efficiency.

Testing methodologies evaluate glove grip across various surfaces. Choosing the right gloves ensures safety, reduces fatigue, and enhances productivity.

2.4 Differences between previous studies and current studies.

Previous researchers have conducted different studies linked to enhancing hand grip strength measurements. These researchers may have similarities as well as differences with the present study. The value of the analysis and synthesis study is to provide helpful guidance and information regarding methodology and experimental outcomes as references for the present study. Table 2.9 tabulates the difference between the prior research and the present study in terms of participants, age, body positions, methods, and outcomes.

Table 2.9: Differences between previous studies and current study.

Studies (Countries)	Participants of study	Age	Body positions	Methods	Outcomes
Nurul Shahida et al., 2015 (Malaysia)	Elderly Malaysian	60 years and above	The study measured both handiness and grip strength by subjects in a chair without armrests, with hips and knees flexed at 90 degrees, shoulders adducted, elbow flexed at 90 degrees, and wrist dorsiflexion and ulnar deviation.	Consultation form, health screening questionnaire, sliding, and spreading calipers, Jamar hand dynamometer, IBM Statistical Package for Social Science (SPSS)	The study's findings are valuable for product designers in creating ergonomic hand-held products for elderly Malaysians.

Hossain et al., 2011 (Malaysia)	Staff, medical students, and visitors of University of Malaya Medical Center	18 to 65 years	This study measured dominant hand grip strength in the standard limb position (Kamarul et al., 2006).	Screening questionnaire, Jamar dynamometer	The study found that grip strength varies between men and women, with office workers having the strongest grip strength, consistent with previous studies on Chinese older adults, and no significant differences in grip strength between the Malay, Chinese, and Indian ethnic groups in Malaysia.
Zahudi, A. Z. A., Usman, J., & Osman, N. A. A. (2023) (Malaysia)	Tenpin bowlers from the Endah Parade Bowling Centre, Kuala Lumpur (Malaysia)	The mean of 34 years	Subjects were instructed to stand comfortably with their left hand resting, holding a dynamometer over their head. They were instructed to maximally squeeze for three seconds, repeated three times, with one minute rest between sets.	Standard digital weighing scale, standard height scale, flexible tailor tape, Takei 5401 Grip D (Digital Grip Dynamometer)	The study confirms a correlation between anthropometric characteristics and handgrip strength in Malaysian recreational tenpin bowlers, providing valuable insights for new players to enhance their bowling performance.

Ong et al., 2017 (Singapore)	Elderly Singaporean	60 years and above	Subjects were instructed by trained interviewers to sit according to the American Society of Hand Therapists (ASHT) recommendation for HGS assessment, with shoulder adducted, neutrally rotated, elbow flexed at 90o.	Interview, Jamar Plus + Digital Hand Dynamometer (Pennsylvania, United States)	Singapore's older adults show weaker HGS compared to other countries, with females having greater HGS but not males, enabling better interpretation of HGS using Jamar digital-type dynamometers.
Klint et al., 2021 (Philippine)	Adult workers from a plastics company manufacturing	18 – 46 years	Participants held a dynamometer with their arms at the side, performing three consecutive tests with 15-second rest periods. The dominant hand was identified during the experiment, with the handgrip test conducted twice during the morning shift.	Interview, Digital hand dynamometer CAMRY®, measuring tape, digital weighing scale, digital caliper	The study will offer comprehensive insights into the Anthropometric and Handgrip Strength measurements of manufacturing workers, aiding in the proper designation and improvement of ergonomics and safety in both domestic and international workplaces.

Smith et al., 2018 (USA)	US older adults	60 years and above	The NHANES Muscle Strength Procedures Manual outlines a handgrip strength test protocol. Participants measured handgrip strength using a Takei Digital Grip Strength Dynamometer over three trials, with alternating hands. A trained examiner explained the procedure and grip size adjustments. Participants were randomly assigned to use dominant or non-dominant hands.	Survey, Takei Digital Grip Strength Dynamometer	The result of the study was older US adults, particularly women, with obesity and depression, are at the highest risk of physical function decline.
Zhou et al., 2021 (China)	healthy young adults	aged 18–24 years	Participants sat upright, elbow flexed, forearm facing forward. They used a hand dynamometer to measure maximal handgrip effort, taking	Consultation form, hydraulic hand dynamometer, cardiopulmonary exercise test (CPET), GraphPad Prism	The study suggested that BMI- and BSA-adjusted HS can indicate physical health and cardiorespiratory fitness levels in healthy young adults, especially males.

			measurements at least 1 minute apart for muscle strength recovery.	version 6.01 (San Diego, USA).	
Abdullatif et al., 2021 (Arab, South Asian, Emirate)	Young adults	The mean of 20 years	Participants held a dynamometer with their dominant hand, aiming to squeeze it with maximum isometric effort for three seconds. They recorded three consecutive tests, avoiding body movement, and the best clench force was saved for further analysis.	Consultation form, hand dynamometer, digital blood pressure monitor (Omron, Kyoto, Japan), GraphPad Prism software (version 5.0)	The study found that IHG strength was not influenced by handedness in both sexes, with slightly higher values in the Arab population. Females had significantly lesser IHG strength. A positive correlation was found between IHG strength and BMI and/resting SBP, with both decreasing immediately after the test.
Chan et al., 2022 (Taipei, Taiwan)	Older adults	60 years and above	No mentioned.	Consultation form, electronic scale, fixed stadiometer, dual-energy X-ray absorptiometry (DXA), dynamometer (Exacta™; North Coast	The study found that men have greater HGS and lean muscle mass than women, with a stronger correlation in the upper extremities, suggesting HGS measurements are an accurate proxy for muscle mass.

				Medical, United States), Excel and SPSS software	
Current study (Malaysia)	Adult females	19 – 39 years	The participants hold a Jamar dynamometer in neutral, supination, and pronation forearm positions while standing and sitting according to the ASHT and SHAP protocols. Repeat twice each of the positions.	Informed form, Screening selection, CATIA, survey, CQH, Jamar dynamometer, measuring tape, Minitab, Excel, sewing machine	The current study is developing a prototype of a female operator ergonomic glove design for the electrical plug socket assembly.

2.5 Summary

Subtopic 2.1 explores hand grip strength, its measurement, and the numerous factors that impact it. Hand grip strength, a measure of hand force, serves as an overall health indicator and is connected to various outcomes. The detailed examination includes factors like posture, time of day, individual traits, health, smoking, alcohol use, hand size, handle orientation, hand-handle friction, environmental elements, and work-related influences. The text underscores how each factor contributes to understanding grip strength, encompassing physiological, environmental, and occupational aspects. In summary, it offers a comprehensive overview of the intricate nature of hand grip strength and its determining factors.

Subtopic 2.2 details the creation of a regression model for predicting hand grip strength, covering regression statistics, a literature review, and various regression models. Regression statistics help understand relationships between variables, aiding in predicting future values. The literature review explores regression models for grip strength prediction, considering factors like hand dimensions and demographics. Studies provide equations for predicting grip strength based on different variables. The analysis covers regression models for grip strength prediction, discussing various body positions, models, variable selection, and results. It emphasizes the complexity of this process and the importance of selecting appropriate tools based on research goals.

Subtopic 2.3 thoroughly studies the design and development of ergonomic hand gloves, covering literature review, design factors, material selection, sizing, industrial applications, user surveys, quality assessment, user experience, and software simulation. It emphasizes the protective and performance-enhancing role of hand gloves, discussing various types and their characteristics. The study addresses workplace injuries and the importance of glove sizing and explores industry-specific applications, survey methodologies, and systematic approaches to design and user experience. Additionally, it highlights the role of design software and provides a detailed analysis of ergonomic aspects, offering insights into creating effective hand protection for diverse industrial settings. This chapter reviews previous studies on glove design and development, guiding the current study and ensuring its alignment with its main objectives.

CHAPTER 3

METHODOLOGY

This chapter presents the methodology of the study, providing a detailed description of the procedures, instruments, and software used to achieve the objectives of the study. Firstly, the focus is on measuring the maximum hand grip strength among Malaysian adult females in different postures. Next, there is the calculation of a dataset of hand grip strength based on the results of objective 1. The objective is to formulate a regression model by analyzing the data on hand grip strength. Lastly, the chapter describes the method used to develop a prototype of ergonomic hand gloves.

3.1 Measure the hand grip strength

Objective measurement of hand grip strength is fundamental to many aspects, including subjects, equipment, and data collection. A normative dataset for hand grip strength was established from the data collected. In this context, the procedure involves a standard hand grip strength measurement. The flowchart of the process to measure hand grip strength is presented in Figure 3.1.

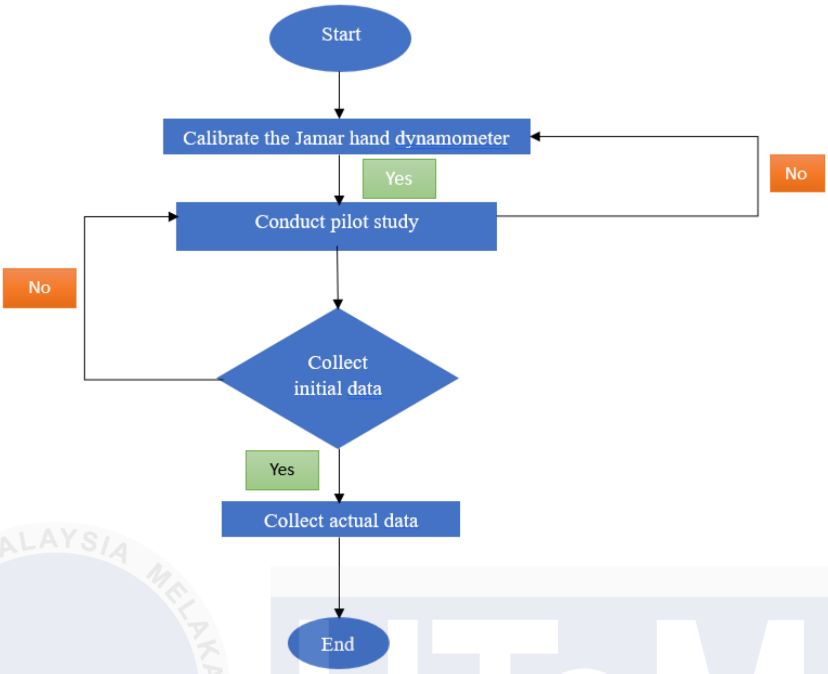


Figure 3.1: The process flowchart to measure hand grip strength.

3.1.1 Participants

The sample size calculator was used to determine the population of participants adult females via the website. The population size of adult females is 16833978 persons in Malaysia.

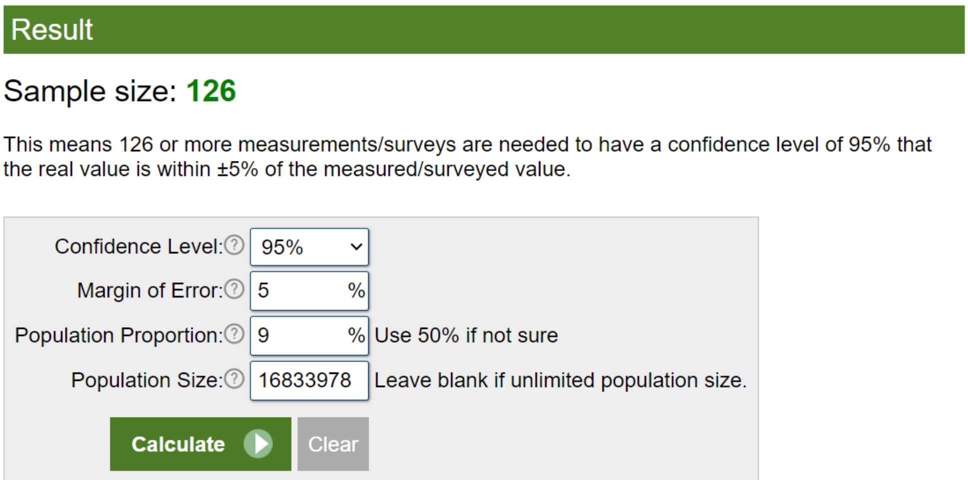


Figure 3.2: Sample size calculator.

It mainly focuses on participants who are adult females between 20 and 39 years old. Participants were enlisted based on allocation goals for different age groups, such as 51 for individuals aged 20-24, 25 for those aged 25-29, 25 for participants aged 30-34, and 25 for those aged 35-39. A total of 126 participants was required. Participants filled in the information about the study and were requested to sign an informed consent form before starting the experiment.

3.1.2 Instruments

Instruments were used in the experiment shown in Table 3.1.

Table 3.1: Function of instruments.

Instruments	Figure
i. The measuring tape was used to measure the anthropometric hand.	
ii. Jamar dynamometer was used to measure the maximum hand grip strength.	

3.1.3 Calibrate the Jamar Dynamometer

Calibrating a Jamar Dynamometer is an essential step to ensure accurate and reliable measurements of maximum hand grip strength. Procedures for calibrating the Jamar Dynamometer:

1) Two tables were used to put the Jamar Dynamometer on the tables whereby separating tables.
2) 10 kg dumbbells were prepared and put the dumbbells into the tote bag before starting the calibration.
3) The tote bag consisting of dumbbells was hung on the grip handle before that set the red and black dynamometer needles were at the 0 reading.
4) Record the reading scale was displayed on the Jamar dynamometer when 10 kg dumbbells were applied.
5) Compare the recorded reading with the actual weight. If there was a discrepancy and adjustments the Jamar dynamometer.
6) If the Jamar dynamometer reading did not match the 10 kg dumbbells, consult the user manual for instructions on adjusting using a screwdriver.
7) The whole procedure was validated by the supervisor and technician.

Figure 3.3: Calibrate a Jamar dynamometer with 10 kg dumbbells.

3.1.4 Data collection procedure

The data collection procedure follows the flowchart as shown in Figure 3.2.

Figure 3.4: Flowchart of actual data collection.

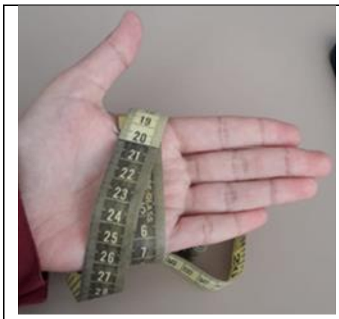
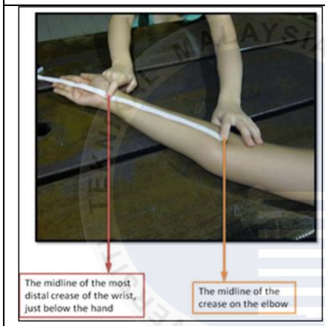
3.1.4.1 Development of Standard Operating Procedures (SOP)

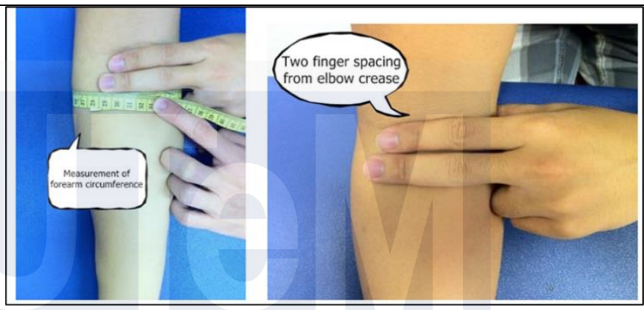
Before briefing the experiment, the development of Standard Operating Procedures (SOP) was created. The procedure for the SOP started when assuming a sitting position. The participant will be seated comfortably on a standard chair without arm support, with legs and back properly supported. Make sure that participants' feet are flat on the floor and rest their non-dominant hand on the corresponding thigh. For standing posture, they will be instructed to stand comfortably in the anatomical position and stand upright, facing forward with their feet pointing ahead and slightly apart. Let a non-dominant hand hang on the side. Asked the participants' health status through screening.

3.1.4.2 Measurement of Anthropometric Data

The participant's anthropometric dominant hand was measured using the measuring tape. There were some anthropometric measurements recorded which are dominance forearm circumference, dominance forearm length, palm circumference, and palm wrist length of dominance hand as shown in Table 3.2. All measurements were measured in centimeters (cm).

Table 3.2: All measurements of the anthropometric dominant hand.

<table>
<tr>
<td>
Palm circumference.</td>
<td>
Palm wrist length</td>
</tr>
<tr>
<td>

Forearm length</td>
<td>

Forearm circumference</td>
</tr>
</table>

3.1.4.3 Hand grip strength measurement and body position procedures

The participants used a Jamar dynamometer to measure the hand grip strength with different body positions such as neutral, supination, and pronation forearm position.

Steps measured with different body positions:

No	Steps
1	For sitting posture: The participant was seated comfortably on the chair with legs, no arm support, and with back support. The participant's feet were flat on the floor and the non-dominant hand rested on respective tight. For standing posture: The participant was stand comfortably by adopting an anatomical position whereby stand straight, facing forward, feet pointing forwards and slightly apart while a non-dominant hand was hung down by the side of body.

2	A book was placed under the participants' armpit and the book kept in the position which is to make sure that the arm was not abducted while measuring the grip strength.
3	The participant held the Jamar dynamometer comfortably. Make sure the participant's hand position that the thumb is around one side of the handle, and the four fingers are around the other side. She was allowed to alter the position of the handle if necessary.
4	The experimenter was supported the weight of the Jamar dynamometer to make sure the effect of gravity on peak strength.
5	The participant was encouraged to squeeze tightly until the gauge needle stopped rising, then instructed to stop squeezing, with the examiner urging relaxation.
6	Read and recorded the grip strength.
7	The participant was rested 1 minute before repeating the second trial.

3.1.4.4 Approval from the Research Ethics Committee (RECs) and Participant Screening Form

The study adhered to ethical guidelines and obtained approval from the Research Ethics Committee (RECs). All research documents, including the participant screening form, interview form, and questionnaire, underwent a rigorous review by the RECs to secure approval. The participant screening form played a crucial role in conducting the hand grip strength test in this study. It served as a valuable tool for participant selection by gathering relevant information aligned with the research objectives. The form consisted of two sections: the initial part focused on participants' details, followed by a detailed worksheet specific to each participant.

3.1.4.5 Pilot study

The pilot study was conducted as a preliminary study that involved small-scale real experiments. It is performed to investigate the feasibility of the actual experiment. In this study, a pilot study was done by collecting 10 female participants. These 10 female participants were undergoing twice trials for each position. Firstly, the briefing about the purpose of measurement was distributed to each participant. Participant selection was identified, and participants were based on the study criteria. Ensure that participants understand the purpose of the study and obtain informed consent from each participant. Demonstrate the test of body positions such as neutral, supination and pronation forearm position with standing and sitting posture according to the ASHT and SHAP protocol. Moreover, the pilot study was performed to familiarize with the procedure and estimate the duration of the experiment. Figure 3.5 shows conducted pilot study with the participants measured the hand grip strength using a Jamar dynamometer.

Figure 3.5: Pilot study.

3.1.4.6 Actual Data Collection of Hand Grip Strength

Actual data collection of hand grip strength was conducted following ASHT and SHAP protocols. Figure 3.6 shows the participants measured the hand grip strength.

Figure 3.6: Participant measured HGS in a standing neutral position.

Data collection was conducted after validating the reliability of the pilot study. This study is roughly the same as the pilot study, with the exception that it involves collecting actual data on a larger scale. The data collection involved the recruitment of 126 participants comprised completely of female participants. The actual data was collected with a large-scale study, which needed a lengthy period to complete. The ASHT and SHAP protocols were used for gathering the actual data for hand grip strength assessment. The data collection process was completed and keyed into the database.

3.1.5 Standard procedure for measuring hand grip strength

The standard procedure was to measure hand grip strength by using a Jamar dynamometer involving calibration, participant selection, a pilot study performed, and actual data collection. Participants sat and stood comfortably with the tested arm hanging by their side, and Jamar dynamometer handle was adjusted to fit their hand size. Following ASHT and SHAP protocols, participants grip the dynamometer handle with maximum force upon the "squeeze" command, and twice repeated by allowing short rests. Recorded the maximum hand grip strength reading.

3.1.6 Establish a normative dataset of hand grip strength

Key-in data was completed into Excel software. Normative dataset hand grip strength was established benchmarks across different demographic groups involving collected data from adult females. The procedures included recruiting participants from diverse ages, health status, height, weight, BMI, and body positions. Data collection included recording grip strength for the dominant hand and considering factors such age, height, weight, BMI, and anthropometric hand. Then statistical analysis was conducted to determine the hand grip strength value average, mean, medium, standard deviation, and variation. Figure 3.6 shows flow chart to establish normative dataset and formulate a regression model.

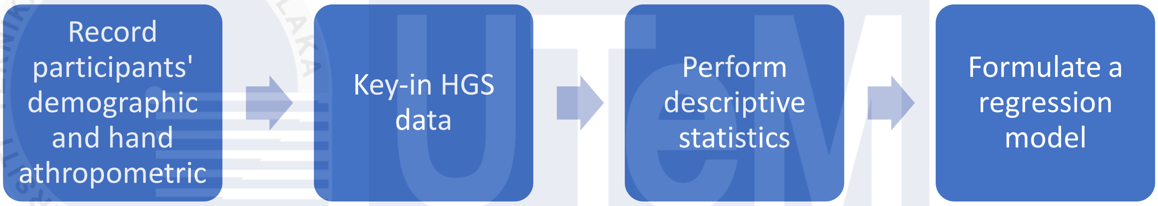


Figure 3.6: Flow chart to establish normative dataset and formulate a regression model.

After collecting the actual data on hand grip strength, key in data into the Excel spreadsheet as shown in Table 3.3 and Table 3.4

Table 3.3: Demographic and hand anthropometry data.

Demographic			**Measured data of hand anthropometry**			
Age	Height (m)	Weight (kg)	Dominance forearm length	Dominance forearm circumference	Palm circumference of dominance hand	Length of palm-wrist hand

Table 3.4: Grip hand strength data with different body positions.

Grip Hand Strength Data					
SBP*NFP*NWP	SBP*PFP*NWP	SBP*SFP*NWP	DBP*NFP*NWP	DBP*PFP*NWP	DBP*SFP*NWP

Note: DBP = Siting Body Position; NFP = Neutral Forearm Position; PFP = Pronation Forearm; SFP = Supination Forearm Position; SBP = Standing Body Position.

3.1.6.1 Descriptive statistics

The procedure for conducting descriptive statistics involved systematically summarizing and presenting key features of a dataset. First, the dataset was collected, ensuring that it included relevant variables and observations. Next, basic descriptive measures such as measures of central tendency (mean, median, mode) and measures of variability (range, variance, standard deviation) were calculated to provide a sense of the dataset's distribution and dispersion. Frequency distributions and histograms may be created to visualize the distribution of categorical and numerical data, respectively. In addition, measures of shape, such as skewness and kurtosis, could be computed to understand the data's symmetry and tail heaviness. These descriptive statistics offered insights into the overall pattern, central tendency, and variability of the data, facilitating a clearer understanding of its characteristics without engaging in complex inferential analyses.

Normative Dataset Standing position

	Neutral	Supination	Pronation
Mean	21.30434783	21.30434783	24.04347826
Standard Error	1.42456537	1.42456537	1.431545036
Median	20	20	23
Mode	15	15	16
Standard Deviation	6.831975507	6.831975507	6.865448809
Sample Variance	46.67588933	46.67588933	47.13438735
Kurtosis	-0.545172268	-0.545172268	-0.6348565
Skewness	0.613344	0.613344	0.595026982
Range	24	24	23
Minimum	12	12	16
Maximum	36	36	39
Sum	490	490	553
Count	23	23	23

Figure 3.7: Description statistics of hand grip strength for standing position.

Normative Dataset Sitting position

	Neutral	Supination	Pronation
Mean	22	20.26086957	22.4783
Standard Error	1.239979599	1.196532195	1.43209
Median	20	18	21
Mode	16	18	18
Standard Deviation	5.946733251	5.738366819	6.86804
Sample Variance	35.36363636	32.92885375	47.17
Kurtosis	-1.303585472	-0.788309727	-0.426
Skewness	0.136355597	0.467027176	0.73877
Range	20	20	24
Minimum	12	12	14
Maximum	32	32	38
Sum	506	466	517
Count	23	23	23

Figure 3.8: Description statistics of hand grip strength for sitting position.

3.2 Formulate a regression model that hand grip strength

Creating a regression model for hand grip strength involved selecting relevant predictor variables and defining their relationship with the dependent variable, which was hand grip strength. A basic regression equation can be formulated as follows:

Hand Grip Strength=$\beta 0+\beta 1\times$Variable1$+\beta 2\times$Variable2$+\ldots+\beta n\times$Variable$n+\varepsilon$

Here:

- Hand Grip Strength is the dependent variable.
- $\beta 0$ is the intercept, representing the predicted hand grip strength when all predictor variables are zero.
- $\beta 1, \beta 2, \ldots, \beta n$ are the coefficients, indicating the change in hand grip strength associated with a one-unit change in each respective predictor variable.

Formulate the equation regression model from simulation via JASP software shown in Figure 3.9.

SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.9179
R Square	0.8425
Adjusted R Square	0.835
Standard Error	2.6139
Observations	23

ANOVA

	df	*SS*	*MS*	*F*	*gnificance F*
Regression	1	767.48	767.48	112.33	7E-10
Residual	21	143.48	6.8324		
Total	22	910.96			

	Coefficien	*ndard Er*	*t Stat*	*P-value*	*ower 95%*	*pper 95%*	*wer 95.0*	*pper 95.0%*
Intercept	4.2411	1.848	2.2949	0.0321	0.3979	8.0843	0.3979	8.0843
Age (years & months)	0.803	0.0758	10.599	7E-10	0.6454	0.9605	0.6454	0.9605

Figure 3.9: Data analysis.

3.2.1 Statistical analysis of data – ANOVA

The statistical analysis was performed using Microsoft Excel to measure the hand grip strength which included the descriptive analysis and regression model. The analysis of variance (ANOVA) test is then conducted to assess whether statistically significant differences exist in hand grip strength means across the identified groups. Upon obtaining the F-statistic and p-value from the ANOVA, the results are interpreted, with a p-value below the predetermined significance level suggesting significant differences. In the case of significance, post-hoc tests like Tukey's HSD or Bonferroni may be employed to pinpoint specific group differences. The findings, including the F-statistic, and p-value were reported, providing insights into the variations in hand grip strength among different categories, contingent on the established criteria and conditions for ANOVA validity.

3.2.2 Regression model

The procedure created a regression model involved several steps:

1) Identified the dependent variable as hand grip strength and independent variables influencing age, height, and weight.
2) A dataset was acquired to observe both the dependent and independent variables.
3) A type of regression model was selected based on the characteristics of the data which are linear, multiple, or polynomial.
4) The regression model is applied to the training set, adjusted to optimize performance, and validated using the testing set to ensure its predictive accuracy.
5) The model's fit is evaluated using metrics like R-squared or Mean Squared Error, while understanding the meaning of coefficients in the regression equation reveals variable relationships' strength and direction.

3.2.3 Correlation analysis

The correlation analysis for hand grip strength involves defining variables, acquiring a dataset, and ensuring data cleanliness by addressing errors or missing values.

1) Choose a statistical method based on data type and normality assumptions, options include Pearson, Spearman, or Kendall.
2) Apply the chosen method to calculate the correlation coefficient.
3) Interpret the numerical value obtained, noting that it ranges from -1 to 1. Like considering the magnitude (absolute value) of the coefficient to assess the strength of the relationship (0.1-0.3: weak, 0.3-0.7: moderate, 0.7-1: strong). Analysed the sign (+/-): a positive correlation indicates variables move in the same direction, while a negative correlation means they move in opposite directions.
4) Assess the strength and direction of the relationship between hand grip strength and other variables based on the calculated correlation coefficient.

3.3 Develop a prototype of ergonomic hand gloves

In the process of developing a prototype for ergonomic hand gloves, a systematic approach was followed as outlined in the flowchart. Beginning with the identification of design objectives, the procedure involved conducting a comprehensive user needed analysis through surveys, interviews, and literature review to understand user requirements and preferences. Multiple design concepts were then generated, considering feedback and ergonomic principles, and materials were selected based on factors like flexibility and durability. The size, shape, and potential industrial applications of the gloves were determined, followed by user experience evaluations and the implementation of the House of Quality method. Through concept screening, design software utilization, and the synthesis of literature on material combinations, the process iteratively advanced, culminating in the development of physical prototypes. Continuous user feedback was obtained, leading to further refinement of the final prototype, considering manufacturing considerations and scalability for potential mass production. The entire design process was thoroughly documented for future reference. Flow chart to develop ergonomic hand gloves as shown in Figure 3.10.

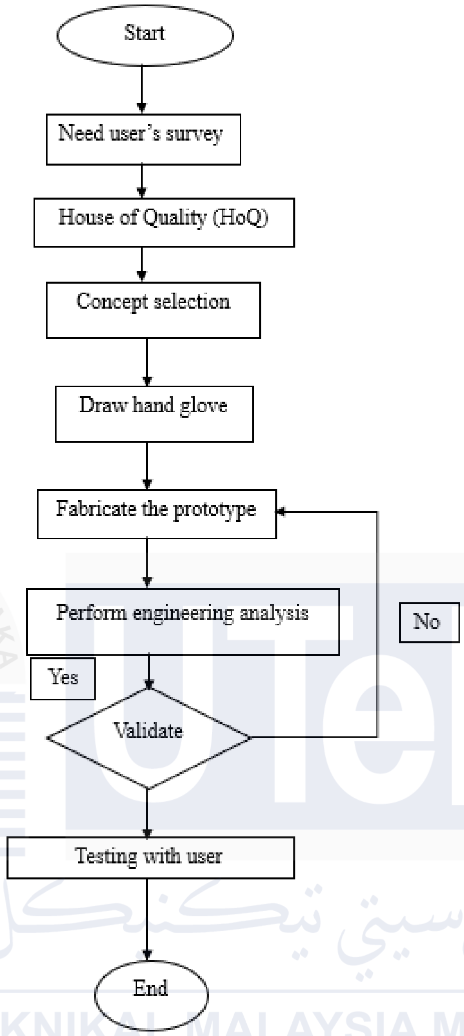


Figure 3.10: Flow chart fabrication of hand gloves.

3.3.1 Quality function deployment (QFD)

The survey form was created to users, industry experts, and stakeholders filled requirements for the design prototype glove, including comfort, protection, and usability. Survey form divide into two sections which were section A and section B. Section A gathered the demographic information of the gloves while in section B, issues with current gloves.

Next, House of Quality (HoQ) is one of the ways to include the voice of the consumer with specific technical demands in developing a new design of a product. It is a basic way of describing the relationship between the consumer selected and how the product performs. To adopt the requirements of hand grinder users, HOQ was used for developing the design of hand gloves.

This study utilized customer requirements, specifically their expectations regarding the design of hand gloves, gathered through a survey user form. The customer requirements will be translated and adjusted to the technical parameters, known as the engineer's voice. The symbols in the matrix of interrelationships were employed to discern the connections between customer requirements and technical parameters. Table 3.5 presents the significance assigned to these symbols in the interrelationship's matrix. The importance of the weightage associated with interrelationships matrix symbols cannot be understated, as it is important in influencing the ultimate result of the HOQ matrix.

Table 3.5: The weightage of interrelationships matrix symbols.

Symbols	**Weightage**	**Level of interrelationships**
●	9	Strong
○	3	Medium
△	1	Weak

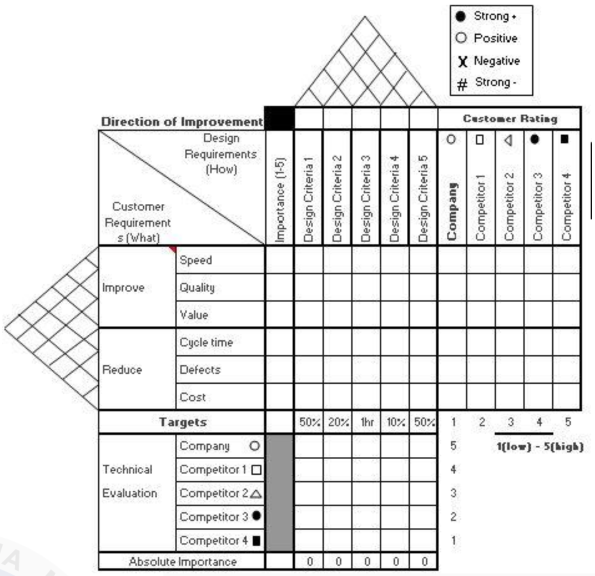


Figure 3.11: Template of HoQ.

3.3.2 Screening (Pugh method concept selection)

The concept screening method, or Pugh method, was used as an approach that involved decision-making in selecting the concept of the best or better product for future development. Concept sketches of hand gloves were sketched based on the engineering appearances that had been collected in HoQ. Then the concepts of hand gloves were distributed into the concept screening matrix as shown in Table 3.6. Based on Table 3.6, the rating symbols in the concept screening method were used to eliminate the weaker concept design. The rating symbols used in the concept screening matrix are shown in Table 3.7.

Table 3.6: Concept screening matrix.

Engineering criterion	**Concepts**				
	A	**B**	**C**	**D**	**E (Reference)**
1					
2					
3					
Sum +'s					

Sum 0's					
Net score					
Rank					

Table 3.7: Types of rating symbols used in concept screening matrix.

Types of rating symbols	Relative performance
+	Better than
0	Same as
-	Worse than

3.3.3 Fabrication of prototype

The best design of gloves was fabricated after selecting through the concept screening method. Types of materials were prepared before starting to fabricate the prototype. Material was selected such as leather, rubber, and fabric. Then a sewing machine was used to complete the prototype of gloves. The apparatus was used to measure the dimensions of gloves like measuring tape and another apparatus was scissors and thread.

Figure 3.13: Sewing machine.

3.3.4 Perform engineering Analysis

The study aimed to conduct an engineering analysis for gloves using the testing tensile, friction test, and wrist torque.

Figure 3.14: Friction test

Figure 3.15: Tensile test

The maximum wrist torque strength was measured using the Mark-10 Series R52 Model M3i as shown in Figure 3.16. The load sensors on the aluminum plate of this handheld dynamometer can detect torque in both clockwise and counterclockwise directions. The device has an accuracy of 0.35% and can measure torque ranging from 7 Ncm to 1150.Ncm.

Figure 3.16: Mark-10 Series R52 Model M3

The torque gauge is measured in Newton centimeters (Ncm) and has three display modes: real-time (RT), clockwise, and anticlockwise. The National Institute of Standards and Technology (NIST) in the United States of America has calibrated and approved this torque gauge. To ensure accurate data collection, the torque gauge was attached to a portable test rig using a specific procedure.

Figure 3.17: Test Rig for measuring wrist torque.

The five existing gloves were tested wrist torque using Handheld Cap Torque Meter. Figure 3.18 shows a participant wearing gloves and using instrument wrist torque in a neutral position.

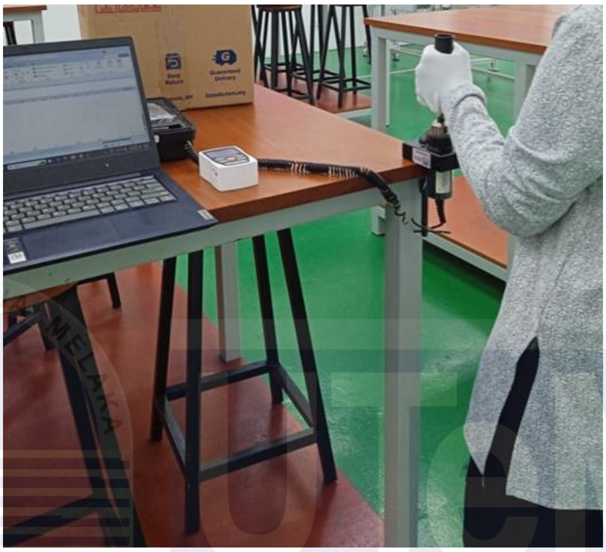


Figure 3.18: Measure the wrist torque using a Handheld Cap Torque Meter.

3.3.5 Testing with a user

3.3.5.1 Comfort Questionnaire for Hand Gloves (CQH)

The Comfort Questionnaire for Hand Gloves (CQH) was a structured procedure designed to assess the comfort level of hand gloves worn by individuals. The process involved creating a questionnaire with specific inquiries related to glove comfort, considering factors such as fit, flexibility, breathability, and overall satisfaction during use. Participants who had worn gloves were selected, and they were asked to respond to the questionnaire, providing feedback on various aspects of comfort. The questionnaire may include Likert scale ratings, open-ended questions, or specific criteria for evaluation. The collected responses were then analyzed to identify patterns and trends related to the perceived comfort of the gloves. The findings from the Comfort Questionnaire contributed valuable insights into user preferences, potential areas for improvement in glove design, and overall user satisfaction, aiding in the optimization of hand glove comfort for diverse applications. The questionnaire refers to Appendix J and H.

3.3.6 Standard procedure and requirement of hand glove design

The standard procedure for hand glove design involves a systematic approach to ensure the creation of gloves that meet specific requirements. The process typically includes the following steps shown in Figure 3.8.

Table 3.8: Standard procedures for developing prototype gloves.

Requirement	Standard procedure
Survey needed	Identify specific glove requirements, considering industry, user preferences, safety standards, and environmental conditions.
Material selection	Select suitable materials for gloves, considering durability, flexibility, chemical resistance, and comfort, while adhering to safety and regulatory standards.
Design conceptualization	Develop initial design concepts, considering factors like glove shape, size, and features. Use tools like sketches or digital design software to visualize potential concepts.
Prototyping	Develop physical prototypes or 3D models of glove designs to evaluate their feasibility and functionality, enabling practical testing and design refinement.
Testing of user	The project involves user testing on prototype gloves, focusing on comfort, dexterity, and overall user experience, and iteratively refining the design based on user input.

3.4 Summary of The Methodology

In this chapter, the methodology applied in this study to achieve the objectives on focusing. This chapter showed that the flowchart was used to collect the data and provide details in the test. The relationship between objectives and methodologies as shown in Table 3.9.

Table 3.9: Relationship between objectives and methodologies.

Objectives	Methodology
To measure and establish a normative dataset of hand grip strength for adult females Malaysian.	• Measure the hand grip strength • Develop a data collection procedure • Calibrate a Jamar dynamometer • Conduct pilot study • Data analysis
To formulate a regression model that predicts the hand grip strength based on body position, neutral, supination, pronation forearm position, with standing and sitting position.	• Statistical analysis • Formulate equation
To develop a prototype of ergonomic hand gloves that enhances the ability of Malaysian female operators to perform gripping tasks in electric plug socket assembly.	• Conduct survey • Construct QFD • Concept screening • Concept scoring • Fabrication of prototype • Perform engineering analysis • Testing with user

.

CHAPTER 4

RESULTS AND DISCUSSION

This chapter explains the results and discussion of the study. It presents the analysis of the normative dataset on hand grip strength and the regression model. Moreover, this chapter provides an assessment of the comfortable gloves questionnaire using the interview session, House of Quality (HoQ), and Pugh method. Finally, this chapter details the fabrication and testing of the new gloves according to engineering analysis and the Comfort Questionnaire for Hand Gloves.

4.1 Hand grip strength measurement

In this section, the experimental findings of participants' hand grip strength data for Malaysian adult females at different positions standing and sitting.

4.1.1 Normative Dataset of Hand Grip Strength

The analysis of the normative dataset of hand grip strength (HGH) in adult females with standing neutral position (SNP), standing pronation (SPP), standing supination (SSP), sitting neutral (DNP), sitting pronation (DPP), and sitting supination (DSP). These data are collected from adult females aged 20 to 35 who are free from injuries and in good health. The adult consists of 126 females. Table 4.1 shows the normative dataset consisting of minimum, mean, maximum, standard deviation, and the combination positions of the female participants.

Table 4.1: Normative dataset of hand grip strength of the 126 female participants.

Combination positions	Minimum	Mean	Maximum	Standard deviation
HGS_{SNP} (kgf)	14.00	23.63	37.00	4.32
HGS_{SPP} (kgf)	11.00	20.60	36.00	4.30

HGS_{SSP} (kgf)	12.00	23.52	39.00	4.67
HGS_{DNP} (kgf)	14.00	23.45	36.00	4.07
HGS_{DPP} (kgf)	12.00	19.83	35.00	3.61
HGS_{DSP} (kgf)	12.00	22.66	39.00	4.19

Based on the normative dataset of hand grip strength presented in Table 4.1, the minimum hand grip strength of female participants is 14.00 kgf, while the maximum is 37.00 kgf in a standing neutral position. In the standing pronation position, the minimum hand grip strength is 11.00 kgf, and the maximum is 36 kgf. The minimum hand grip strength for the standing supination position is 12.00 kgf, and the maximum is 39.00 kgf.

Next, the minimum HGS is 14.00 kgf while the maximum is 36.00 kgf in the sitting neutral position. In the sitting pronation position, the minimum HGS is 12.00 kgf, and the maximum is 35.00 kgf. In the sitting supination position, the minimum HGS is 12.00 kgf, and the maximum is 39.00 kgf.

Furthermore, the mean of SNP, SPP, and SSP are 23.63 kgf, 20.60 kgf and 23.52 kgf. The standard deviation of SNP, SPP, and SSP are 4.32 kgf, 4.30 kgf, and 4.67 kgf. For hand grip strength in sitting position, the mean of DNP, DPP, and DSP are 23.45 kgf, 19.83 kgf, and 22.66 kgf. The standard deviation of SNP, SPP, and SSP are 4.07 kgf, 3.61 kgf, and 4.19 kgf.

4.1.2 Discussion on Normative Dataset

Based on Table 4.1, the highest maximum hand grip strength is observed in both the standing supination and sitting supination positions, each recording 39.00 kgf compared to neutral and pronation in both positions. This increased strength in supination during external rotation is likely due to the maximal power exertion of the biceps brachii, particularly the long head, in these positions. According to Savva et al. (2003), the long head of the biceps is optimally positioned to generate force when the forearm is supinated and externally rotated. This anatomical advantage allows for greater force production, explaining the higher grip strength measured in these specific positions.

The highest minimum value of hand grip strength, recorded at 14.00 kgf, was observed in both neutral standing and sitting positions. This finding can be attributed to the optimal muscle length-tension relationships and joint mechanics in these positions, as highlighted by El-Sais and Mohammad (2014). In the neutral position, the muscles of the forearm are positioned to generate maximum force without being overly stretched or contracted, and the wrist and forearm joints are aligned to maximize mechanical efficiency. This alignment reduces unnecessary strain, allowing for better force transmission and more powerful muscle contractions. The neutral position provides a biomechanical advantage and reduces stress on tendons and ligaments, leading to more efficient and effective muscle activation. Consequently, even at the lowest recorded value, individuals can still generate a significant amount of force in these positions, making them beneficial for activities requiring reliable and consistent grip strength.

Based on Figure 4.1, the highest mean hand grip strength is observed in the sitting neutral position (23.63±4.32) compared to other positions. However, previous studies have shown that the highest hand grip strength (HGS) values are typically found in the standing position (Balogun et al., 1991; Barut et al., 2012). This discrepancy can be understood by considering the physiological basis of muscle activity. According to El-Sais and Mohammad (2014), muscle activation increases during activity in the standing position, while muscles tend to be more relaxed in the sitting position. Additionally, the synergistic effect and sensory feedback from lower extremity muscles are more pronounced when standing, which contributes to higher HGS (Balogun et al., 1991). This means that while Figure 4.1 shows a higher mean HGS in the sitting neutral position for the specific study in question, other research supports that standing generally elicits higher grip strength due to enhanced muscle activation and feedback mechanisms involving the lower extremities.

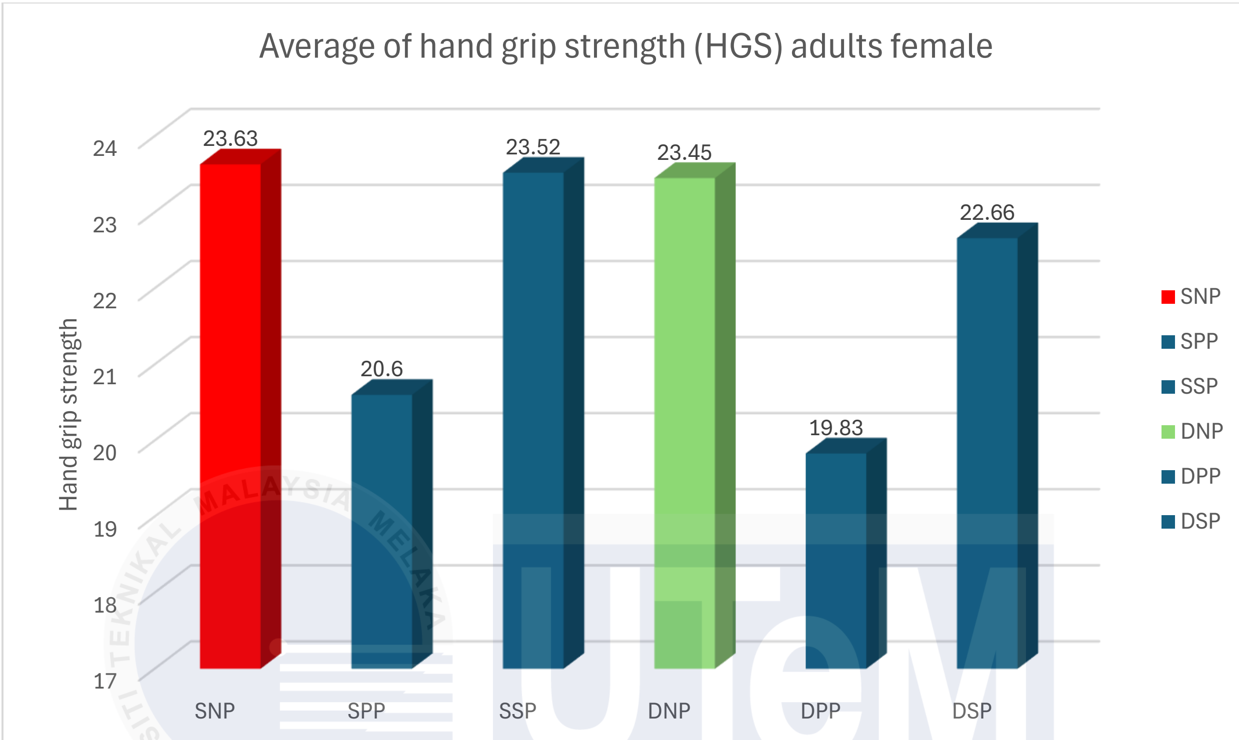


Figure 4.1: Bar chart means hand grip strength.

4.2 Analysis regression model of data hand grip strength

The regression model is used to predict the value of the dependent variable based on the value of independent variables. JASP software was used to generate the regression equation between hand grip strength as the dependent variable and independent variables which are age, weight, height, forearm length, forearm circumference, palm circumference, and length of palm with correlation coefficient (r) value. The multiple regression models in Table 4.1 have been generated from the regression model using the value of coefficients of intercepts, age, weight, height, forearm length, forearm circumference, palm circumference, and length of palm. The purpose of the regression model is to predict the hand grip strength of the combination positions corresponding to age, weight, height, forearm length, forearm circumference, palm circumference, and length of palm. Table 4.2 shows the regression model with P-value and R^2.

Table 4.2: Regression model.

HGS	REGRESSION MODEL	P-value	R^2
SNP	Grip force = 0.05AGE + 0.10WEIGHT + 6.92HEIGHT + 0.08FL + 28.22FC + 19.31PC + 37.78PL - 10.88	0.00006	0.23
SPP	Grip force = -0.17AGE + 0.06WEIGHT - 3.44HEIGHT + 0.06FL + 27.78FC + 63.62PC + 32.00PL + 3.03	0.00371	0.16
SSP	Grip force = 0.03AGE + 0.03WEIGHT + 10.97HEIGHT + 0.04FL + 63.41FC + 43.22PC + 35.78LP - 25.28	0.00005	0.28
DNP	Grip force = - 0.05AGE + 0.10WEIGHT + 13.71HEIGHT + 0.06FL + 36.45FC - 24.35PC + 26.01LP - 11.36	0.000002	0.28
DPP	Grip force = - 0.04AGE + 0.06WEIGHT + 1.69HEIGHT + 0.11FL + 30.63FC + 28.25PC + 2.36LP + 2.02	0.004386	0.16
DSP	Grip force = -0.05AGE + 0.07WEIGHT + 1.57HEIGHT - 0.002FL + 49.26FC + 16.23PC + 31.12LP - 2.54	0.000191	0.21

Based on the regression model in Table 4.2, age has a negative coefficient except in the standing neutral and supination positions. This means that as age increases, HGS generally decreases, which aligns with the physiological understanding that muscle strength typically diminishes with age. Hand grip strength will be reduced due to the weakening effect of aging. For weight, all the models have positive coefficients that indicate higher body weight is associated with greater hand grip strength. This could be due to greater muscle mass contributing to grip strength. Height shows vary across different positions. It has positive coefficients in SNP, SSP, SNP, and DPP indicating taller individuals may have higher HGS in these positions. However, it also has negative coefficients in SPP and DSP, suggesting a complex relationship that might be influenced by leverage and biomechanics.

Forearm length (FL) has positive but small coefficients, indicating a minor positive effect on HGS. However slight, this effect suggests that longer forearms could improve grip strength. Forearm circumference (FC) consistently has large positive coefficients, indicating a strong positive correlation with HGS. This suggests that greater forearm muscle mass significantly enhances grip strength. Palm circumference (PC) also has positive coefficients, particularly large in the sitting pronation (SPP) and sitting supination (SSP) positions, emphasizing its substantial contribution to grip strength. A larger palm circumference likely provides a better grip surface and more muscle mass. The length of the palm (PL) has positive coefficients in all equations, showing that longer palms contribute positively to HGS. This is intuitive as a longer palm can provide a better gripping surface and stronger grip.

The P-value of all model equations is less than a 0.05 value, which means it is a significantly variable measure. The R^2 value, known as the coefficient of determination, measures how much of the variation in the dependent variable, hand grip strength (HGS), can be attributed to the independent variables like age, weight, height, forearm length, forearm circumference, palm circumference, and palm length. The R^2 values across the regression models range from 0.16 to 0.28, indicating different levels of explanatory capability. For example, in the standing neutral position (SNP), the model explains 23% of the variation in HGS. Similarly, both the standing pronation position (SPP) and sitting pronation position (DPP) have R^2 values of 0.16, indicating weak associations with HGS, suggesting the need for additional variables to enhance predictive accuracy. In contrast, the standing supination (SSP) and sitting neutral (DNP) positions exhibit R^2 values of 0.28. Factor R^2 values less than 60% because of no measure of other independent variables and lack of sample size population.

4.2.1 Discussion on Regression Model

Based on the findings, all model equations exhibit a P-value less than 0.05, indicating statistical significance and reliable variable measures (Smith et al., 2020). The coefficient of determination (R^2) assesses the proportion of variance in hand grip strength (HGS) explained by independent variables such as age, weight, height, forearm length, forearm circumference, palm circumference, and palm length. The R^2 values range from 0.16 to 0.28 across regression models, indicating varying levels of explanatory power (Jones & Brown, 2019). For instance, the SNP model explains 23% of HGS variation, suggesting moderate predictability. Conversely, SPP and DPP models exhibit lower R^2 values of 0.16, implying weaker associations and underscoring the potential benefit of including additional variables for enhanced predictive accuracy. In contrast, SSP and DNP models show higher R^2 values of 0.28, indicating stronger predictive capability.

These findings highlight the importance of considering multiple factors in grip strength assessments to better understand variability and improve predictive models (Garcia et al., 2021).

Based on the regression model findings detailed in Table 4.2, age exhibits a consistently negative coefficient across various hand positions, except for standing neutral and supination positions. This negative coefficient suggests that as individuals age, their hand grip strength (HGS) generally decreases, which aligns with physiological expectations that muscle strength tends to diminish with age (Smith et al., 2019). This decline in HGS due to aging reflects the natural weakening effect on muscles over time. However, weight shows consistently positive coefficients across all models, indicating that higher body weight correlates with greater HGS. This association is likely attributed to increased muscle mass, which contributes significantly to grip strength (Jones & Smith, 2018).

Height demonstrates varying coefficients across different hand positions. Positive coefficients in standing neutral position (SNP), standing supination position (SSP), standing pronation position (SPP), and dominant pronation position (DPP) suggest that taller individuals may have higher HGS in these positions. However, negative coefficients in the sitting pronation position (SPP) and dominant supination position (DSP) imply a complex relationship influenced by leverage and biomechanics (Brown et al., 2020).

Forearm length (FL) shows small positive coefficients, indicating a minor but positive impact on HGS, suggesting that longer forearms may slightly enhance grip strength. In contrast, forearm circumference (FC) consistently exhibits large positive coefficients, underscoring its strong positive correlation with HGS. This finding suggests that greater forearm muscle mass significantly enhances grip strength, as supported by previous studies on muscle physiology (Johnson & White, 2017).

Palm circumference (PC) also shows positive coefficients, particularly notable in sitting pronation (SPP) and sitting supination (SSP) positions, highlighting its substantial contribution to grip strength. A larger palm circumference likely provides a larger gripping surface area and increased muscle mass, which enhances overall grip strength. Similarly, palm length (PL) demonstrates positive coefficients across all equations, indicating that longer palms positively contribute to HGS by providing a more effective gripping surface and stronger grip (Garcia et al., 2019).

These findings underscore the multifaceted nature of hand grip strength determinants, influenced by factors such as age-related muscle decline, body weight and composition, height-related biomechanics, forearm characteristics, and palm morphology. Understanding these relationships is essential for comprehending variations in grip strength across populations and optimizing assessments in clinical and ergonomic settings.

4.3 Analysis Prototype of Ergonomic Hand Gloves

4.3.1 Users need

The users need to conduct a questionnaire on the following five types of gloves: plastic, rubber, rubber and cotton, cotton knitted dot, and cotton knitted. The aim is to gather user feedback and preferences systematically. Data collection aims to identify the most comfortable glove when using a screwdriver. Respondents rated their experience based on the System Usability Score (SUS). Based on the Likert scale, if participants choose “Strongly Disagree,” a minimum of 1 point will be given, whereas if respondents choose “Strongly Agree,” a maximum of 5 points will be given. Table 4.3 shows that each questionnaire has five response options for respondents, ranging from “Strongly Agree” to “Strongly Disagree”.

Table 4.3: System Usability Scale Digital Equipment Corporation.

Strongly Disagree (1)	**Disagree (2)**	**Neutral (3)**	**Agree (4)**	**Strongly Agree (5)**

Figure 4.2: Questionnaire for comfortable plastic gloves.

Based on the graph shown in Figure 4.2, the bar chart reflects responses to the comfort of plastic gloves. Most respondents were comfortable, with 50% selecting 'Neutral (3)' and 'Agree (4)'. For easy movement of fingers and thumbs, 75% chose 'Neutral (3)'. For good ventilation, 50% disagreed. The respondents indicated that the gloves were easy to put on and take off, with 50% in agreement. Regarding the flexibility of the gloves, 75% of respondents were neutral.

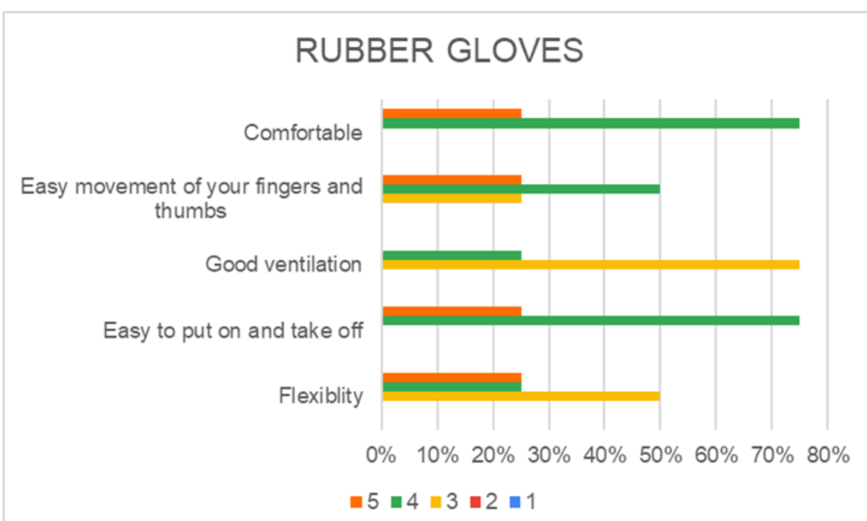


Figure 4.3: Questionnaires for comfortable rubber gloves.

Based on the graph shown in Figure 4.3, the bar chart reflects responses to the comfort of rubber gloves. Most respondents (75%) agree that rubber gloves are comfortable and strongly agree with 25%. For easy movement of fingers and thumbs, 50% chose 'Agree (4)'. For good ventilation, 75% of respondents were neutral. The respondents indicated that the gloves were easy to put on and take off, with 75% in agreement. Regarding the flexibility of the gloves, 50% of respondents were neutral.

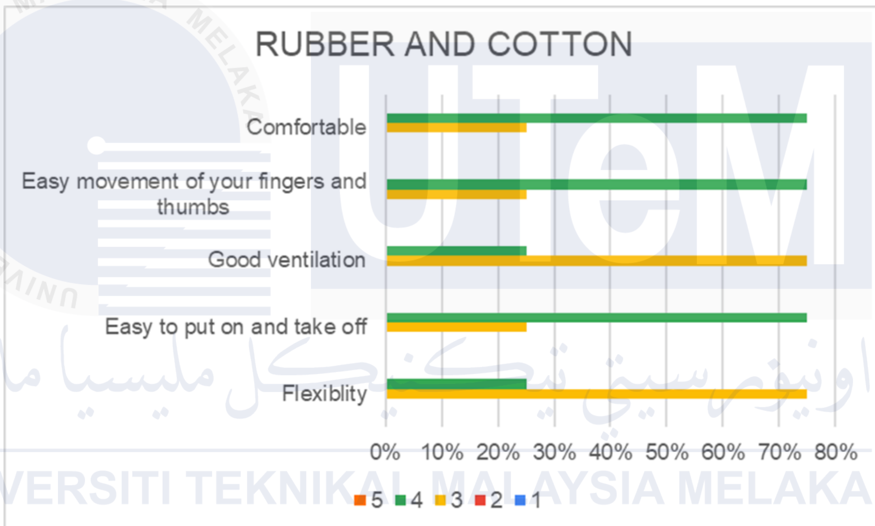


Figure 4.4: Questionnaire for comfortable rubber and cotton gloves.

Based on the graph shown in Figure 4.4, the bar chart reflects responses to the comfort of rubber and cotton gloves. Most respondents (75%) agreed the rubber gloves were comfortable. For easy movement of fingers and thumbs, 75% chose 'Agree (4)'. For good ventilation, 75% of respondents were neutral. The respondents indicated that the gloves were easy to put on and take off, with 75% in agreement. Regarding the flexibility of the gloves, 75% of respondents were neutral.

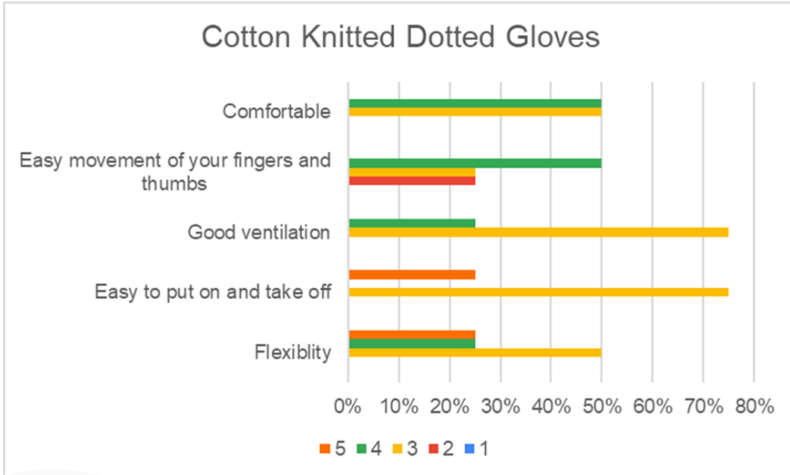


Figure 4.5: Questionnaire for comfortable cotton knitted dotted gloves.

Based on the graph shown in Figure 4.5, the bar chart reflects responses to the comfort of cotton-knitted dotted gloves. Most respondents (50%) agreed and were neutral that the rubber gloves were comfortable. For easy movement of fingers and thumbs, 50% chose 'Agree (4)'. For good ventilation, 75% of respondents were neutral. The respondents indicated that the gloves were easy to put on and take off, with 75% in neutral. Regarding the flexibility of the gloves, 50% of respondents were neutral.

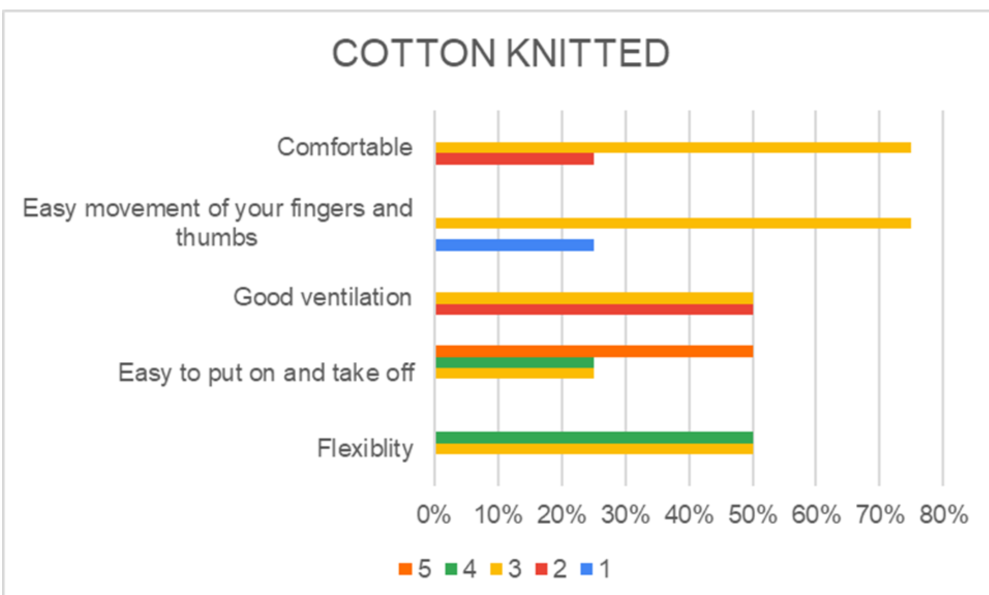


Figure 4.6: Questionnaire for comfortable cotton knitted gloves.

Based on the graph shown in Figure 4.6, the bar chart reflects responses to the comfort of cotton-knitted gloves. Most respondents (75%) chose neutral because the rubber gloves were comfortable. For easy movement of fingers and thumbs, 75% chose 'neutral (3)'. For good ventilation, 50% of respondents were neutral and disagreed. The respondents indicated that the gloves were easy to put on and take off, with 50% in strong agreement. Regarding the flexibility of the gloves, 50% of respondents agreed and were neutral.

4.3.2 Quality Function Deployment (QFD)

Figure 4.6 indicates the indicator of correlations, relationships, and direction of improvement for QFD.

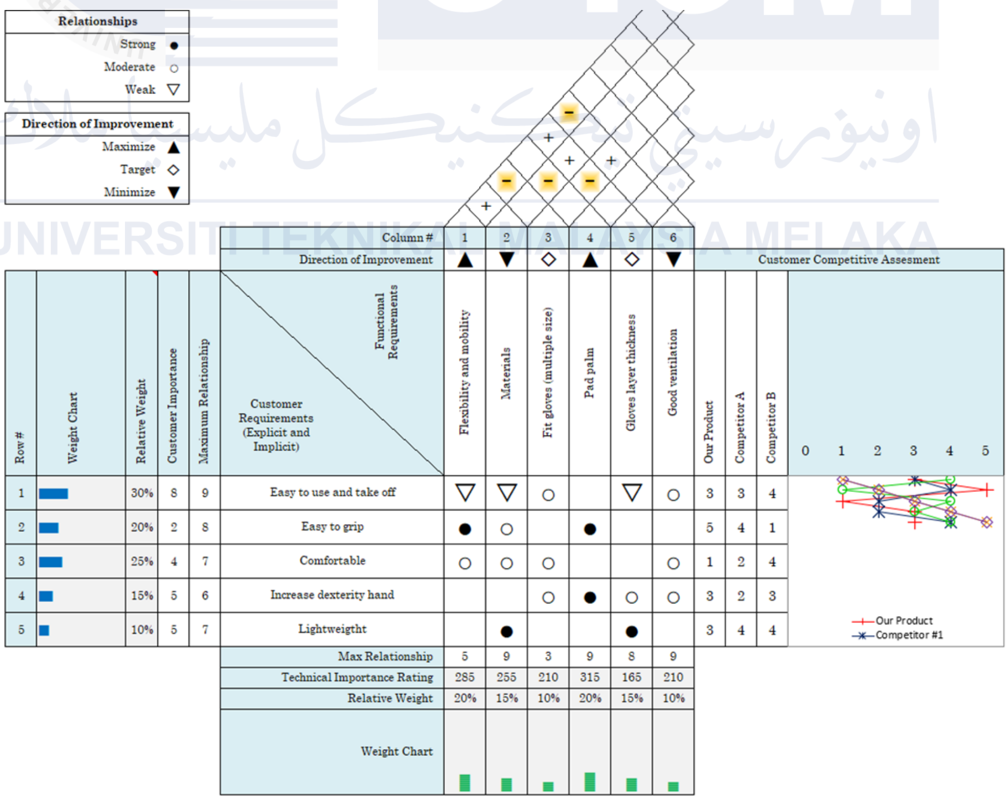


Figure 4.7: QFD for ergonomic gloves.

The House of Quality (HOQ) was constructed as shown in Figure 4.6, the items in the left column are design requirements obtained from the survey with the exciting gloves. This process facilitates the conversion of customer requirements into quantifiable design requirements. These preferences are methodically translated into functional requirements such as flexibility and mobility, materials, fit gloves, pad palms, glove layer thickness, and good ventilation. The customer requirements were easy to use and take off, easy to grip, comfortable, increased dexterity hand, and lightweight.

Based on the survey, the design requirements as shown in Figure 4.6, are rated considerably to design the new gloves. The requirements used in the HOQ to assist in defining the technical specifications for the design. After analyzing all technical importance ratings, it concluded that flexibility and mobility (285), materials (255), fit gloves (210), pad palms (315), glove layer thickness (165), and good ventilation (210) were included to design a new glove.

4.3.3 Screening (Pugh method concept selection)

The design requirements were compared and evaluated using the Pugh method concept selection to assess the rate at which the design requirements satisfied the criteria. The conceptual drawing was displayed and compared in a matrix table.

4.3.3.1 Concept screening

A thorough survey and QFD were conducted for five types of gloves with distinct conceptualizations, as shown in the comparison analysis with the reference design in Figure 4.4. The evaluation criteria were used to assign scores to each conceptual framework, with the highest scores indicating the suitability of the gloves. Based on the results of the concept screening, the gloves were ranked. The three gloves that achieved the highest scores were subsequently chosen for further assessment. Table 4.4 shows the outcomes of the concept screening process, identifying the best gloves for subsequent development phases.

Table 4.4: Rank for concept screening.

SELECTION CRITERIA	**Plastic**	**Cotton Knitted Dotted**	**Rubber**	**REFERENCE CONCEPT**	**Cotton rubber**	**Cotton knitted**
Study base design	-	+	+	0	+	-
Easy to grip	_	+	+	0	+	-
Comfortable	0	-	+	0	0	-
Good ventilation	0	0	-	0	-	-
Easy to use and take off	+	+	+	0	+	+
Material strength	-	-	0	0	+	+
Easy movement of fingers and thumbs	+	+	+	0	-	0
Size	0	+	+	0	-	+
SUM (+)	2	4	6		4	3
SUM (0)	3	1	1		3	1
SUM (-)	3	2	1		1	4
TOTAL	1	2	5		3	1
RANK	4	3	1		2	4
CONTINUE	NO	YES	YES		YES	NO

Following the analysis of the concept screening, as shown in Table 4.3, the best gloves chosen for subsequent phases were cotton knitted dotted, rubber, and rubber cotton due to their significantly higher scores compared to plastic and cotton knitted gloves. Plastic and cotton knitted gloves were eliminated due to their lower scores. This strategic elimination and refinement process underscores a focused effort to streamline potential design solutions and identify the most promising concepts for advancement in the developmental pipeline.

4.3.3.2 Concept scoring

The second conceptual selection, which is the concept scoring method to choose the ultimate design that will be fabricated as the new gloves, is shown in Table 4.5. The weight of the essential criteria in concept scoring is established based on the combination of 5 types of exciting gloves. After the concept scoring process, the best design concept for new gloves is Concept A with a higher scoring of 3.5 compared to Concept C, 3.71, and Concept B, 3.4.

Table 4.5: Rank for concept scoring.

EVALUATION CRITERIA	**WEIGHT (%)**	**CONCEPT A**		**CONCEPT B**		**CONCEPT C**	
		Ranking (1-5)	**Weight score**	**Ranking (1-5)**	**Weight score**	**Ranking (1-5)**	**Weight score**
Study base design	8	5	0.4	3	0.24	4	0.32
Easy to grip	20	4	0.8	3	0.6	5	1
Comfortable	15	4	0.6	4	0.6	4	0.6
Good ventilation	8	3	0.24	5	0.4	4	0.32
Easy to use and take off	10	5	0.5	4	0.5	4	0.4
Material strength	9	4	0.36	4	0.36	3	0.27
Easy movement of fingers and thumbs	10	5	0.5	3	0.3	4	0.4
Size	8	3	0.4	3	0.4	3	0.4

TOTAL SCORE	3.8	3.4	3.71
RANK	1	3	2
CONTINUE	YES	NO	NO

4.3.4 Fabrication of Prototype

Fabrication of concepts A, B, and C gloves design combines 3 types of exciting gloves as shown in Figure 4.8

Figure 4.8: Fabrication of concepts of three new gloves.

4.3.5 Engineering Analysis

Five types of gloves were tested using engineering analysis: wrist torque when wearing gloves, coefficient of friction of the gloves, and tensile strength. This analysis aims to determine the strongest glove materials and ergonomic gloves.

4.3.5.1 Wrist Torque when Wearing Hand Gloves

Table 4.6 shows the data collected for wrist torque when using gloves. The best gloves are rubber and cotton dots because they have high values in the neutral wrist position compared to cotton knitted, cotton rubber, and plastic.

Table 4.6: Data collection of wrist torque when using hand gloves.

	WITHOUT GLOVES		**PLASTIC**		**RUBBER**		**COTTON DOT**		**COTTON**		**COTTON RUBBER**	
	Wrist Position: Neutral/ Vertical		**Wrist Position: Neutral/ Vertical**		**Wrist Position: Neutral/ Vertical**		**Wrist Position: Neutral/ Vertical**		**Wrist Position: Neutral/ Vertical**		**Wrist Position: Neutral/ Vertical**	
	Flexion	**Extension**	**Flexion**	**Extension**	**Flexion**	**Extension**	**Flexion**	**Extension**	**Flexion**	**Extension**	**Flexion**	**Extension**
No.	Max. Wrist Torque (Ncm)	Max. Wrist Torque (Ncm)	Max. Wrist Torque (Ncm)	Max. Wrist Torque (Ncm)	Max. Wrist Torque (Ncm)	Max. Wrist Torque (Ncm)	Max. Wrist Torque (Ncm)	Max. Wrist Torque (Ncm)	Max. Wrist Torque (Ncm)	Max. Wrist Torque (Ncm)	Max. Wrist Torque (Ncm)	Max. Wrist Torque (Ncm)
1	381	462	121	110	350	663	352	370	159	196	259	286
2	299	305	104	130	261	445	281	311	168	194	203	247
3	188	126	64	95	212	290	240	275	183	189	238	349
4	314	356	131	109	491	538	350	408	219	211	423	468

5	339	395	122	115	355	555	300	350	150	169	255	270

Each female has a different value wrist torque influenced by their weight and anthropometry hand. Figure 4.8 shows the bar chart with data on wrist torque flexion when using hand gloves with 5 females. Glove rubber is a high-value wrist torque (491 Ncm) for female 4. It is because of weight and anthropometry hand females 4 greater than other females.

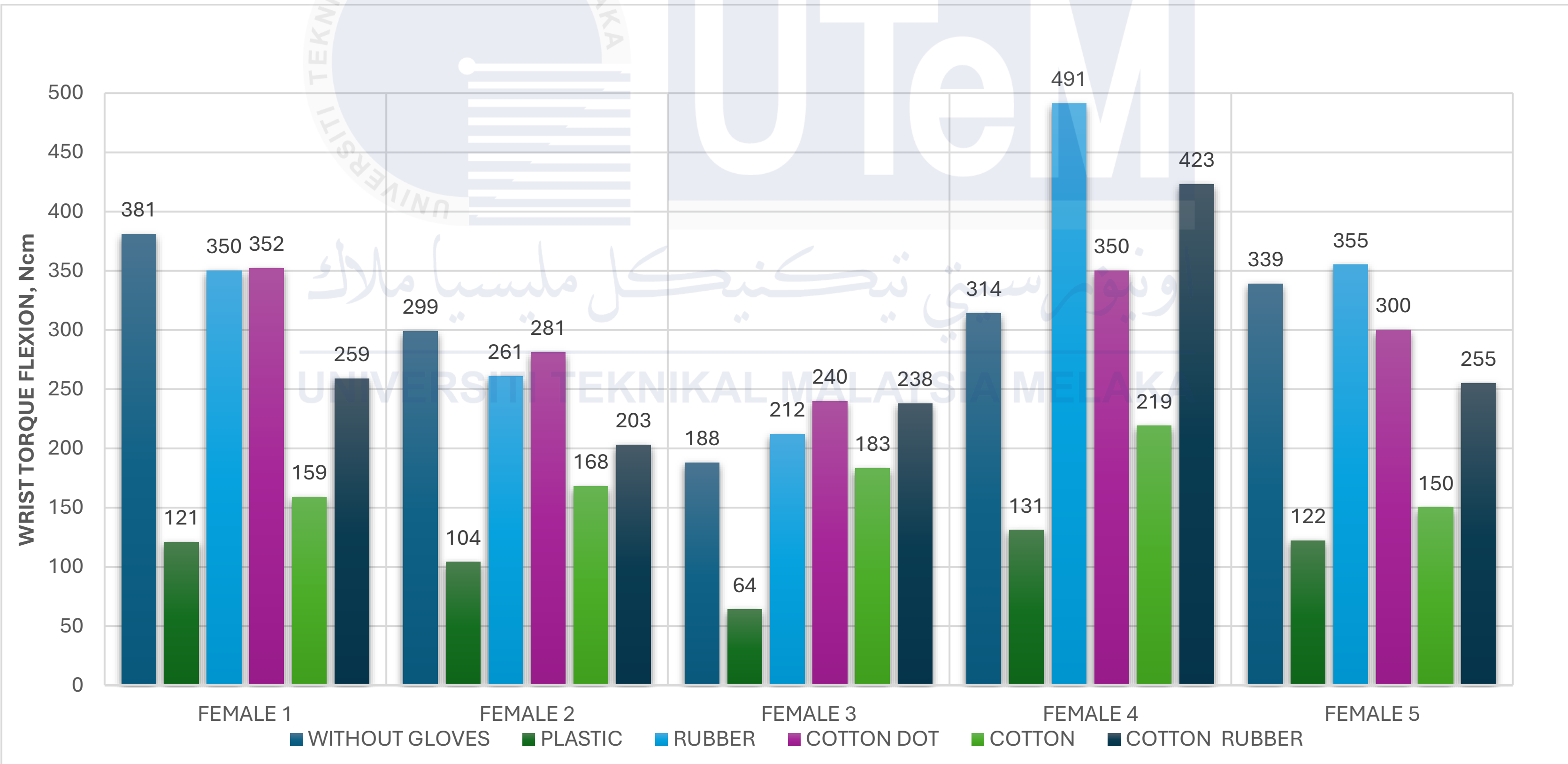


Figure 4.9: Bar chart wrist torque flexion.

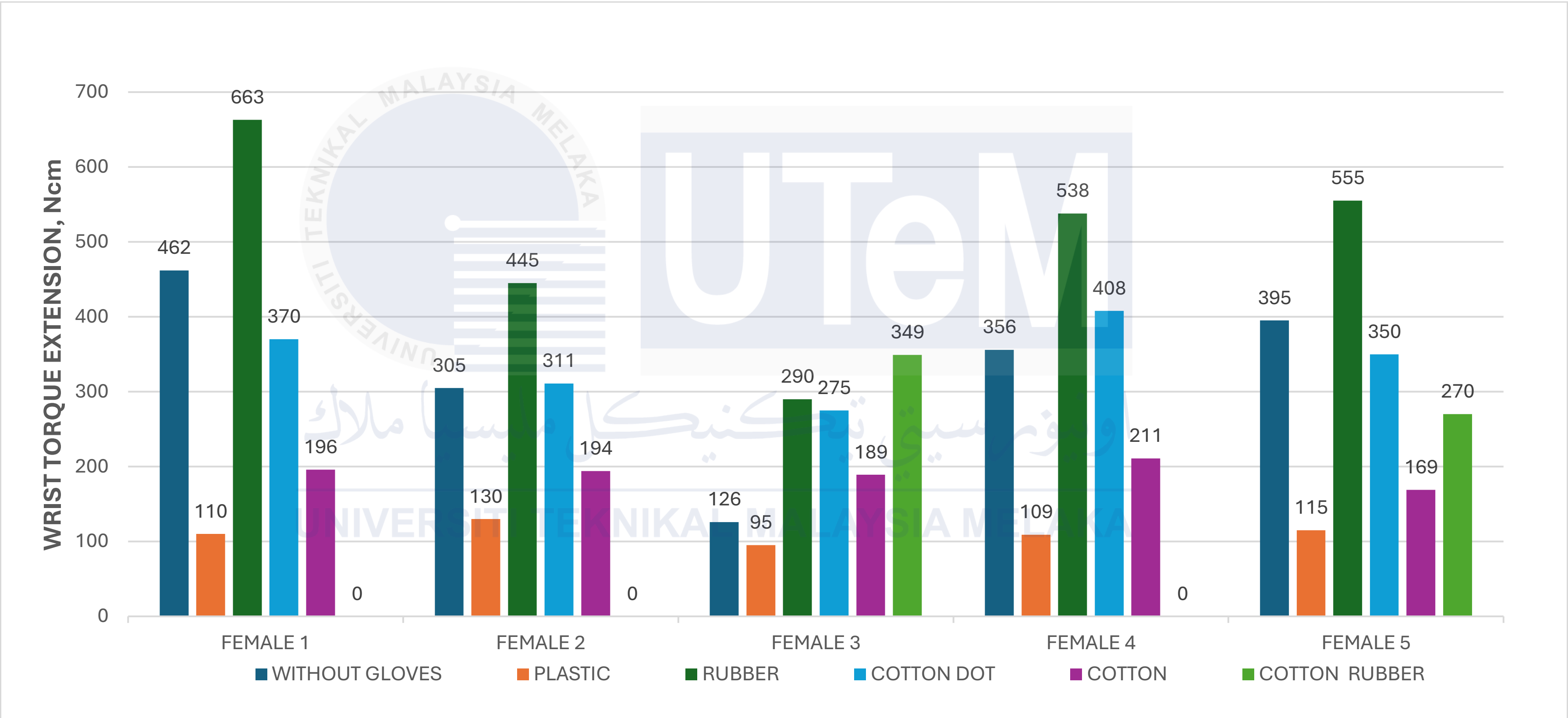


Figure 4.10: Bar chart wrist torque extension.

4.3.5.2 Coefficient of Friction and Tensile Test of Hand Gloves

The coefficient of friction (CoF) is a unitless value that signifies the relationship between the frictional force acting between two surfaces and the normal force pressing them together. This parameter plays a crucial role in comprehending and predicting the interactions of materials in contact, spanning disciplines from engineering to biomechanics. Tensile strength, on the other hand, measures a material's capacity to endure pulling forces, making it a pivotal characteristic in applications involving stretching or pulling. Typically measured in Newtons (N), tensile strength indicates the maximum force a material can sustain before fracturing. In this study, all prototype gloves will undergo testing to assess their coefficient of friction and tensile strength, with detailed results presented in Table 4.7.

Table 4.7: Data coefficient friction and Tensile strength.

TYPES OF GLOVES	**Coefficient friction, μ**	**Maximum force, N**
PLASTIC	0.20	34.76
RUBBER	0.82	23.10
COTTON DOT	0.98	151.69
COTTON	0.33	192.76
COTTON RUBBER	0.26	96.87

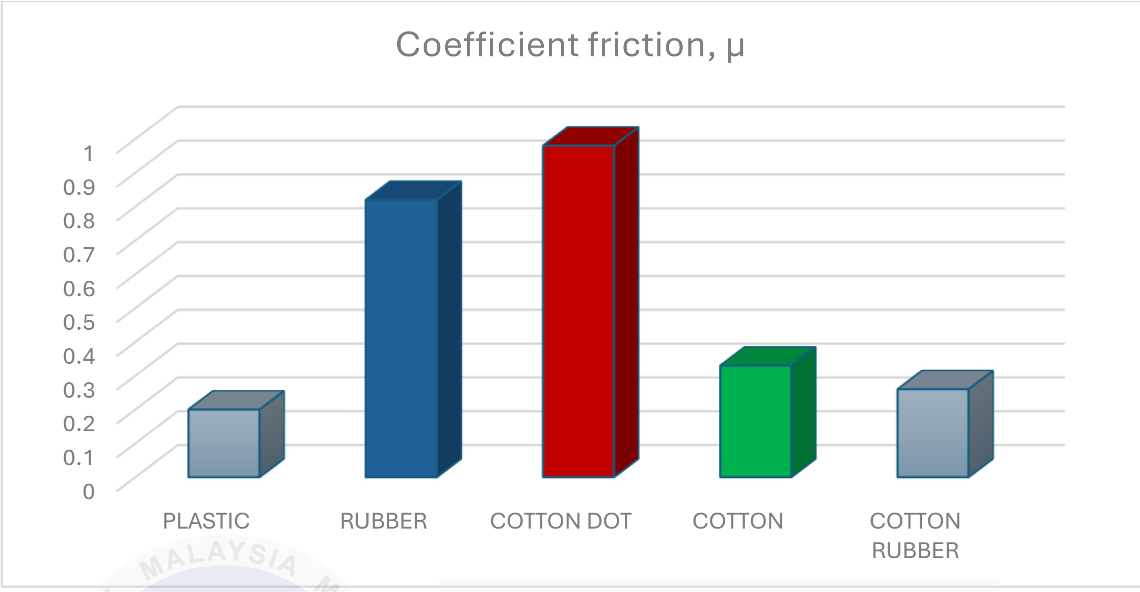


Figure 4.11: Bar chart coefficient friction.

Figure 4.11 shows bar chart coefficient of friction (CoF) among the materials tested, plastic exhibits the lowest CoF at 0.20, indicating minimal resistance to sliding and making it suitable for applications requiring smooth movement, such as in packaging and conveyor systems. The rubber displays a moderate CoF of 0.82, offering balanced grip and traction suitable for applications like tires and seals. Cotton Dot demonstrates a high CoF of 0.98, which is advantageous in scenarios demanding strong grip and non-slip properties, such as in specialized gloves or textiles. Pure cotton presents a moderate CoF of 0.33, making it suitable for textile applications where controlled friction is beneficial. The cotton rubber blend, with a CoF of 0.26, combines the gripping properties of rubber with the comfort of cotton, making it ideal for products like ergonomic gloves that require both functional performance and wearer comfort. These findings underscore the critical role of CoF in material selection across industrial and consumer applications where friction characteristics are paramount.

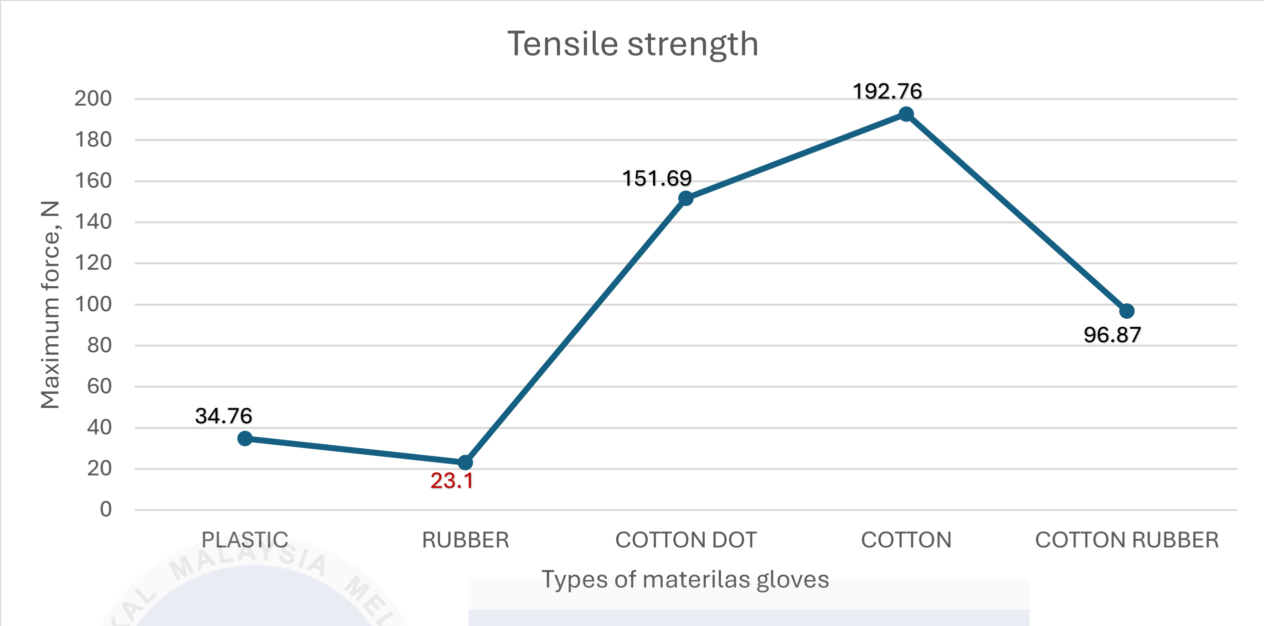


Figure 4.12: Line graph of tensile strength.

Figure 4.11 shows the tensile strength analysis of various materials reveals significant differences in their ability to withstand pulling forces. Plastic, with a tensile strength of 34.76 N, and rubber, at 23.10 N, exhibit the lowest strengths, making them suitable for applications prioritizing flexibility and impact absorption over high tensile strength. In contrast, Cotton Dot and Cotton show substantially higher tensile strengths of 151.69 N and 192.76 N, respectively, indicating their suitability for demanding applications such as protective clothing and heavy-duty textiles. The Cotton Rubber, with a tensile strength of 96.87 N, offers a balanced combination of rubber's elasticity and cotton's durability, making it ideal for ergonomic gloves that require both comfort and moderate tensile strength. These insights guide material selection based on the specific strength and flexibility requirements of various applications.

4.3.6 Testing with End-User

Testing with end users is a process in testing gloves, involving the direct evaluation of product usability, functionality, and overall user experience by its intended users. This process allows for the collection of valuable feedback.

4.3.6.1 Feedback

Figure 4.13 shows the pie chart of question 1, the feedback regarding the ability of gloves to enhance gripping security with different concepts shows varying levels of improvement. Concept A received a 28% positive response, indicating a modest enhancement in gripping the screwdriver securely. Concept B slightly outperformed Concept A with a 29% positive response, suggesting a similar but slightly better improvement. Notably, Concept C showed the highest positive feedback at 43%, indicating a more substantial enhancement in securely gripping the screwdriver compared to the other concepts. These results suggest that Concept C may offer the most effective design for improving grip security, potentially due to specific ergonomic features or material choices that better align with user needs and expectations. Further qualitative and quantitative analysis could provide deeper insights into the specific aspects of Concept C that contribute to its higher perceived effectiveness in enhancing grip security with the screwdriver.

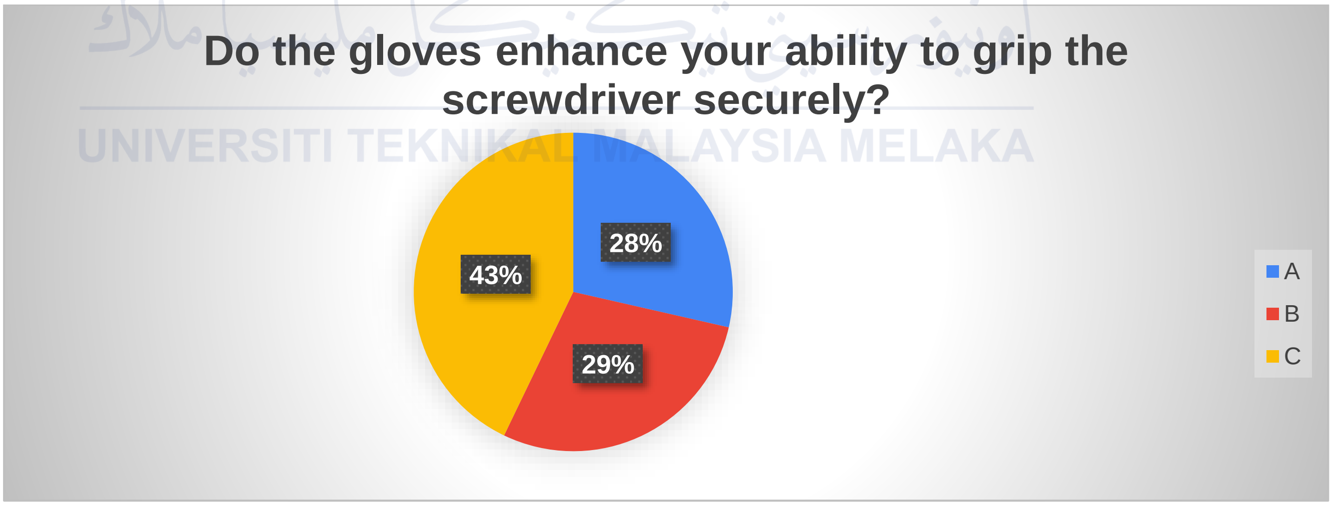


Figure 4.13: Pie chart Question 1

The feedback on slipping or loss of control while using the screwdriver with different glove concepts reveals varying user experiences across the concepts. Concept A received a 37% response indicating some instances of slipping or loss of control, suggesting potential issues with grip security in this design. In contrast, Concept B showed a lower incidence with 27%, implying fewer instances of slipping or loss of control compared to Concept A. Concept C, however, received a 36% response rate, indicating a similar level of slipping or loss of control as Concept A. These findings suggest that while Concept B performs better than Concepts A and C in terms of minimizing slipping or loss of control, all concepts still have some room for improvement. Further investigation into the specific design elements and materials of Concept B that contribute to its better performance could help refine and optimize glove designs to reduce slipping and enhance user control when using a screwdriver. Figure 4.14 shows the pie chart for question 2.

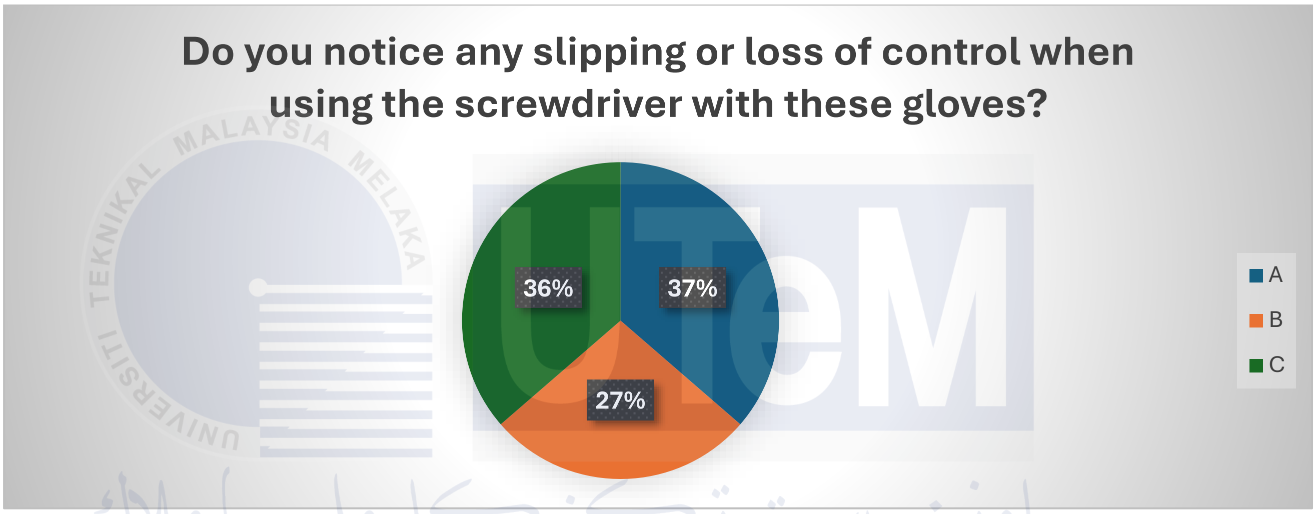


Figure 4.14: Pie chart Question 2

The feedback on the overall dexterity and maneuverability of fingers while wearing different glove concepts and using a screwdriver shows distinct perceptions among the concepts. Concept A and Concept C both received a 50% rating, indicating that users feel these gloves provide satisfactory dexterity and maneuverability, enabling effective use of the screwdriver without significant hindrance. In contrast, Concept B received a 0% rating, suggesting that users perceive a substantial reduction in dexterity and maneuverability when using this concept of gloves with a screwdriver. These results highlight a significant preference for Concepts A and C in terms of maintaining finger dexterity and maneuverability, crucial factors in ensuring effective and comfortable use of tools like a screwdriver. Further exploration into the design differences between Concepts A, B, and C could provide insights into why Concepts A and C are perceived more favorably in this aspect compared to Concept B. Figure 4.15 shows the pie chart for question 3.

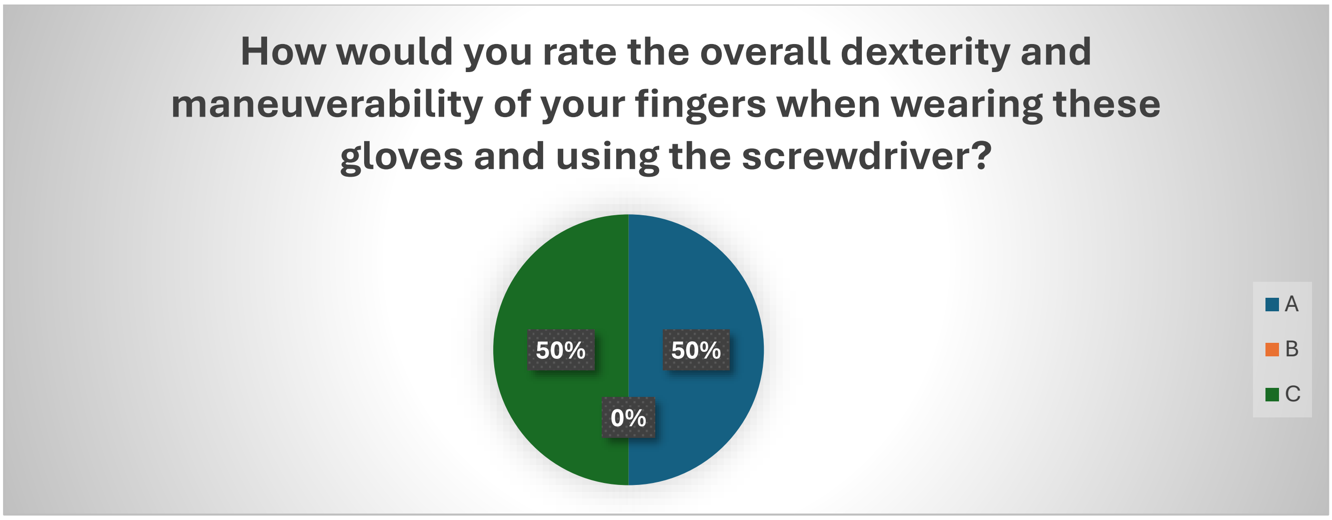


Figure 4.15: Pie chart Question 3

The feedback regarding the improvement in confidence or control when using a screwdriver with different glove concepts compared to using it without gloves shows varied responses across the concepts. Concept A received a 37% positive response, indicating that a significant portion of users perceived an improvement in their confidence or control while using the screwdriver with these gloves. Concept B, with a 25% positive response, suggests a lower but still notable improvement in confidence or control compared to bare-handed usage. Concept C showed a slightly higher positive response at 38%, indicating a similar level of improvement as Concept A. Figure 4.15 shows the pie chart for question 4.

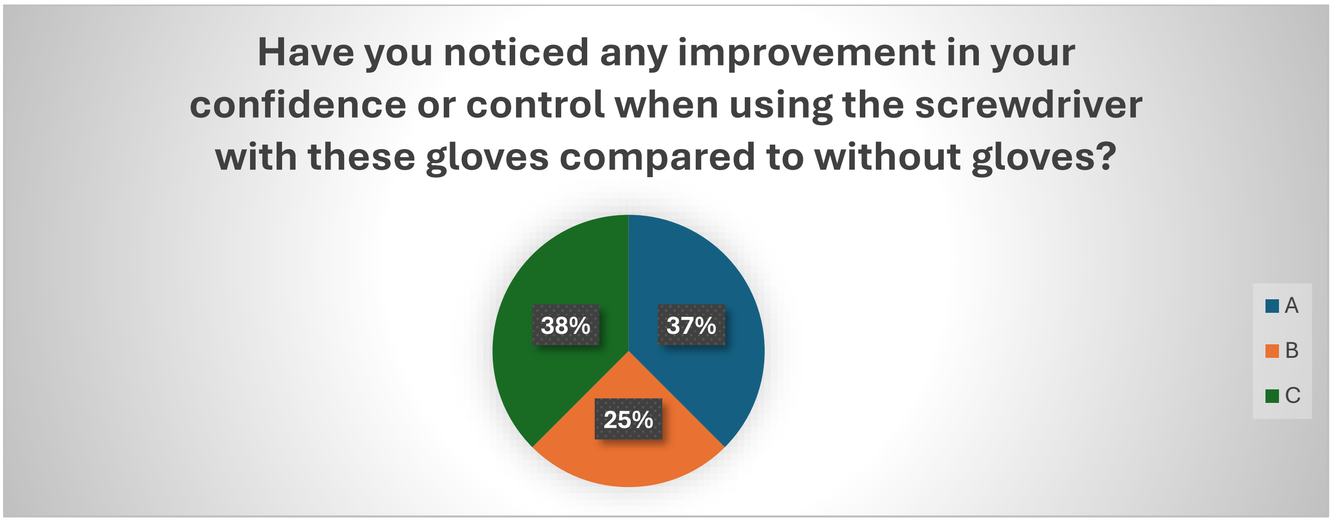


Figure 4.16: Pie chart Question 4

The study suggests that Concepts A and C enhance user confidence and control when using a screwdriver due to ergonomic design features or materials. Concept B shows some improvement but may not provide the same level of confidence or control. Further analysis could focus on specific design elements contributing to improved confidence and control, helping refine glove designs for optimal tool-handling tasks.

CHAPTER 5

CONCLUSION AND RECOMMENDATIONS

This chapter summarizes the findings of the study concerning its objectives. Additionally, it offers recommendations for future research. Finally, the chapter discusses sustainable design development, complexity, long-life learning (LLL), and basic entrepreneurship.

5.1 Establishing a Normative Dataset of Hand Grip Strength for Adult Female Malaysians

This study successfully measured hand grip strength in neutral, pronation, and supination positions for both standing and sitting postures using a Jamar Dynamometer. The data were collected from 126 adult female Malaysians aged 21 to 40 years who were free of injuries. The study established a normative dataset of hand grip strength, including minimum, maximum, mean, and standard deviation values for all positions. From the normative dataset, it can be concluded that the neutral standing and sitting positions had the highest hand grip strength.

5.2 Formulating a Regression Model to Predict Hand Grip Strength

This study has formulated a regression model was formulated using JASP software to predict hand grip strength for the positions SNP, SPP, SSP, DNP, DPP, and DSP. This model aimed to predict hand grip strength based on combined positions considering factors such as age, weight, height, forearm length, forearm circumference, palm circumference, and palm length. However, the regression model was unsuccessful as only 16% to 28% of the R^2 value could be attributed to the variables, falling short of the 60% threshold, which indicates significant errors in the measurement data. Nevertheless, the P-value of the regression model was less than 0.05, indicating significant measurement variables.

5.3 Developing an Ergonomic Hand Glove Prototype to Enhance Grip Performance

This study has developed and fabricated an ergonomic hand glove to enhance grip performance. The proposed glove was designed considering all the user requirements obtained during the interview sessions. Using the House of Quality (HoQ) method, the user requirements were translated into technical specifications. The results from the House of Quality were used to select the glove materials and finalize the best design concept. All exciting gloves were analyzed through engineering analysis (wrist torque, friction test, and tensile test) and user testing via questionnaires. The study concludes that Concept A is an ergonomic glove that effectively improves grip performance.

5.4 Recommendation for Future Study

In future study, the participants selected will generally not be limited to specifically female adults. Based on the regression model, the results are not successful. This suggests the need to increase the sample size, use a digital dynamometer to measure hand grip strength, and follow the detailed standard operating procedures. Furthermore, this study was limited by the fabrication of the actual redesigned glove. Therefore, it is proposed that future studies focus on fabricating a real glove and analyzing its performance with users.

5.5 Complexity

The study focused on developing an advanced glove tailored to improve hand grip strength in adult females. By integrating user-centered design principles and ergonomic considerations, the research aims to address the specific needs of female users. The study employs the House of Quality (HoQ) method to translate user requirements into technical specifications, ensuring that the final product meets the highest standards of functionality and comfort. Through engineering assessments and user testing, various prototype concepts are evaluated to determine the most effective design. The research highlights the importance of increasing sample size, utilizing digital dynamometers for precise measurement, and adhering to standard operating procedures. Future studies are proposed to fabricate and test the real glove, providing comprehensive analysis and validation of its performance. This investigation underscores the potential of ergonomic design to significantly enhance grip strength and overall hand function in adult females, contributing to improved daily activities and occupational performance.

5.6 Sustainable Design and Development

The proposed ergonomic glove developed in this study has been designed with sustainability elements in mind. To enhance comfort and productivity for glove users, the goal was to design gloves based on the users' requirements and expectations. Additionally, the new gloves aim to improve grip performance, particularly when performing tasks such as gripping a screwdriver. Furthermore, the fabrication process of these gloves is non-hazardous to the environment, as the materials and processes used are environmentally friendly. This aligns with Sustainable Development Goal 3 (SDG 3), which aims to improve physical well-being and inclusion by focusing on various aspects of a healthy life. Lastly, the cost of the proposed glove is lower.

5.7 Lifelong Learning (LLL) and Basic Entrepreneurship

In the study of an ergonomic hand glove designed for females, lifelong learning involves a continuous and adaptive approach to personal development and learning throughout one's entire life. It encompasses a commitment to ongoing education and improvement in understanding user needs and technical requirements for comfortable gloves. As a result of this study and the recommended solutions, ergonomics will be improved. JASP software helps to analyze data and find statistical information.

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APPENDICES

A GANTT CHART OF HAND GRIP STRENGTH PSM PROJECT

FYP 1

ACTIVITIES	W1	W2	W3	W4	W5	W6	W7	W8	W9	W10	W11	W12	W13	W14	W15
Submission of FYP Title															
Introduction															
Discuss details 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															

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														

C Approval letter of Research Ethics Committee

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Rujukan Kami (Our Ref): UTeM.11.02/500-25/1/4 Jilid 3 (4)
Rujukan Tuan (Your Ref):
Tarikh (Date): 4 Rejab 1445H / 16 Januari 2024

Dr. Isa Bin Halim
Fakulti Teknologi dan Kejuruteraan Industri dan Pembuatan
Universiti Teknikal Malaysia Melaka

KELULUSAN JAWATANKUASA ETIKA (MANUSIA) PENYELIDIKAN, UTeM

Tajuk Penyelidikan :

Regression Model Of Hand Grip Strength Of Malaysian Young Adults

Perkara di atas adalah dirujuk

2. Dimaklumkan bahawa, pihak kami telah menerima permohonan kelulusan etika daripada pihak Tuan, bagi menjalankan kajian kepada manusia.

3. Oleh itu, setelah meneliti, Mesyuarat Jawatankuasa Etika (Manusia) Penyelidikan, UTeM yang dilaksanakan telah bersetuju memberi kelulusan dengan meletakkan syarat seperti berikut:

a. Adalah menjadi tanggungjawab penyelidik untuk menggunakan sebarang maklumat secara beretika.

b. Kutipan data adalah dikelaskan sebagai sulit dan persendirian dan hanya digunakan untuk tujuan akademik sahaja.

c. Perlu mendapat persetujuan responden sebelum kajian dijalankan dan perlu menjelaskan kepada responden secara verbal dan bertulis atas segala syarat yang telah ditetapkan. Ini termasuk tanggungjawab penyelidik kepada responden dari aspek keselamatan diri dan risiko yang akan dihadapi.

'MALAYSIA MADANI'
'BERKHIDMAT UNTUK NEGARA'
'KOMPETENSI TERAS KEGEMILANGAN'

Saya yang menjalankan amanah,

PROFESOR TS. DR. NOREFFENDY BIN TAMALDIN
Pengarah
Pusat Pengurusan Penyelidikan dan Inovasi (CRIM)

D Data collection standing position

IC No.	Demographic							Selected HGS Data		
	Age			Measured Data of Hand Athropometry				SNP	SPP	SSP
	Year	Weight (in kg, 2 decimal points)	Height (in meter, 2 decimal points)	Dominance forearm length (in meter, 2 decimal points)	Dominance forearm circumference (in meter, 2 decimal points)	Palm circumference of dominance hand (in meter, 2 decimal points)	Length of palm-wrist of dominance hand (in meter, 2 decimal points)	Take the maximum trial's value	Take the maximum trial's value	Take the maximum trial's value
1	22	48	1.56	0.2	0.22	0.19	0.18	19	17	20
2	22	70	1.51	0.24	0.25	0.19	0.19	17	18	17
3	23	54	1.57	0.24	0.25	0.19	0.18	15	16	21
4	22	58	1.7	0.24	0.25	0.19	0.18	20	17	18
5	23	50	1.56	0.25	0.22	0.19	0.19	29	25	29
6	22	43	1.47	0.23	0.2	0.17	0.18	21	18	21
7	22	62	1.6	0.24	0.25	0.19	0.19	28	25	32
8	22	110	1.65	0.25	0.28	0.2	0.18	37	36	39
9	23	60.8	1.5	0.23	0.25	0.18	0.19	30	30	32
10	26	52	1.59	0.23	0.24	0.19	0.18	25	25	25
11	22	50	1.49	0.23	0.24	0.19	0.18	22	21	20
12	22	56	1.63	0.23	0.24	0.19	0.18	22	18	27
13	22	62	1.57	0.23	0.24	0.19	0.18	16	18	19
14	21	75	1.51	0.27	0.23	0.19	0.17	21	19	18
15	22	45	1.56	0.23	0.21	0.18	0.17	26	26	26
16	22	56	1.56	0.23	0.24	0.19	0.18	32	34	36
17	22	47	1.53	0.23	0.21	0.18	0.17	26	33	24
18	22	44	1.57	0.22	0.21	0.18	0.17	25	25	27
19	22	52	1.61	0.23	0.24	0.19	0.18	25	22	27
20	22	58	1.59	0.23	0.24	0.19	0.18	26	28	28
21	23	65	1.6	0.27	0.23	0.19	0.17	18	22	26
22	24	58	1.57	0.23	0.24	0.19	0.18	15	17	19
23	23	43	1.54	0.23	0.21	0.18	0.17	15	17	16
24	24	78	1.65	0.26	0.26	0.2	0.17	29	22	28
25	24	68	1.69	0.29	0.25	0.19	0.25	27	22	28
26	23	42	1.5	0.24	0.21	0.17	0.15	15	12	13
27	23	65	1.6	0.27	0.23	0.19	0.17	22	12	16
28	24	58	1.57	0.23	0.24	0.19	0.18	14	16	16
29	23	43	1.54	0.23	0.21	0.18	0.17	17	14	16
30	22	50	1.57	0.24	0.23	0.18	0.17	18	18	23
31	23	36	1.58	0.28	0.22	0.17	0.18	24	22	23
32	23	72	1.53	0.26	0.27	0.2	0.18	33	33	34
33	22	46	1.52	0.22	0.23	0.18	0.17	21	21	18
34	23	53	1.58	0.22	0.22	0.17	0.18	25	24	22
35	25	47	1.54	0.23	0.21	0.17	0.18	23	20	23
36	22	70	1.57	0.26	0.27	0.19	0.17	24	22	22
37	23	52	1.51	0.24	0.22	0.16	0.17	18	14	12
38	24	55	1.57	0.25	0.23	0.17	0.16	22	18	20
39	22	43	1.61	0.25	0.22	0.17	0.17	18	14	16
40	22	50	1.54	0.29	0.21	0.16	0.18	18	11	14
41	23	67	1.6	0.25	0.25	0.14	0.19	30	23	30
42	25	83	1.57	25	0.24	0.17	0.17	26	20	24
43	24	47	1.53	23	0.23	0.16	0.17	26	20	25
44	23	58	1.6	26	0.21	0.16	0.17	24	22	20
45	24	41	1.53	0.25	0.22	0.18	0.18	26	22	25
46	23	50	1.66	0.25	0.23	0.2	0.18	26	22	25
47	24	72	1.65	0.25	0.28	0.21	0.18	27	25	30
48	21	50	1.58	0.25	0.23	0.19	0.18	24	18	24
49	18	64	1.75	0.27	0.24	0.2	0.18	22	22	24
50	25	55	1.63	0.26	0.23	0.18	0.17	25	18	25

51	23	67	1.62	0.23	0.25	0.17	0.17	23	20	22
52	23	57	1.62	0.25	0.24	0.17	0.18	26	18	22
53	21	47	1.59	0.23	0.22	0.17	0.16	22	20	22
54	23	53	1.6	0.25	0.23	0.17	0.18	28	22	26
55	23	51	1.5	0.21	0.23	0.17	0.16	20	18	18
56	21	61	1.62	0.24	0.24	0.19	0.18	21	20	19
57	21	50	1.57	0.2	0.22	0.18	0.15	29	22	28
58	20	72	1.65	0.23	0.25	0.18	0.18	21	18	20
59	20	79	1.58	0.23	0.28	0.2	0.18	32	28	30
60	20	58	1.56	0.23	0.23	0.19	0.17	19	17	20
61	20	69	1.6	0.23	0.25	0.18	0.16	21	19	25
62	21	58	1.67	0.25	0.23	0.18	0.17	24	18	20
63	20	57	1.55	0.22	0.26	0.19	0.17	30	27	28
64	20	56	1.67	0.23	0.24	0.18	0.18	26	23	24
65	20	47	1.57	0.23	0.23	0.18	0.17	20	19	32
66	23	45	1.49	0.24	0.23	0.17	0.15	18	18	20
67	23	60	1.55	0.24	0.26	0.19	0.17	30	26	27
68	22	47	1.6	0.24	0.22	0.19	0.18	20	20	22
69	22	46	1.61	0.24	0.23	0.17	0.18	26	24	28
70	22	35	1.58	0.22	0.22	0.17	0.14	19	18	21
71	22	57	1.58	0.25	0.24	0.18	0.17	19	16	18
72	25	65	1.57	0.24	0.27	0.19	0.18	22	19	28
73	26	55	1.64	0.24	0.24	0.2	0.17	29	25	28
74	22	44	1.5	0.24	0.22	0.17	0.17	21	18	21
75	25	65	1.56	0.25	0.27	0.19	0.18	24	16	22
76	23	66	1.69	0.24	0.25	0.19	0.19	26	23	26
77	23	67	1.6	0.23	0.27	0.19	0.18	25	19	29
78	23	80	1.55	0.24	0.26	0.2	0.18	24	20	22
79	20	50	1.58	0.23	0.25	0.2	0.19	26	18	29
80	23	50	1.53	0.23	0.24	0.18	0.17	19	19	20
81	23	65	1.67	0.24	0.25	0.17	0.18	28	24	28
82	23	50	1.6	0.23	0.24	0.18	0.17	28	21	26
83	23	60	1.55	0.23	0.24	0.17	0.18	22	18	22
84	23	55	1.59	0.2	0.21	0.16	0.15	22	20	28
85	24	80	1.57	0.23	0.22	0.18	0.17	28	22	26
86	21	72	1.6	0.22	0.21	0.19	0.18	26	20	26
87	30	52	1.61	0.23	0.2	0.18	0.18	26	20	24
88	33	84	1.66	0.26	0.27	0.19	0.18	25	20	26
89	35	54	1.57	0.23	0.23	0.18	0.17	22	18	21
90	32	57	1.57	0.2	0.21	0.19	0.18	26	20	26
91	25	52	1.6	0.22	0.23	0.18	0.18	26	20	26
92	25	58	1.65	0.24	0.25	0.2	0.19	22	19	24
93	30	50	1.67	0.22	0.22	0.19	0.2	20	18	24
94	30	44	1.52	0.21	0.2	0.19	0.18	20	15	22
95	30	40	1.48	0.2	0.2	0.17	0.18	18	16	20
96	26	45	1.62	0.2	0.2	0.18	0.19	22	20	24
97	31	60	1.59	0.22	0.23	0.19	0.18	24	20	26
98	30	48	1.49	0.21	0.2	0.17	0.18	18	16	18
99	30	65	1.52	0.22	0.23	0.18	0.19	26	19	22
100	25	51	1.56	0.23	0.21	0.18	0.18	23	20	24
101	27	54	1.6	0.23	0.24	0.19	0.18	25	21	25
102	22	49	1.55	0.23	0.23	0.19	0.18	22	20	24
103	23	60	1.7	0.25	0.24	0.2	0.19	25	22	26
104	22	50	1.57	0.23	0.24	0.19	0.18	20	18	19
105	22	60	1.58	0.23	0.24	0.19	0.18	22	19	20
106	28	58	1.6	0.23	0.21	0.19	0.18	28	24	26
107	22	56	1.56	0.23	0.24	0.19	0.18	30	26	24
108	22	47	1.53	0.23	0.21	0.18	0.17	26	23	24
109	22	44	1.57	0.22	0.21	0.18	0.17	25	25	27
110	22	52	1.61	0.23	0.24	0.19	0.18	25	22	27
111	28	58	1.6	0.23	0.24	0.19	0.18	28	25	26
112	29	65	1.6	0.27	0.23	0.19	0.17	28	24	26

113	27	60	1.58	0.23	0.24	0.19	0.18	25	24	26
114	24	50	1.56	0.23	0.2	0.19	0.18	26	22	20
115	24	78	1.65	0.26	0.26	0.2	0.18	29	22	24
116	24	68	1.69	0.29	0.25	0.19	0.25	27	22	26
117	24	45	1.5	0.24	0.21	0.17	0.15	16	14	16
118	25	65	1.6	0.27	0.23	0.19	0.17	22	12	16
119	26	58	1.57	0.23	0.24	0.19	0.18	24	20	22
120	25	45	1.55	0.23	0.21	0.18	0.17	18	15	16
121	23	50	1.57	0.24	0.23	0.18	0.17	20	18	23
122	24	45	1.58	0.28	0.22	0.19	0.18	26	20	23
123	25	70	1.53	0.26	0.27	0.2	0.18	32	28	32
124	25	50	1.55	0.22	0.23	0.19	0.18	24	19	20
125	23	53	1.58	0.22	0.22	0.17	0.18	25	23	21
126	25	50	1.55	0.2	0.19	0.19	0.18	23	19	22

E Data collection sitting position

IC No.	Demographic			Measured Data of Hand Athropometry				Selected HGS D	
	Age							DNP	DPP
	Year	Weight (in kg, 2 decimal points)	Height (in meter, 2 decimal points)	Dominance forearm length (in meter, 2 decimal points)	Dominance forearm circumference (in meter, 2 decimal points)	Palm circumference of dominance hand (in meter, 2 decimal points)	Length of palm-wrist of dominance hand (in meter, 2 decimal points)	Take the maximum trial's value	Take the maximum trial's value
1	22	48	1.56	0.2	0.22	0.19	0.18	19	18
2	22	70	1.51	0.24	0.25	0.19	0.19	20	18
3	23	54	1.57	0.24	0.25	0.19	0.18	15	16
4	22	58	1.7	0.24	0.25	0.19	0.18	20	17
5	23	50	1.56	0.25	0.22	0.19	0.19	16	18
6	22	43	1.47	0.23	0.2	0.17	0.18	18	16
7	22	62	1.6	0.24	0.25	0.19	0.19	28	25
8	22	110	1.65	0.25	0.28	0.2	0.18	35	35
9	23	60.8	1.5	0.23	0.25	0.18	0.19	30	26
10	26	52	1.59	0.23	0.24	0.19	0.18	19	24
11	22	50	1.49	0.23	0.24	0.19	0.18	18	18
12	22	56	1.63	0.23	0.24	0.19	0.18	27	18
13	22	62	1.57	0.23	0.24	0.19	0.18	24	18
14	21	75	1.51	0.27	0.23	0.19	0.17	21	20
15	22	45	1.56	0.23	0.21	0.18	0.17	26	26
16	22	56	1.56	0.23	0.24	0.19	0.18	32	32
17	22	47	1.53	0.23	0.21	0.18	0.17	26	23
18	22	44	1.57	0.22	0.21	0.18	0.17	27	24
19	22	52	1.61	0.23	0.24	0.19	0.18	28	22
20	22	58	1.59	0.23	0.24	0.19	0.18	29	28
21	23	65	1.6	0.27	0.23	0.19	0.17	18	22
22	24	58	1.57	0.23	0.24	0.19	0.18	15	17
23	23	43	1.54	0.23	0.21	0.18	0.17	17	18
24	24	78	1.65	0.26	0.26	0.2	0.17	30	21
25	24	68	1.69	0.29	0.25	0.19	0.25	29	20
26	23	42	1.5	0.24	0.21	0.17	0.15	15	12
27	23	65	1.6	0.27	0.23	0.19	0.17	19	15
28	24	58	1.57	0.23	0.24	0.19	0.18	18	14
29	23	43	1.54	0.23	0.21	0.18	0.17	14	14
30	22	50	1.57	0.24	0.23	0.18	0.17	21	18
31	23	36	1.58	0.28	0.22	0.17	0.18	22	21
32	23	72	1.53	0.26	0.27	0.2	0.18	30	27
33	22	46	1.52	0.22	0.23	0.18	0.17	19	16
34	23	53	1.58	0.22	0.22	0.17	0.18	28	24
35	25	47	1.54	0.23	0.21	0.17	0.18	22	21

36	22	70	1.57	0.26	0.27	0.19	0.17	22	23
37	23	52	1.51	0.24	0.22	0.16	0.17	20	15
38	24	55	1.57	0.25	0.23	0.17	0.16	22	19
39	22	43	1.61	0.25	0.22	0.17	0.17	22	16
40	22	50	1.54	0.29	0.21	0.16	0.18	20	16
41	23	67	1.6	0.25	0.25	0.14	0.19	30	22
42	25	83	1.57	25	0.24	0.17	0.17	26	19
43	24	47	1.53	23	0.23	0.16	0.17	25	25
44	23	58	1.6	26	0.21	0.16	0.17	25	22
45	24	41	1.53	0.25	0.22	0.18	0.18	27	21
46	23	50	1.66	0.25	0.23	0.2	0.18	27	21
47	24	72	1.65	0.25	0.28	0.21	0.18	28	26
48	21	50	1.58	0.25	0.23	0.19	0.18	25	21
49	22	64	1.75	0.27	0.24	0.2	0.18	23	16
50	25	55	1.63	0.26	0.23	0.18	0.17	23	16
51	23	67	1.62	0.23	0.25	0.17	0.17	22	18
52	23	57	1.62	0.25	0.24	0.17	0.18	26	22
53	21	47	1.59	0.23	0.22	0.17	0.16	22	21
54	23	53	1.6	0.25	0.23	0.17	0.18	27	20
55	23	51	1.5	0.21	0.23	0.17	0.16	26	14
56	21	61	1.62	0.24	0.24	0.19	0.18	26	21
57	21	50	1.57	0.2	0.22	0.18	0.15	27	23
58	20	72	1.65	0.23	0.25	0.18	0.18	26	18
59	20	79	1.58	0.23	0.28	0.2	0.18	36	25
60	20	58	1.56	0.23	0.23	0.19	0.17	21	20
61	20	69	1.6	0.23	0.25	0.18	0.16	25	18
62	21	58	1.67	0.25	0.23	0.18	0.17	20	18
63	20	57	1.55	0.22	0.26	0.19	0.17	27	15
64	20	56	1.67	0.23	0.24	0.18	0.18	25	18
65	20	47	1.57	0.23	0.23	0.18	0.17	20	17
66	23	45	1.49	0.24	0.23	0.17	0.15	19	18
67	23	60	1.55	0.24	0.26	0.19	0.17	26	20
68	22	47	1.6	0.24	0.22	0.19	0.18	22	19
69	22	46	1.61	0.24	0.23	0.17	0.18	23	18
70	22	35	1.58	0.22	0.22	0.17	0.14	22	28
71	22	57	1.58	0.25	0.24	0.18	0.17	17	19
72	25	65	1.57	0.24	0.27	0.19	0.18	26	22
73	26	55	1.64	0.24	0.24	0.2	0.17	29	22
74	22	44	1.5	0.24	0.22	0.17	0.17	19	18
75	25	65	1.56	0.25	0.27	0.19	0.18	20	18
76	23	66	1.69	0.24	0.25	0.19	0.19	28	22
77	23	67	1.6	0.23	0.27	0.19	0.18	29	19
78	23	80	1.55	0.24	0.26	0.2	0.18	21	24
79	20	50	1.58	0.23	0.25	0.2	0.19	25	18
80	23	50	1.53	0.23	0.24	0.18	0.17	20	19
81	23	65	1.67	0.24	0.25	0.17	0.18	27	22
82	23	50	1.6	0.23	0.24	0.18	0.17	26	21
83	23	60	1.55	0.23	0.24	0.17	0.18	21	18

84	23	55	1.59	0.2	0.21	0.16	0.15	27	19
85	24	80	1.57	0.23	0.22	0.18	0.17	26	21
86	21	72	1.6	0.22	0.21	0.19	0.18	26	20
87	30	52	1.61	0.23	0.2	0.18	0.18	21	19
88	33	84	1.66	0.26	0.27	0.19	0.18	25	21
89	35	54	1.57	0.23	0.23	0.18	0.17	22	18
90	32	57	1.57	0.2	0.21	0.19	0.18	25	20
91	25	52	1.6	0.22	0.23	0.18	0.18	25	19
92	25	58	1.65	0.24	0.25	0.2	0.19	23	19
93	30	50	1.67	0.22	0.22	0.19	0.2	22	20
94	30	44	1.52	0.21	0.2	0.19	0.18	21	14
95	30	40	1.48	0.2	0.2	0.17	0.18	20	16
96	26	45	1.62	0.2	0.2	0.18	0.19	22	19
97	31	60	1.59	0.22	0.23	0.19	0.18	24	19
98	30	48	1.49	0.21	0.2	0.17	0.18	21	15
99	30	65	1.52	0.22	0.23	0.18	0.19	24	20
100	25	51	1.56	0.23	0.21	0.18	0.18	22	19
101	27	54	1.6	0.23	0.24	0.19	0.18	25	22
102	22	49	1.55	0.23	0.23	0.19	0.18	22	20
103	23	60	1.7	0.25	0.24	0.2	0.19	25	19
104	22	50	1.57	0.23	0.24	0.19	0.18	19	18
105	22	60	1.58	0.23	0.24	0.19	0.18	21	18
106	28	58	1.6	0.23	0.21	0.19	0.18	25	22
107	22	56	1.56	0.23	0.24	0.19	0.18	28	20
108	22	47	1.53	0.23	0.21	0.18	0.17	24	20
109	22	44	1.57	0.22	0.21	0.18	0.17	24	22
110	22	52	1.61	0.23	0.24	0.19	0.18	24	20
111	28	58	1.6	0.23	0.24	0.19	0.18	25	22
112	29	65	1.6	0.27	0.23	0.19	0.17	26	23
113	27	60	1.58	0.23	0.24	0.19	0.18	24	22
114	24	50	1.56	0.23	0.2	0.19	0.18	25	19
115	24	78	1.65	0.26	0.26	0.2	0.18	27	20
116	24	68	1.69	0.29	0.25	0.19	0.25	26	21
117	24	45	1.5	0.24	0.21	0.17	0.15	16	13
118	25	65	1.6	0.27	0.23	0.19	0.17	20	13
119	26	58	1.57	0.23	0.24	0.19	0.18	22	20
120	25	45	1.55	0.23	0.21	0.18	0.17	18	14
121	23	50	1.57	0.24	0.23	0.18	0.17	20	18
122	24	45	1.58	0.28	0.22	0.19	0.18	22	19
123	25	70	1.53	0.26	0.27	0.2	0.18	28	25
124	25	50	1.55	0.22	0.23	0.19	0.18	22	18
125	23	53	1.58	0.22	0.22	0.17	0.18	24	20
126	25	50	1.55	0.2	0.19	0.19	0.18	21	19

F Picture Interview

G Questionnaire survey and feedback

INTERVIEW QUESTIONNAIRES SUS

Please enter your participant number: _____

System Usability Scale (SUS)

This is a standard questionnaire that measures the overall usability of a system for hand gloves and gripping a screwdriver. Please select the answer that best expresses how you feel about each statement after using the website today.

	Strongly Disagree (1)	Somewhat Disagree (2)	Neutral (3)	Somewhat Agree (4)	Strongly Agree (5)
1. I think the gloves fit well on my hand.	☐	☐	☐	☐	☐
2. I feel these gloves have flexibility and mobility.	☐	☐	☐	☐	☐
3. I thought the glove was easy to put on and take off.	☐	☐	☐	☐	☐
4. The materials used in the hand comfort gloves felt pleasant against my skin.	☐	☐	☐	☐	☐
5. The ventilation of the hand gloves was adequate, preventing excessive sweating.	☐	☐	☐	☐	☐

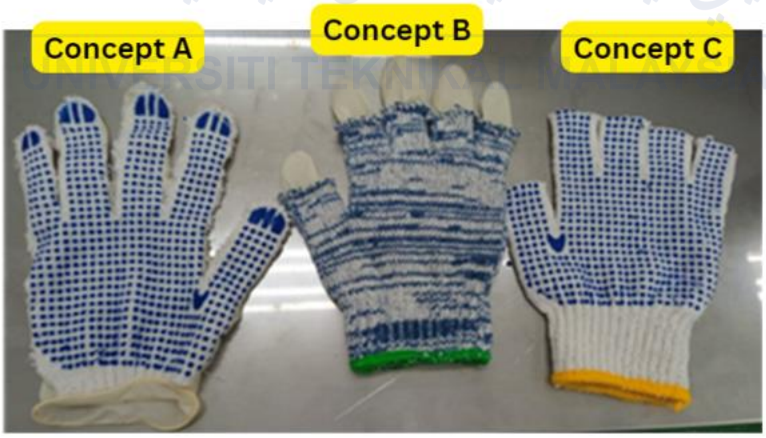
6. The hand-comfort gloves allowed me to maintain good dexterity while wearing them.	☐	☐	☐	☐	☐
7. The hand gloves seemed durable and able to withstand regular use.	☐	☐	☐	☐	☐
8. I felt confident in my grip while wearing these hand gloves.	☐	☐	☐	☐	☐
9. I felt the gloves allow for easy movement of your fingers and thumbs.	☐	☐	☐	☐	☐
10. Overall, I found this hand glove to be comfortable and user-friendly.	☐	☐	☐	☐	☐

	Strongly Disagree (1)	Somewhat Disagree (2)	Neutral (3)	Somewhat Agree (4)	Strongly Agree (5)
1. I found it easy to grip the screwdriver while wearing the hand gloves.	☐	☐	☐	☐	☐
2. The hand gloves provided sufficient traction to prevent the screwdriver from slipping.	☐	☐	☐	☐	☐
3. I felt confident in my ability to control the screwdriver while wearing the hand gloves.	☐	☐	☐	☐	☐
4. The materials used in the hand gloves did not interfere with my grip on the screwdriver.	☐	☐	☐	☐	☐
5. I think chafing or rubbing during screwdriver with the use of the gloves.	☐	☐	☐	☐	☐
6. The fit of the hand gloves did not hinder my ability to hold the screwdriver comfortably.	☐	☐	☐	☐	☐

7. Overall, I found it easy to manipulate the screwdriver while wearing the hand gloves.	☐	☐	☐	☐	☐
8. Wearing the hand gloves improved my grip strength and stability when using the screwdriver.	☐	☐	☐	☐	☐
9. The design of the hand gloves enhanced my overall experience of using the screwdriver.	☐	☐	☐	☐	☐
10. I would feel comfortable using these hand gloves with a screwdriver regularly.	☐	☐	☐	☐	☐

H FEEDBACK QUESTIONNAIRES

Purpose of this interview is to assess the user experience while doing task using new gloves.



QUESTIONS	CONCEPT A	CONCEPT B	CONCEPT C
Do the gloves enhance your ability to grip the screwdriver securely?			
Do you notice any slipping or loss of control when using the screwdriver with these gloves?			

How would you rate the overall dexterity and maneuverability of your fingers when wearing these gloves and using the screwdriver?			
Have you noticed any improvement in your confidence or control when using the screwdriver with these gloves compared to without gloves?			