DESIGN AND ANALYSIS OF WUDU' (ABLUTION) WORKSTATION FOR ELDERLY IN MALAYSIA

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ABSTRACT

Every mosque and musolla will equipped with wudu' (ablution) workstation to facilitate the Muslims to perform their ablution. Muslims are obligated to perform ablution as a cleaning ritual before praying. Currently, the specifications in design of the wudu' workstation is still inadequate especially for elderly. Therefore, this study is conducted to design an ergonomic wudu' workstation for elderly to perform their ablution independently based on the elderly anthropometric dimensions. In prior to that, there are 15 (7 males and 8 females) subjects were involved in collecting the anthropometric data around Malaysia and mostly in Kuala Lumpur and Selangor. Data collected of the anthropometric measurements are distributed in a table and the mean is calculated. Based on the calculation, an improved design of the wudu' workstation is proposed referring to the ergonomics design principles. Then, the inclinometers were used to record the angle of upper trunk and pelvic. There are 11 anthropometric dimensions (stature, shoulder height, standing elbow height, kneecap height, span, elbow span, shoulder breadth, arm reach forward, forearm-hand length, hand length and foot length) were considered important in designing the workstation. The proposed design scores 3 for face cleaning and hands cleaning, and scores 2 for foot cleaning in RULA analysis. The results for the inclinometer show that they experienced more flexion and extension during foot cleaning which resulted in positive and negative value of angle reading. The workstation will become one of the worthy social contributions to the Muslim elderly population especially in Malaysia.

ABSTRAK

Setiap masjid dan surau telah dilengkapi dengan stesen wuduk untuk digunakan oleh setiap orang Islam untuk menyempurnakan wuduk mereka. Mereka diwajibkan untuk mengambil wuduk sebagai salah satu upacara pembersihan diri sebelum menunaikan solat. Kini, spesifikasi untuk rekabentuk stesen wuduk masih tidak mencukupi terutamanya untuk warga emas. Oleh yang demikian, kajian ini dijalankan untuk merekabentuk satu stesen wuduk yang bercirikan ergonomic untuk warga emas mengambil wuduk tanpa bantuan orang lain. Reka bentuk ini akan dilakukan berdasarkan data ukuran antropometri warga emas. Oleh itu, seramai 15 subjek (7 lelaki dan 8 perempuan) telah terlibat dalam pengumpulan data ukuran antropometri seluruh Malaysia terutamanya di Kuala Lumpur dan Selangor. Data ukuran antropometri yang telah dikumpul akan diagihkan ke dalam jadual dan min telah dikira. Berdasarkan kiraan tersebut, satu penambahbaikan rekabentuk telah dibuat dengan merujuk kepada prinsip rekabentuk ergonomik. Kemudian, inclinometer telah digunakan untuk merekod sudut atas tulang belakang dan pelvis. Sebanyak 11 ukuran antropometri (tinggi, tinggi bahu, tinggi siku ketika berdiri, tinggi lutut, depa, span siku, lebar bahu, panjang lengan kehadapan, panjang tangan lengan, panjang tangan dan panjang kaki) telah dipertimbangkan sebagai penting dalam merekabentuk stesen berkenaan. Cadangan rekabentuk berkenaan telah mendapat skor 3 untuk basuh muka dan basuh tangan, manakala telah mendapat skor 2 untuk basuhan kaki dalam analisis RULA. Hasil kajian inclinometer mendapati bahawa mereka mengalami banyak fleksi dan ekstensi ketika membasuh kaki yang menghasilkan nilai positif dan negative bagi bacaan sudut. Stesen wuduk ini akan menjadi salah satu sumbangan berharga kepada komuniti Islam warga emas di Malaysia.

ACKNOWLEDGEMENT

The process of learning and writing this report is long and arduous, and it is definitely not done singlehandedly. This project required a lot of guidance and assistance from many people and I am extremely fortunate to have got this all along the completion of this report. First and foremost, I would like to express my deepest gratitude to my supervisor, Associate Professor Ir. Dr. Siti Zawiah Binti Md Dawal who in spite of being an extraordinarily busy with her duties, took extra time to guide and keep me on the correct path and continually conveyed a spirit of adventure in research. Without her guidance, patience and persistent help this research report would not have been possible.

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CHAPTER 1: INTRODUCTION

1.1 Background of the Project

The population of elderly is progressively increased year after year owing to the dramatic decline in fertility and mortality rates in tandem globally with longer life expectancy (Hamid, 2012). Table 1.1 shows the life expectancy by Department of Statistics Malaysia. In terms of life expectancy, female Chinese life expectancy at birth is the longest with 75.0 for male and 79.7 for female, followed by Bumiputera with 71.3 for male and 76.1 for females in 2013 (DOSM, 2014). Similarly life expectancy at age 60 favours ethnic Chinese, where males can expect to add another 19.6 years and female add another 22.3 years. Bumiputera and Indian males can expect to add another 17 years, while Bumiputera and Indian females can expect to add another 20 years. Hence, ethnic Chinese, due to their longevity in life recorded higher number of aged population compared to other ethnic groups. The advancement of healthcare technology and awareness of healthy lifestyles can also contribute to the raising number of golden agers.

Table 1. 1: Life expectancy (in years) at birth and at 60 years by ethnicity, Malaysia, 1990-2013

Life Expectancy	1990*		2000		2010		2013e	
	Male	Female	Male	Female	Male	Female	Male	Female
At Birth								
Total	68.9	73.5	70.0	74.7	71.9	76.6	72.6	77.2
Malay & B.	69.0	72.4	69.0	73.3	70.7	75.4	71.3	76.1
Chinese	70.6	76.3	72.4	77.6	74.4	79.1	75.0	79.7
Indian	64.4	70.4	65.7	73.5	67.6	75.7	67.9	76.2
At 60								
Total	16.1	18.4	16.7	19.0	17.9	20.1	18.3	20.6
Malay & B.			15.9	17.8	17.1	19.4	17.6	19.8
Chinese			18.1	21.1	19.1	21.7	19.6	22.3
Indian			15.2	19.1	16.9	19.8	17.4	20.3

Source: Department of Statistics (1986; 1993; 2002; 2013)
* Peninsular Malaysia Only

Not only that, the Muslim population globally is also increasing based on the PEW Research Center, 2015. Asia has 69% of the world Muslim population while Africa has 27%. In addition, Muslims constitute 24% of the world population, or 1.65 billion people. This is expected to increase by over one percentage point each decade, reaching one out of four by 2020 and one out of three by 2075 (Kettani, 2010).

Ablution (wudu') is the compulsory ritual washing performed by Muslims before prayer five times daily. This ritual had been followed from the Prophet in order to ensure cleanliness before prayer and He (prophet) even used to brush his teeth before each prayer (Besari, Zamri, Yusaeri, Palil, & Prabuwono, 2009). Malaysia is one of the Islamic country had provided the praying facilities equipped with ablution area at all mosques, musolla, public rest area and shopping complex to ease the Muslim to pray. For all the ablution area, it has different design concept and appearance to meet the variety of demands.

Ageing causes the spinal disc to shrink in height and distributes more stresses and pains to the bones and joints. Yamamoto et al. (1989) discovered that the range of motions of the spine is influenced by age and degeneration. Increased stiffness in the degenerated intervertebral discs is the main cause of reduced mobility with age. Elderly will experience more neck flexion, shoulder angle and ulnar deviations compared to the youngster. As the age increasing, the muscle tend to experience fatigue more frequently and increase the risk of contracting MSD.

With the limited movement, elderly will facing difficulties to manage their routines independently. Malaysia standard of building public facilities which can be accessed by vulnerable group such as disabled and elderly had been developed as a guideline to provide better information for developers. Thus, it is vital to design a proper

workstation with the use of ergonomic aspects that can serve elderly to the utmost possible.

1.2 Problem Statement

Ablution is compulsory for every Muslim as a cleaning ritual before they pray five times daily. Every mosque and musolla at public rest area will provide facilities of ablution area for Muslim to perform their ablution. However, the design guidelines, research and documentation about the standard dimension of the workstation is still lacking (Mokhtar, 2005). The dimension of the ablution area component is very important in designing the concept of the area, it includes the accessibility and comfortability of the users. Elderly has limited movement of the body and they tend to fall with limited support. The elderly resides and found that the greatest perceived hazard is in the toilet and bathroom areas (Rashid, 2006).

Instead of the aesthetic value of the design, the plan of the ablution area should highlight the correct dimension according to the anthropometry measurements. This is one of the ergonomic aspect which should be taken into consideration for safe, low risk and user friendly environment. Hence, in this study, the proposed design will consider the ergonomic aspect and then the wudu' workstation will be analyzed using RULA analysis and inclinometer.

1.3 Aim

To improve a design of an ergonomic wudu' (ablution) workstation for elderly using specifications of the anthropometry measurements and postural angle analysis.

1.4 Objectives

1. To identify the mismatch of the existing wudu' workstation.

2. To determine the significant anthropometry dimensions of elderly related to the wudu' workstation.
3. To propose an improved design and analyze posture using RULA analysis in CATIA V5R21.
4. To analyze the postural angle of the proposed design using inclinometer

1.5 Scope and limitations of the study

This study is conducted to focus on elderly when they are performing their ablution. Elderly tend to experience difficulties during the process because of the lacking in designing the ablution workstation. In order to fulfil the aim and objectives of the study, mosques in Kuala Lumpur, Selangor, Kelantan and Terengganu had been visited to observe and measure the dimensions of their existing workstation. The proposed design should follow the anthropometry dimension of elderly population in Malaysia. The experiment of inclinometers is carried out in the laboratory to test the proposed workstation.

Time constraint is very crucial in this project because the prototype of the workstation took some times to complete fabrication. The analysis of back postural angle can be determined as an initial test and need to investigate further in future plan.

1.6 Project Outline

This report consists of 6 chapters, the first chapter is an introduction of the project which include the background of the project, problem statement, aim and objectives, scope and limitations as well as the outline of the study.

The literature review related to elderly population, Muslim population, regular practice of ablution, back postural angle and ergonomic design principle are

presented in details in Chapter 2. While in Chapter 3 will cover on the methodology throughout the project. Data collection for anthropometry dimensions and postural angle were discussed in this chapter.

Result and discussion had been presented in Chapter 4 and related to the proposed design in Chapter 5. Last but not least, Chapter 6 conclude the whole project which include the recommendation for future studies.

CHAPTER 2: LITERATURE REVIEW

2.1 Introduction

Ergonomics involves the interaction and the fit between human capabilities and the demands of the job (Smith, 1989). This is not excluded the people with disabilities to fulfil the demands of the job. In this chapter, the definitions of elderly is presented and the previous study of wudu' workstation is discussed critically. The existing design of the workstation are reviewed and then the back postural angle were discussed. The topics will be covered in this chapter are the elderly populations, Muslim populations, Muslim regular practices: Ablution and back postural angle.

2.2 The Elderly Populations

2.2.1 Definition of Elderly

The definition of elderly is varies greatly in every country depending on their societies. Most developed world countries have accepted the chronological age of 65 years as a definition of 'elderly' or older person and at the moment, there is no United Nations (UN) standard numerical criterion, but the UN agreed cut-off is 60+ years to refer to the older population (Kowal, 2014). Although there are commonly used definitions of old age, there is no general agreement on the age at which a person becomes old. The common use of a calendar age to mark the threshold of old age assumes equivalence with biological age, yet at the same time, it is generally accepted that these two are not necessarily synonymous. As far back as 1875, in Britain, the Friendly Societies Act, enacted the definition of old age as, "any age after 50", yet pension schemes mostly used age 60 or 65 years for eligibility (Roebuck, 1979). The UN has not adopted a standard criterion, but generally uses 60+ years to refer to the older population (UN, 2001). Thus, in contrast to the chronological milestones which mark life stages in the developed world, old age in many developing countries is seen to begin at the point when active contribution is no longer possible (Gorman, 2000).

Study results published in 1980 provides a basis for a definition of old age in developing countries (Glascock, 1980). This international anthropological study was conducted in the late 1970's and included multiple areas in Africa. Definitions fell into three main categories: 1) chronology; 2) change in social role (i.e. change in work patterns, adult status of children and menopause); and 3) change in capabilities (i.e. invalid status, senility and change in physical characteristics). Results from this cultural analysis of old age suggested that change in social role is the predominant means of defining old age. When the preferred definition was chronological, it was most often accompanied by an additional definition (Kowal, 2014)

2.2.2 Increment of Elderly Population

Until recently, elderly people have not been a priority in international development policies. However, with changing demographic scenarios in many countries, older people have become key targets in development agendas. This shift has led to a new paradigm for looking at issues of older persons (Omar, 1999). From 1950 to 2009, the world's older population has increased by an average of 9 million persons per year (UN, 2010). In 2010, the older population reached 760 million persons globally, with 447 million (59 percent) located in less developed region. While the proportion of older people (8.7 percent) in less developed regions was smaller than in the more developed regions (21.7 percent), their absolute numbers was significantly larger proportion of older people will in the future be concentrated in less developed countries (1.4 billion), there being more than thrice the number of older persons in the more developed regions for the next four decades (Lim, 2012).

According to the World Population Prospects database (UN, 2013), there is an estimated 895.3 million older persons aged 60 years or over in the world today with 504.2 million or 56.3% of them residing in Asia in 2015. By 2050, the number of older

persons will more than double to 2 billion, where one out of every five persons in the world will be an elderly. Elderly population is estimated to rise from 12% to 22% (900 million to 2 billion) of the total global population. This is expected also between year 2000 and 2050, the number of people aged 60 and above is expected to double. (WHO, 2015). Based on Table 2.1 below, percentage of elderly (50 years and above) is 21.88% out of the total world population which estimated to reach 7.5 billion in 2017 (UN, 2015).

Table 2. 1: : WHO World Standard Population Distribution (%), based on world average population between year 2000-2025

Age group	World Average 2000-2025
0-4	8.86
5-9	8.69
10-14	8.60
15-19	8.47
20-24	8.22
25-29	7.93
30-34	7.61
35-39	7.15
40-44	6.59
45-49	6.04
50-54	5.37
55-59	4.55
60-64	3.72
65-69	2.96
70-74	2.21
75-79	1.52
80-84	0.91
85-89	0.44
90-94	0.15
95-99	0.04
100+	0.005
Total	100

It is a triumph because people are living longer due to better health care and improved living conditions. It is also a challenge because societies have never experienced this large number of older persons with their unprecedented longevity (Omar, 1999). Like

many other countries around the world, Malaysia is also experiencing a rapid growth of the older population. This is a direct consequence of the decades of socio-economic development and public health policies where falling fertility and rising longevity have resulted in the rise of new generations. Malaysia is in the third stage of her demographic transition, where fertility rates are declining faster than mortality rates (Hamid, 2012).

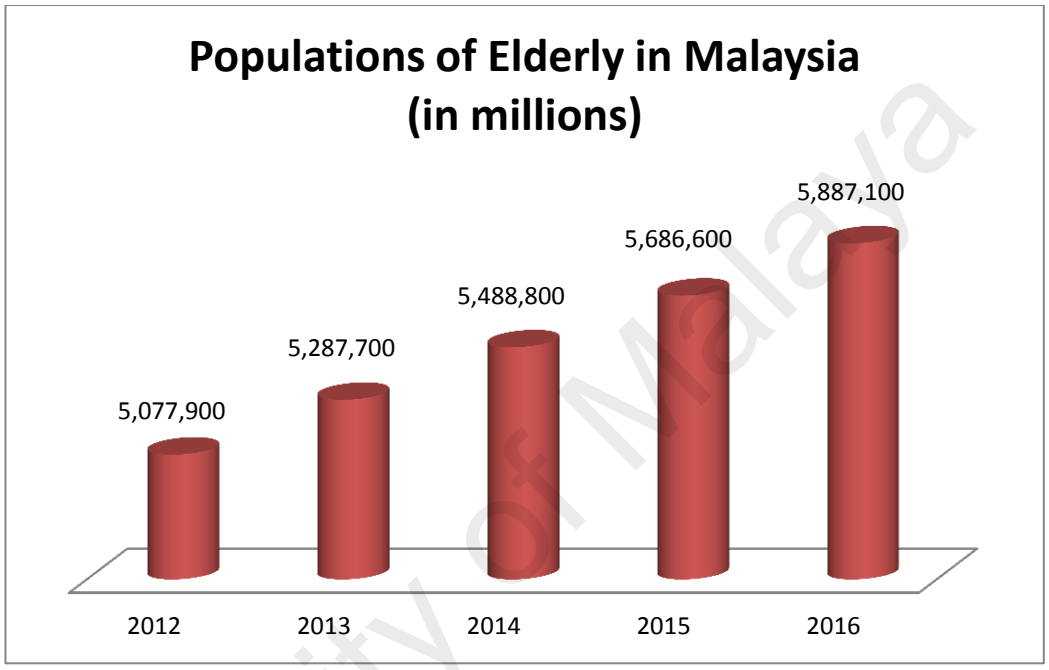


Figure 2. 1: Population of elderly (above 50 years old) in Malaysia based on Population Quick Info, Department of Statistics Malaysia.

Between 2050 and 2055, the number of older persons aged 60 years or over will equal the number of young people under the age of 15 years in Malaysia. All these changes will have significant implications on our economy and our society. Lee, Mason and Park (2012) have argued that Asian countries faces two major objectives in relation to population ageing; 1) sustaining strong economic growth, and 2) providing economic security to the increasing number of older persons. Declining fertility rate contributes to population aging by depressing the growth rate of younger population, creating a faster growth rate of older population compared to younger population, thus promoting ageing

from the base of the population pyramid. At the same time, the life expectancy at birth and at age 60 year hastened the growth of the older population (Hamid, 2012). In developed nations, ageing is happening at the apex of the pyramid as declining death rates at older ages and the large birth cohort from the past such as baby boomers is living longer contributed to the number and proportion of older persons (Hamid, 2015).

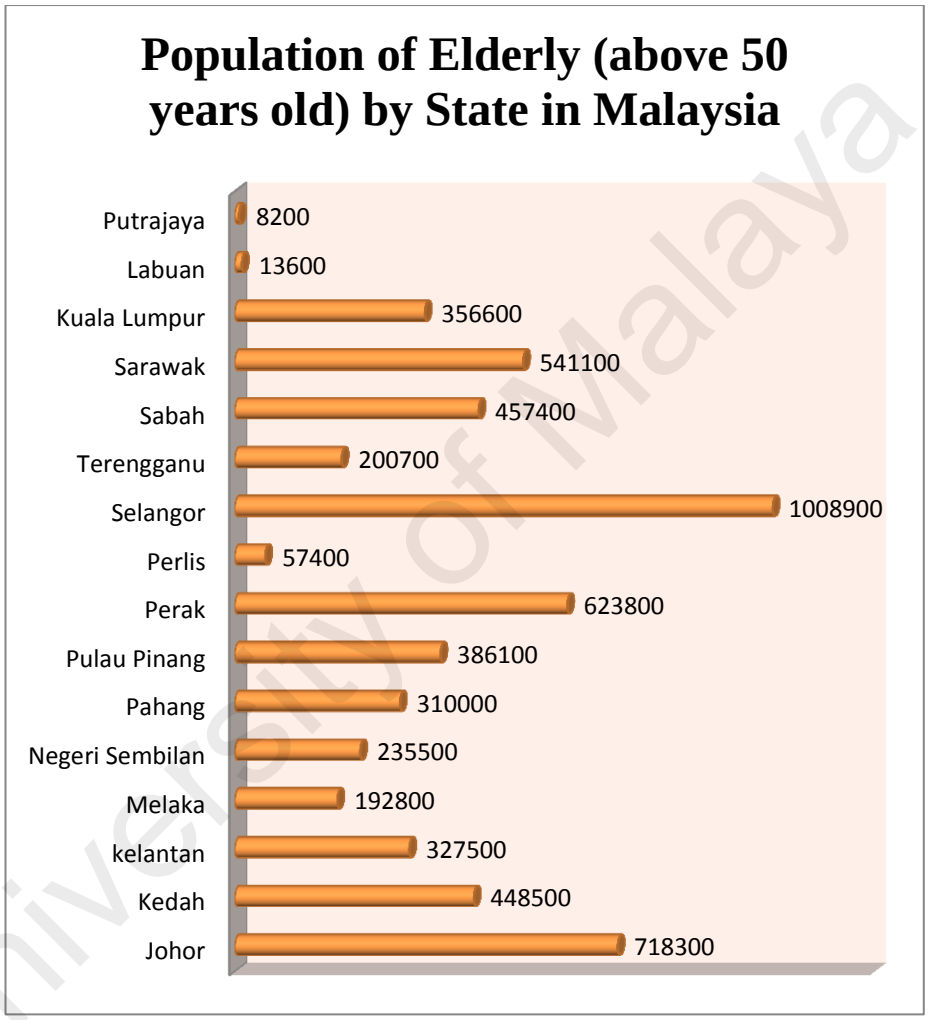


Figure 2. 2:Population of elderly by state in Malaysia (in millions)

(Source: Population Quick Info, Department of Statistics Malaysia)

Older people are trying to make themselves economically useful in the community as long as possible so as to be able to maintain their living standard. Moreover, due to lifestyle changes such as physical exercises, fitness programs, healthy diet, and so forth, a significant number of elderly people is remaining physically fit to

continue in employment. Technology and legislation are extending a helping hand in this regard (Kothiyal & Tettey, 2001). Further, computer and communication technologies have significantly advanced in the last few decades and are now playing a prominent role in modern manufacturing and service industries in making jobs physically and cognitively less demanding (i.e., jobs require low physical strength or force, or are supplemented with decision-making aids, etc.) for workers. This has enabled elderly workers to work nearly as productively as young workers. Although not necessarily demarcating biologic old age, 65 years and over has provided a convenient benchmark for demographers, as despite the relative good health and vigour of many of those aged over 65 years, this age group are more likely than any other to suffer from multiple chronic degenerative diseases. Malaysia can see a rising tide of older people, and will need to swiftly develop systems to cope with this, at the same time recognising any ethnogenic factors that will influence future health and social care needs (Poi et al., 2004).

2.2.3 Elderly: Physical Performances

A higher risk of falls in the elderly is usually related to mobility dysfunction and balance problems. The incidence of falls among older Malaysians can be commonly attributed to problems in turning (Ashari, 2014). The elderly resides and found that the greatest perceived hazard is in the toilet and bathroom areas (Rashid, 2006). An ergonomic solution is needed based on local elderly population's anthropometric parameters (Yusuff et al., 2009).

2.3 Muslim Population

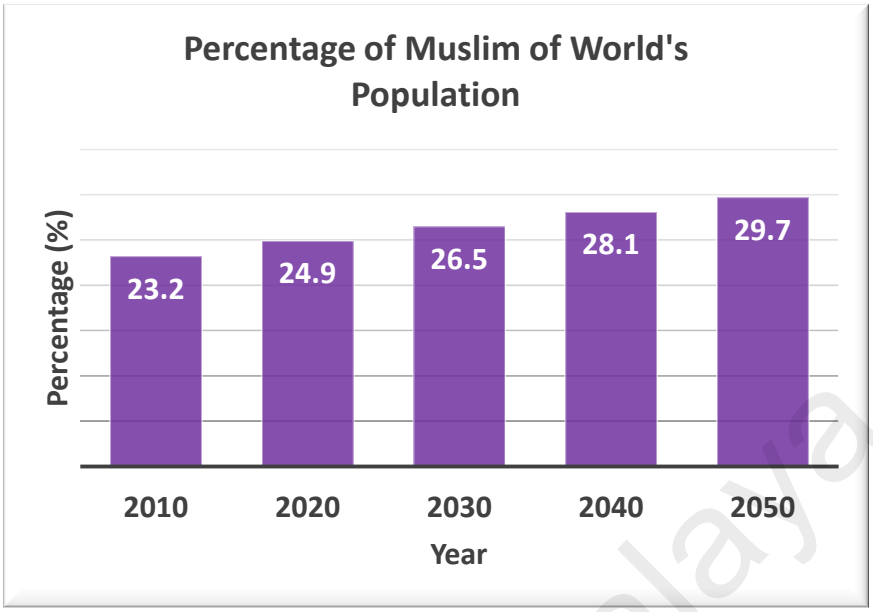
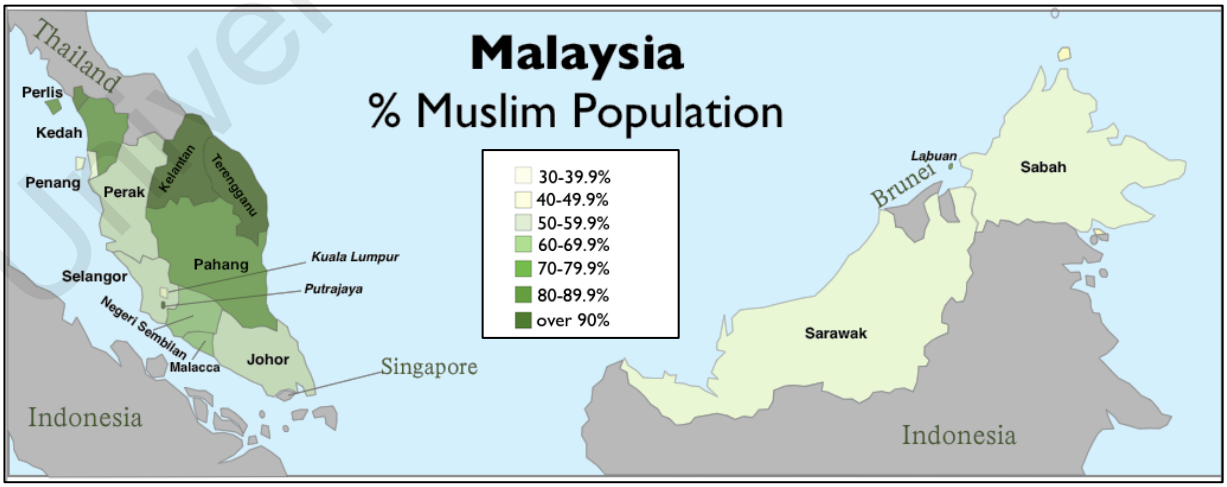


Figure 2. 3: Percentage of Muslim of world's populations

The world population annual growth rate is estimated at 1.194%, the corresponding rate for the World Muslim population is 1.705%. Thus, the representation of Muslims with respect to the total World population is expected to increase at over one percentage point each decade, reaching one out of four by 2020, and one out of three by 2075 (Kettani, 2010) which is presented in Figure above. There are 50 majority Muslim countries; 28 in Asia, 20 in Africa, and two in Europe. In addition, 72.1% of World Muslim population (three out of four) live in a majority Muslim country, and over half of the World Muslim population live in a country with over 90% of its population Muslim. Accordingly, out of a world population of 6.93 billion, Muslims constituted 1.65 billion or 23.9% of the world population. Most Muslims (69.4%) live in Asia, representing 27.4% of the Asian population. On the other hand, 27.0% of the World Muslims live in Africa, constituting 43.3% of the African population (Kettani, 2010).

The percentage of Muslims in Asia is 27.5% with a total Muslim population of one billion and 148 million, which constitutes 69.4% of the World Muslim population. While Asia has the largest number of Muslims among other continents, it is second to Africa in terms of the percentage of Muslims with respect to the total population in the continent. Accordingly, the percentage of Muslims in Africa is 43.3% with a total Muslim population of 447 million, which constitutes 27.0% of the World Muslim population. Europe, on the other hand, has 2.9% of the World Muslim population, or 49 million Muslims, constituting 6.6% of its total population. However, Muslims are still well underrepresented in number and percentage in the Americas and Oceania.

While in the Figure below shows the percentage of Muslim population in Malaysia. The highest population is in Kelantan and Terengganu with over 80% Muslim population. Then it is followed by Pahang and Kedah with more than 70% of Muslim population. For Malaysia, it contains of 24% of Muslims of total Muslims population in Southeast Asia (Kettani, 2010).



Source: GeoCurrent website, September 2013

Figure 2. 4: Percentage of Muslim population in Malaysia

2.4 Muslim Regular Practice: Ablution

The religion of Islam is based on five pillars. One of the pillars is to pray five times a day. Every matured Muslims are obliged to perform the prayers. In preparing oneself to perform a prayer, the person must prepare their self with ablution. Without ablution, the person is not allowed to perform the prayer (Al-Shahri & Al-Khenaizan, 2005). Within the teachings of Islam, ablution is purified procedures that have an essential role. It is one of the requirements of consecration for a person before they get closer to God. Ablution is an act that involves both of physical and spiritual. In term of physical, ablution can be recommended because of body hygiene and in terms of spiritual, it is to protect purity of the soul and spiritual than doing the wrongs (Mirahmadi, 2005). In general, ablution is a washing ritual which involve cleaning at four compulsory area on particular body including washing of face, both hands, forehead to crown of head and both feet and it is recorded in the Holy Book of Quran (Johari et al,, 2013).

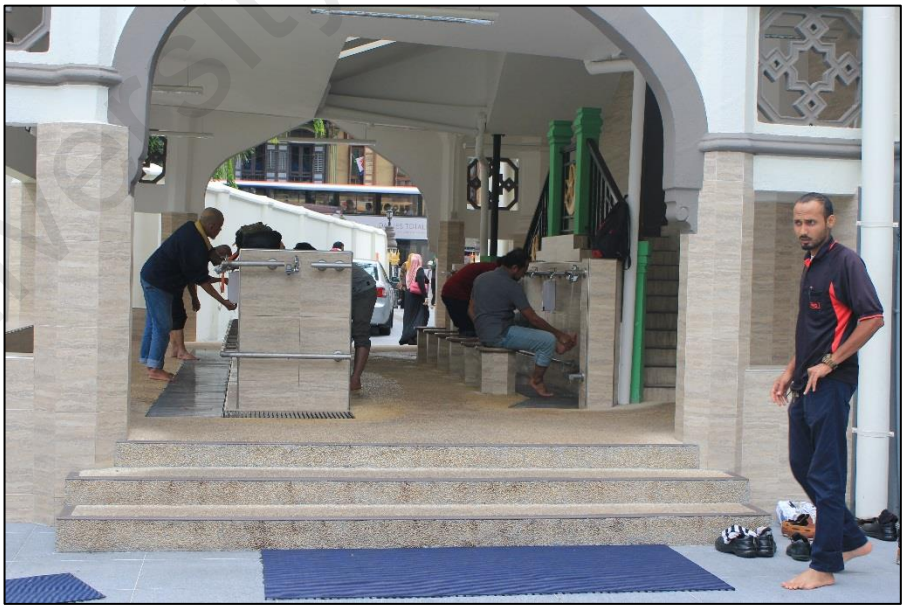


Figure 2. 5: Muslim performing ablution at mosque

There are seven points of biological washed when people take ablution; those are head, eyes, ears, nose, mouth, hands, and feet. Those seven parts are the energy center of human body. Neurologist has proved that ablution water can cool and loosen the muscles and nerves of people's body. Nerve ending of fingers and feet are useful for stabilizing mind concentration (Al-Zuhaili, 1996). The amount of water about half to 2 litres is enough to apply on the body (Besari et al., 2009), because certain hadith mentioned the Prophet Muhammad PBUH used to perform ablution with one *mudd* of water (equal to 2/3 litre) (Faruqui, Biswas, & Bino, 2001).

Ablution ritual is compulsory for those who want to do the praying activities. Without this ritual, prayers are not complete unless in an emergency with replacing ablution with tayammum ritual (Katz, 2002). When the ritual involves the use of water, the Muslims introduced a specific place to perform ablution, to facilitate Muslims to perform this ritual. An ablution station has many design variation that apply plenty of design concept that have been developed nowadays. The average generated design of the ablution tub is developed parallel with the development of sanitaryware products. Besides that, it also involves the framework of the human gestures and human behaviour. Therefore, relationship between water, human gesture and human behaviour becomes the major fundamental factors in designing the product (Liang, Wang, Su, & Xu, 2008).

2.4.1 Current Design on Wudu' Workstation

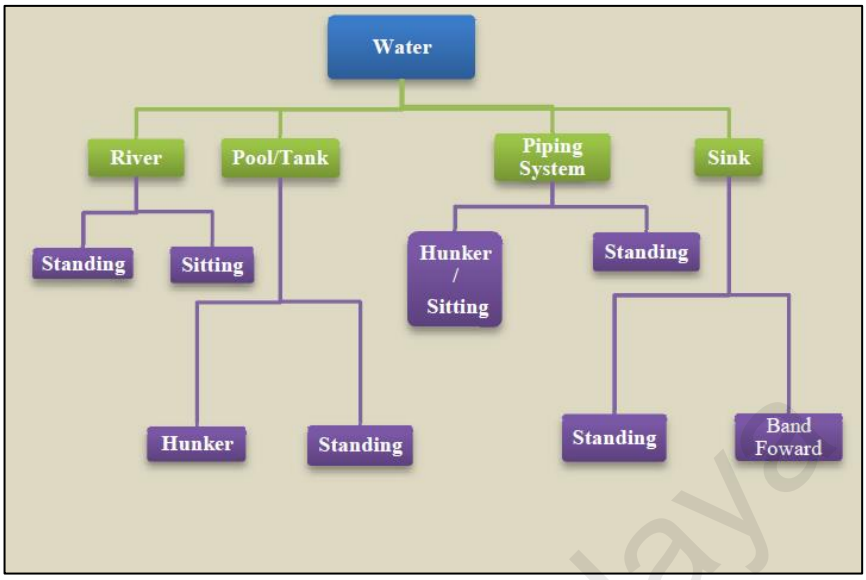


Figure 2. 6: Concept of ablution tub (Johari, 2012)

Figure 2.6 shows the basic concept of the ablution tub which regularly used for ablution and also description framework of the human gestures in ablution ritual. The variations of the human behaviour while performing ablution was based on its ethnography, sociology and geography (N. H. Johari, Anwar, & Hassan, 2012). During this process, people are tend to waste water easily and some of them are use water wisely by controlling the outflow of the water.

(Besari et al., 2009) built an automatic ablution machine using camera (see Figure 2.7) as a sensor and servo motor as an actuator that is embedded on crane to turn it on based on the presence of object under the crane. It means that if there is an object triggered under the crane, it will be opened, and when there is no object traced under the crane, it will be closed. Not only that, it also can detect how much water that Muslim requires while performing the ablution. Nowadays, some researchers have invented the automatic ablution machine, but the purchasing cost is high and could not fulfil the demand.

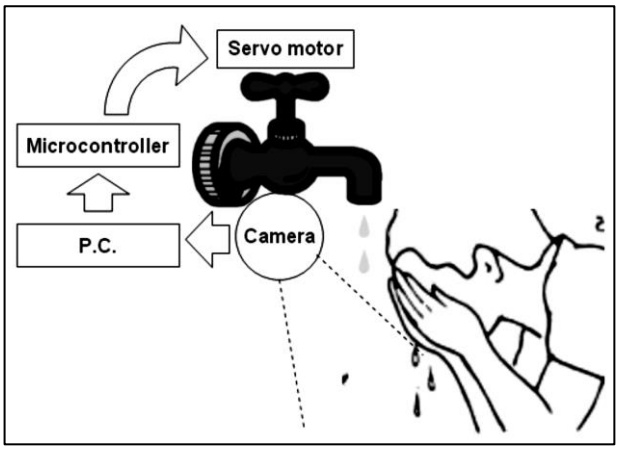


Figure 2. 7: Block diagram of the system

There are several possible models (see Figure 2.8) for the designs of an ablution unit identify by Mokhtar (2005). The simplest design model shows on Model 1. This kind of model includes with a shelf for users to put their belongings and happen to be as support of balancing their bodies by grip strictly on the bench. This low cost model was uncomfortable to perfume ablution because it requires users to sturdily bend their knees or back. Model 2 shows an ablution space that provides seats for users to perform ablution while seated. This design figure shows the most recommended design and dimensions to sit while perform ablution. The design also measures a concern about the level of seat, water drainage, including a shelf. In the other view, Model 3 became as model that includes with a lavatory. This model happens to be most users apply at homes to perform ablution. Based on this model, the main problem is, users need to bend to reach the faucet and require raising their feet as last of ablution process to the lavatory (Anwar, Abidin, & Hassan, 2015).

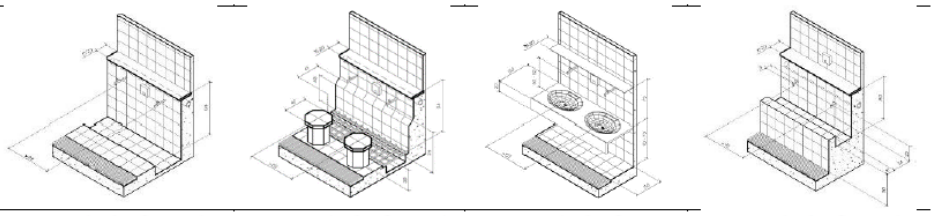
	Model 1	Model 2	Model 3	Model 4
Ablution Design				
Standard Features	Faucet / Platform / Top Shelf	Faucet / Platform / Top Shelf	Faucet / Platform / Top Shelf	Faucet / Platform / Top Shelf
Additional Features	Drain	Seat / Covered Drain	Lavatory / Pipe System Drain	Barrier / Drain

Figure 2. 8: Model of ablution design unit (Mokhtar, 2005)

It is clearly prove that design improvement needed in order to design an ergonomic ablution tub. Cross-section picture with falling water faucets to prevent splashing to user while perform Ablution (Nasharudin, 2008). The important factor need to re-design is the space distance between user and faucet including range between users while performing ablution. The right distance suggestion is defined on Figure 2.10, which give a suitable distance of measurement in accordance to perform ablution.

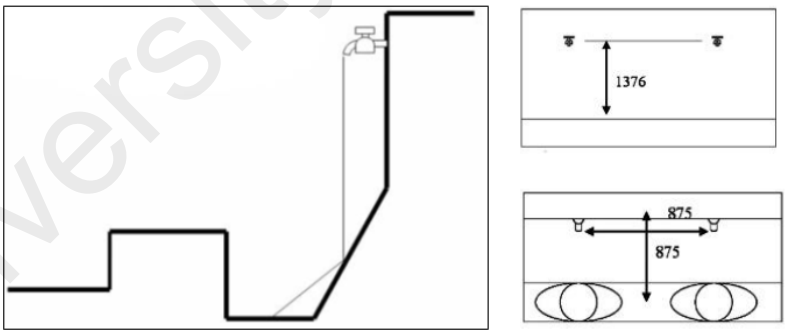


Figure 2. 9: Cross-section of falling water (left) and measurement of space distance between faucet and user (right)

2.5 Current Research on Back Postural Angle

Working postures and movements are addressed in almost every paper in the ergonomic field. Medical and ergonomic field studies indicate that bad standing and sitting postures are sometimes accompanied by pains in muscle and connective tissues

of tendons, joint capsules and ligaments. There is evidence that such pains can become the symptoms of chronic diseases attributed to rheumatic disorders. Recent orthopaedic research revealed that inadequate standing and sitting postures provoke excessive increases of intradiscal pressure. These orthopaedic findings, together with ergonomic investigations on sitting behaviour and somatic troubles, provide good bases for the construction of rest chairs and work seats (Grandjean, 1977).

The maintenance of static postures for prolonged periods of time compresses the veins and capillaries inside the muscles, causing microlesions due to the absence of tissue oxygenation and nutrition. All these factors can cause imbalance, fatigue, discomfort, and pain due to disruption of tissues. Trunk flexion (relative risk-RR of 1.72 for flexion ≥60◦ for more than 5% of working time/day) and rotation (RR of 1.57 for rotation ≥30◦ for more than 10% of working time/day), and weight lifting (RR of 1.79 for weight ≥25 kg for more than 15% of working time/day) were found to be risk factors for low back pain (Hoogendoorn, 2000).

There are distinct differences between men and women in terms of flexibility and extensibility whereas there is an insignificant difference between genders for the lumbar, also was determined by (Sullivan et al., 1994) that gender and age will affect the lumbar spine sagittal plane. Furthermore, it can be concluded that more motions occur at lower levels (L4-5, L5-S1) of the eighth vertebral column than upper levels during flexion and extension (Yamamoto et al., 1989). On other studies, it was found that elderly experience more neck flexion, shoulder angle, elbow angle and ulnar deviations compared to younger people (Hsiao & Cho, 2012).

2.5.1 Suggested Methods to Measure Postural Angle

Interpretation of any postural changes over time relies on an appreciation that during a reasonably limited period, the person's perception of comfortable erect posture

remains sufficiently constant that they can consciously stand with the same degree of spinal curvature when asked to assume such a position, even on occasions separated by a month or a year. Unless they can, there is no reliable basis on which to make a judgement about normalcy or abnormality, or about progressive improvement or deterioration of posture over time. To determine, over time, the degree of variability in spinal curvature and pelvic tilt on the requested assumption of a comfortable erect posture, several assessments were made (Bullock-Saxton, 1993).

Studies have found that the use of quantitative biomechanical measures are more precise and reliable. An advantage of direct measurements is that they provide detailed and accurate values for jobs with different work tasks (Kristensen, 2001). Inclinometers were introduced by Leighton in 1955. They function as pendulum goniometers or gravity dependent goniometers. (Williams, Binkley, Bloch, Goldsmith, & Minuk, 1993) noted that when one inclinometer is used to measure spine movements, the range recorded represents the sum of the spine, pelvic, and hip movements, and thus the two-inclinometer method should be preferred. (Miller et al., 1992) stated that inclinometer is not an ideal method of spine motion assessment, and (Mayer et al. 1996) found low intertester reliability for lumbar inclinometric motion measurements (with a mean error of 8◦).

However for Bullock et al (1987) and Bullock Saxton (1991) described that inclinometer is an extremely accurate instrument which measures the angle of inclination relative to the horizontal in order to provide measurement of thoracic and lumbar curvature. Postural alignment in the sagittal plane was measured by recording the degrees of spinal curvature in the thoracic and lumbar regions, as well as the degree of pelvic tilt. Measurements of the degrees of thoracic and lumbar curvature were made by reference to a formula which used an approach similar to that taken by Cobb (1960).

For example, the index or measure of curvature is represented by the angle calculated by subtracting the angle of inclination of the spine at T12 - Ll from the angle at Tl- T2 (Bullock et aI1987) as shown in Figure 2.11 below.

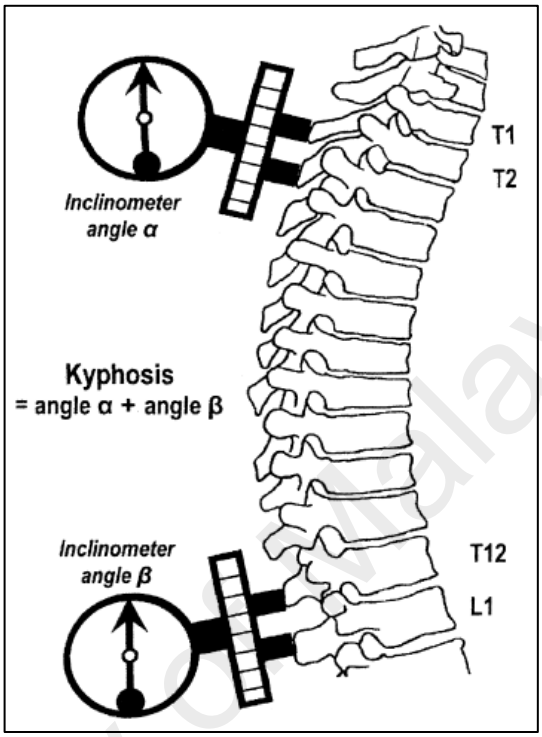


Figure 2. 10: *Placement of inclinometer by Bullock, 1987*

2.6 Summary

Based on the literature review, 50 years of age and older is used in this study as the general definition of an older person. Roebuck (1979) stated that old age is any age after 50 years old and this statement can be used as the definition of the elderly. Furthermore, in Malaysia persons who are aged 50 years old recorded about 5.9 million compared to 3 million for 60 years old out of 31.66 million of total population in 2016 based on the Population Quick Info, Department of Statistics Malaysia.

CHAPTER 3: METHODOLOGY

3.1 Introduction

It is crucial to design a methodology for the problem chosen. It outlines the procedures and experimental design, measurements and instrumentations, and data analysis of the study. Having a perspicuous methodology will guide directions and procedures to increase consistency and to create work which can be repeated elsewhere. Regularly, the project schedule is illustrated by using Gantt chart. The Gantt chart shows the start and finish dates of the tasks in one year period and summary of the project. In this study, it starts with investigating the current workstation which include measure the dimension and determine the mismatch. The improved design is proposed based on the anthropometric data of elderly in Malaysia. Next, the questionnaire was distributed among elderly to know their satisfactions about the existing workstation and opinions about the proposed design. Improvements were made and the design was tested by using RULA analysis in CATIA V5R21 to calculate the RULA score while performing ablution. Back postural angle of upper trunk and pelvic were recorded by using inclinometers.

The flow chart below shows the methods had been carried throughout the study.

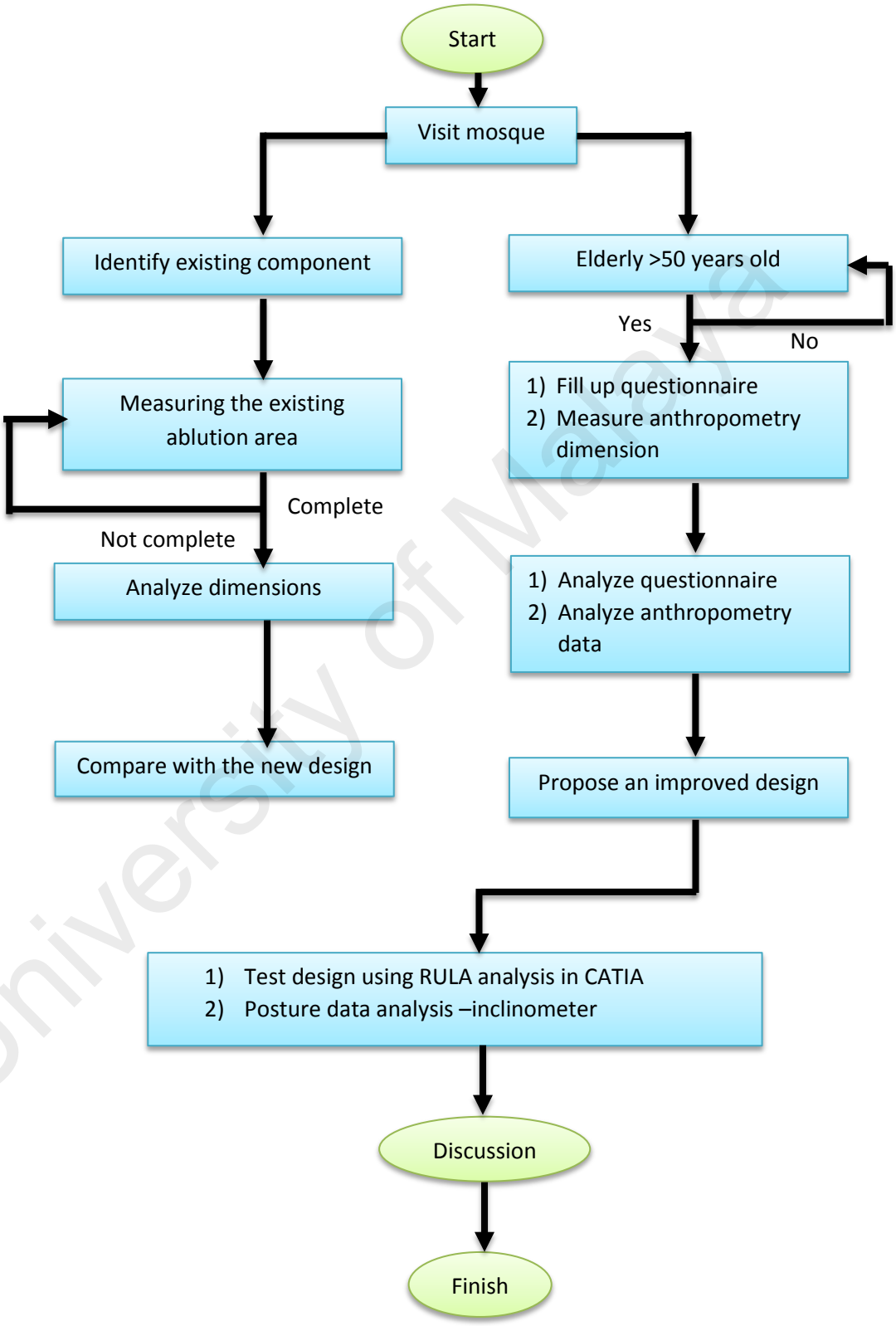


Figure 3. 1: Flow chart of the study

3.2 Evaluation of Existing Wudu' Workstation

For the evaluation process, two mosques in Wilayah Persekutuan Kuala Lumpur were selected; Masjid Wilayah Persekutuan (Federal Territory Mosque) and Masjid Negara (National Mosque). These two mosques can be said as the most famous and most visited by tourists and public because of their unique modern design and as the one of the beautiful sign of Islamic in Malaysia which embodies a contemporary expression of traditional art calligraphy and ornamentation.

The state mosques in Terengganu and Kelantan were chosen because of their majority of Muslim lived there. Masjid Abidin (Abidin Mosque) is an old state royal mosque located in Kuala Terengganu and also known as Masjid Putih (White Mosque). This sentimental mosque was built in 1793 with wood as the original building material. This mosque has provided seat for users to perform their ablution in sitting position.

Lastly, the ablution area at Masjid Muhammadi was chosen. Masjid Muhammadi is the state mosque of Kelantan which originally known as Masjid Besar Kota Bharu. At here, seats are provided to users for those who want to perform their ablution in sitting position.

The evaluation form is attached as in appendix as a guideline to measure the existing wudu' workstation. The standard measuring tape is used as an instrument to complete the measurement.

3.3 Samples

A total of 15 subjects (7 males and 8 females) of elderly aged above 50 years old were involved in this study. This study had been carried out mostly in Wilayah Persekutuan Kuala Lumpur and Selangor while several in Kelantan and Terengganu.

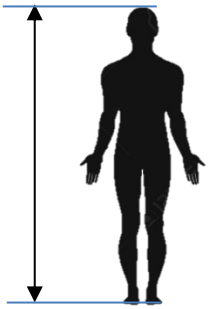
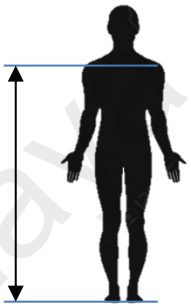
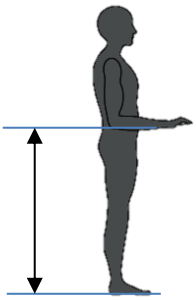
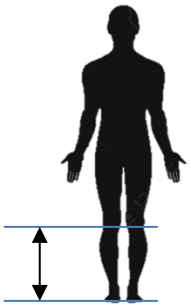
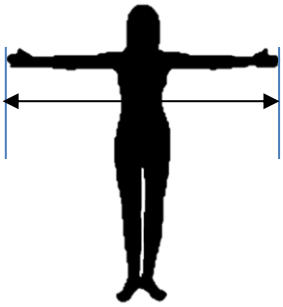
3.4 Anthropometry measurements

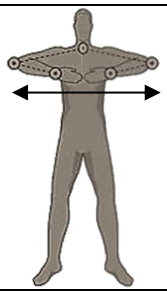
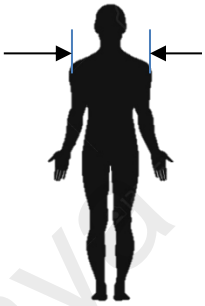
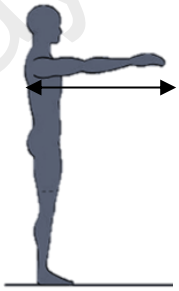
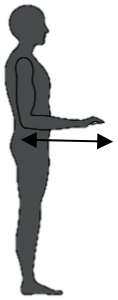
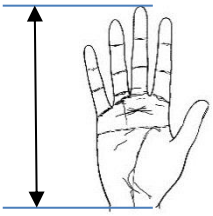
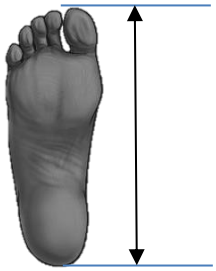
Anthropometry of the subjects was measured using a standard professional anthropometer (TTM Martin's Human Body Measuring Kit, Mentone Educational Centre, Carnegie, Australia), a sliding calliper, a weighing scale, a plastic measuring tape and an adjustable chair for sitting postures (see Figure 3.2).

Figure 3. 2: Anthropometer used to measure anthropometry measurements

There has been considerable work on the effect of ageing on functional capacities such as hearing, vision and physical strength in general, motor and sensory system, and so forth, physical body dimensions, that is, anthropometry, have remained relatively untouched. Apart from a few body dimensions such as height and body weight, there is practically no comprehensive anthropometric information on other body dimensions. According to Kelly and Kroemer (1990) there is no nationwide reliable anthropometric information available in the USA, especially on the dynamic anthropometry of elderly people. Some data on the elderly (e.g., Borkan, Hults, & Glynn, 1983; Damon & Stoudt, 1963; Juergens, 1984; Pheasant, 1986) are available in the literature but are limited in their applicability due either to their small sample size, selective population, or lack of wider demographic coverage. Table 3.1 below shows the 11 selected anthropometry measurement for designing the wudu' workstation.

Table 3. 1: Selected anthropometry measurement and description

No	Measurements	Description	Figures
1	Stature	Vertical distance from a standing surface to the top of the head	
2	Shoulder height	Vertical distance from the floor to the acromion	
3	Elbow height	Vertical distance from the floor to the lowest body point of the bent elbow	
4	Kneecap height	Vertical distance between the standing surface ant the center of the knee at the midpatella landmark	
5	Span	Distance between the tips of the third fingers when the arms are stretched out horizontally	

6	Elbow span	Distance between the elbows when the arms bent horizontally	
7	Shoulder breadth	Distance across the maximum lateral protrusions of the right and left deltoid muscle	
8	Arm reach forward	Distance between shoulder and fingertip when the arm is stretched out forward	
9	Forearm-hand length	Horizontal distance between the back of the tip of the elbow to the tip of the middle finger	
10	Hand length	Length of the hand between the stylion landmark on the wrist and the tip of the middle finger	
11	Foot length	Distance between the tip of the longest toe and the back of the hell of the standing foot	

For design purposes, two key parameters of the normal distribution are the mean and the standard deviation. The mean is the sum of all the individual measurement divided by the number of measurements. It is measure of central tendency. The standard deviation is calculated using difference between each individual measurement and the mean. The estimates of the mean and standard deviation can be calculated by using formula below:

$$\bar{x} = \frac{\sum_{i=1}^{n} x_i}{n}$$

$$s = \frac{\sum_{i=1}^{n} (x_i - \bar{x})^2}{n-1}$$

where, x = individual measurement

n = number of measurement

A low percentile is chosen in determining the maximum height of a product so that the smallest person will be able to reach it. The seat height must be no higher than the 1st or 5th percentile popliteal height in the population. Higher percentile, 95th or 99th percentile can be used to specify a minimum height of a product.

3.5 Propose an Improved Design

After collecting the anthropometry dimensions, all data must be analyzed and calculated to find the range of the dimensions. This method is implemented to avoid any anthropometric mismatches. Ergonomically designed workstation must be flexible and resultant static loading of the musculoskeletal system is to be avoided (Bridger, 1995). Flexibility implies that a person can carry out the task at least some of the time in more than one working posture. This design of wudu' workstation will be illustrated in 3D drawing using CATIA V5R21. When the design is ready, RULA analysis is done in the

same software to obtain the RULA score. The score will indicate the suitability of the design to the users.

3.6 Back Postural Angle Experiment

3.6.1 Experimental Workstation

The experimental workstation is set up (illustration as shown in Figure 3.3) at the Industrial Ergonomics Laboratory in Faculty of Engineering, University of Malaya. The wudu' workstation is placed at suitable spot to avoid any distraction for inclinometers. The workstation is fixed and subjects will perform their ablution at the same workstation.

Figure 3. 3: The illustration of wudu' workstation set-up during experimental procedure

3.6.2 Apparatus

The apparatus used in this experiment is the inclinometer (NORAXON USA, Inc). The system consists of several components which were attached to the participants in order to measure the postural angle during the ablution process. A brief description of each component is presented in the table below.

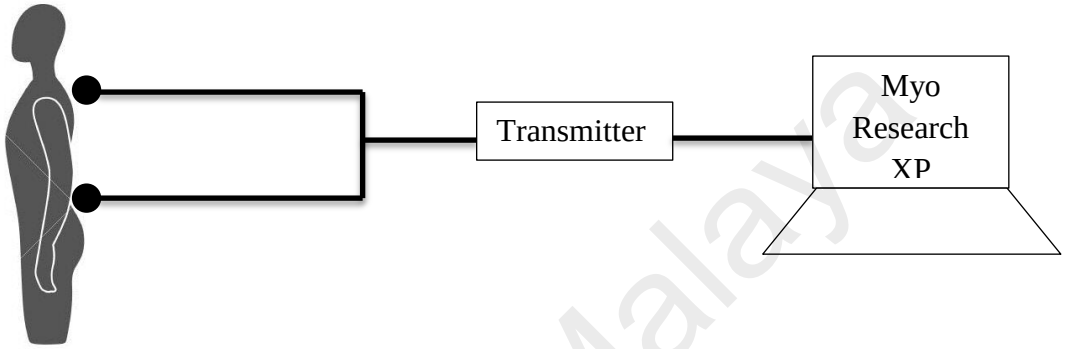


Figure 3. 4: Setup of inclinometer during the experiment

Table 3. 2: Components used during the experiment

Component	Description
 Inline 2D Inclinometer	• Inline 2D inclinometer sensors were used to record the postural angle of the upper trunk and pelvis. • The size of the inclinometer sensor is 3.05 cm (width) x 3.05cm (height) x 3.05cm (depth), with a weight of 45.5kg
 Transmitter TeleMyo 2400T G2-290	• Transmitter send real-time inclinometer signals by wireless transmission to a desktop • Sensors were connected to the TeleMyo 2400T G2-290 transmitter via the cable.

3.7 Experimental Task

The participants were required to demonstrate the ablution process especially for face cleaning, hand cleaning and foot cleaning. The process was repeated for three times to obtain good results of the postural angle of the upper trunk and pelvis. The illustration of participant performing ablution during the experiment is shown in figure below.

Figure 3. 5: Illustration of participant performing ablution

3.7.1 Placement of Sensors

Measurements of the back postural angles were recorded from the upper trunk and pelvis. Inclinometers were placed at the seventh cervical (C7) and fifth lumbar (L5). Forward head posture was determined by calculating the angle made between the horizontal and the tragus of the ear from C7 (Lewis, Green, & Wright, 2005). While the second inclinometer was placed at the L5 to measure the pelvic inclination and (Yamamoto et al., 1989 had concluded that more motions occur at lower levels (L4-5,

L5-S1) of the eighth vertebral column than upper levels during flexion and extension. Figure below shows the placement of the inclinometers during the experiment.

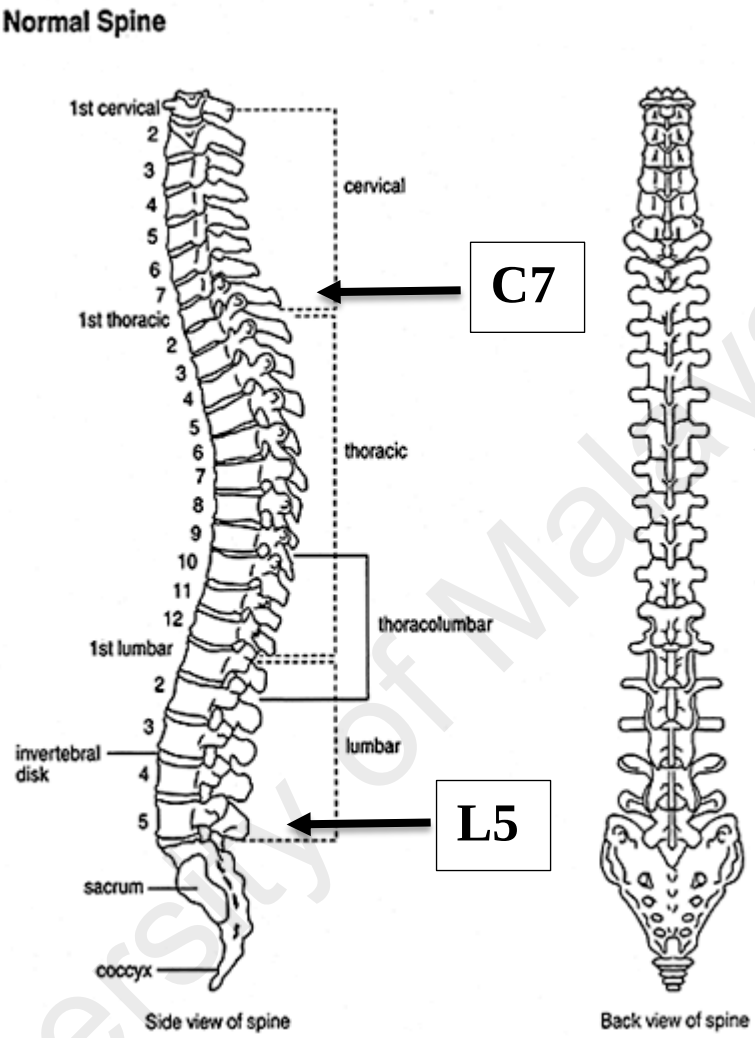


Figure 3. 6: Placement of inclinometer

CHAPTER 4: RESULTS AND DISCUSSION

4.1 Introduction

In this chapter, the measurements of ablution workstation of the four selected mosques were recorded in a table and were then analyzed. The data of the anthropometry dimensions were calculated to obtain the mean, standard deviation, 5^{th} percentile, 50^{th} percentile and 95^{th} percentile. The questionnaire had distributed and the results are presented in pie chart. Results are discussed critically in order to get the best solution to the proposed design in the next chapter.

4.2 Evaluation of Existing Wudu' Workstation

Figure 4.1: Ablution area at Masjid Negara, Kuala Lumpur

Figure 4.1 shows that the ablution area at the Masjid Negara which none of them provided any seat for people performing ablution for sitting position. The ablution area is located quite far from the main prayer hall and cause difficulties for elderly to

perform their ablution. The drain looked wider and the tap height is a bit shorter which can cause user to bend their body to reach the water tap. While Figure 4.2 shows the ablution area at Masjid Wilayah Persekutuan. This mosque mostly influenced by the Blue Mosque in Istanbul for its architectural styles.

Figure 4. 2: Ablution area at Masjid Wilayah, Kuala Lumpur

The left side of the figure is the ablution area for males while on the right side is the ablution area for females. Both are the same in terms of the dimension and design. The figure of the ablution station is quite similar as in Masjid Negara but in here it provided the flexible faucet which can be rotated horizontally.

The ablution area of Masjid Abidin is shown in Figure 4.3. This mosque has provided seat for users to perform their ablution in sitting position. However, they share the same height of the water tap for standing and sitting position. It might cause

difficulties for the standing users to perform their ablution because they need to bend their body to reach the water tap.

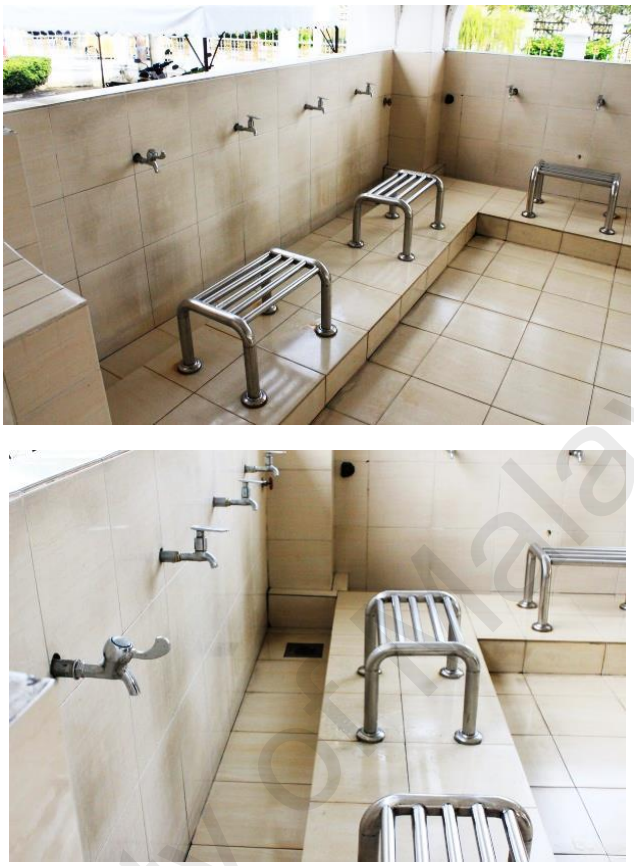


Figure 4.3: Ablution area at Masjid Abidin, Kuala Terengganu

Lastly, the ablution area at Masjid Muhammadi is the state mosque of Kelantan was measured. Figure 4.4 shows the ablution area for Masjid Muhammadi which originally known as Masjid Besar Kota Bharu. At here, seat are provided to users for those who wants to perform their ablution in sitting position. The water tap used is fixed and cannot be adjusted or rotated. The floor elevation (Figure 4.4 b) of the ablution area for males is a bit high and it can cause hazard with the slippery floor.

(a) Females

(b) Males

Figure 4. 4: Ablution area at Masjid Muhammadi, Kelantan

Table 4.1: The dimensions of existing wudu' workstation in Terengganu, Kelantan and Kuala Lumpur

No	Dimension (all dimensions are in cm)	Masjid Abidin	Masjid Muhammadi	Masjid Wilayah	Masjid Negara
1	Seat height	28	22	-	-
2	Seat width	47	36	-	-
3	Seat length	30	140	-	-
4	Tap height	69.5	63	58.5	50
5	Tap-to-user distance	30	40	39	48
6	Handrail height	-	-	-	-
7	Handrail-to-seat distance	-	-	-	-
8	Ablution point-to-point distance	57	63	77	92
9	Barrier height	-	-	17.5	-
10	Barrier width	-	-	33.5	-
11	Drain width	30	27	35	-
12	Barrier-to-user distance	-	-	-	-
13	Floor elevation	13.4	39	17.5	13
14	Foot step width (if seat not available)	-	-	33.5	50.2

Table 4.1 presents the dimensions of the ablution workstation of the four mosques. There are fourteen dimensions were selected to be measured and all dimension are calculated in cm. Based on the observation, there are seats provided in Masjid Abidin and Masjid Muhammadi but no seats available in Masjid Wilayah and Masjid Negara. The tap height is the crucial part of the ablution workstation which need to be highlighted because the posture of the users is depends on it. If the tap height is lower, hence the users need to bend their body to reach the water flow. When they bend too much, it will cause them to experience back aches especially for elderly. Figure 4.5 shows that Masjid Negara has lower tap height compared to other mosques. The dimension is 50 cm, while in Masjid Abidin the dimension is 69.5 cm. To avoid the back pain the water tap must be located above the standing elbow height which leads the user to stand comfortably while performing their ablution.

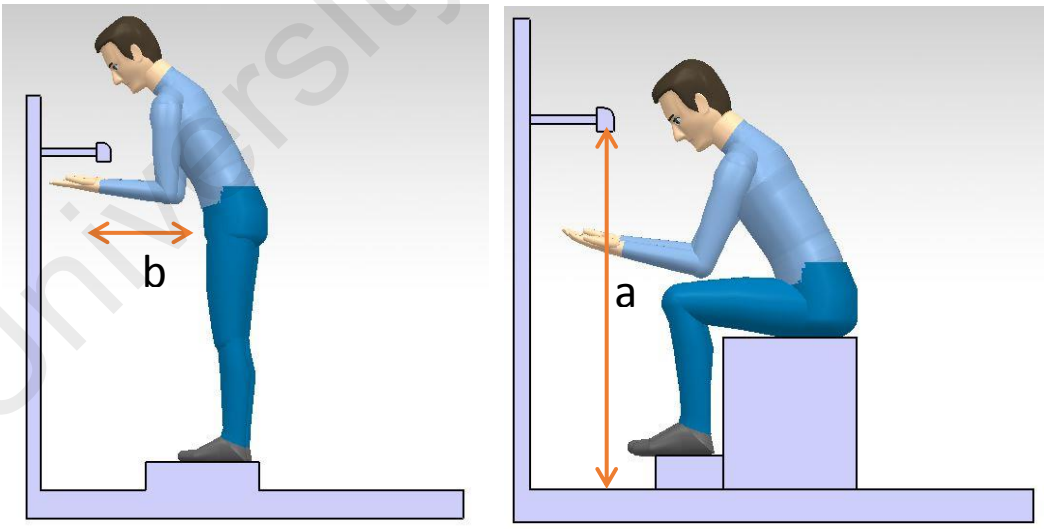


Figure 4. 5: The illustration of wudu' workstation. (a) Tap height and (b) Tap-to-user distance

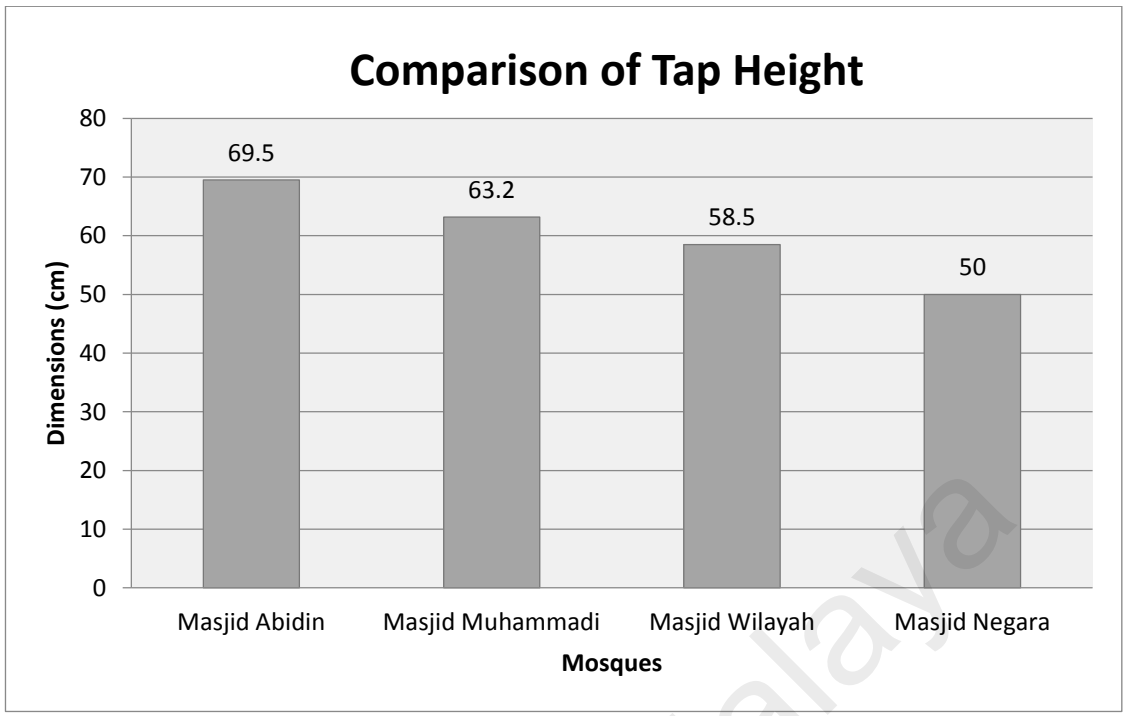


Figure 4. 6: Comparison of tap height

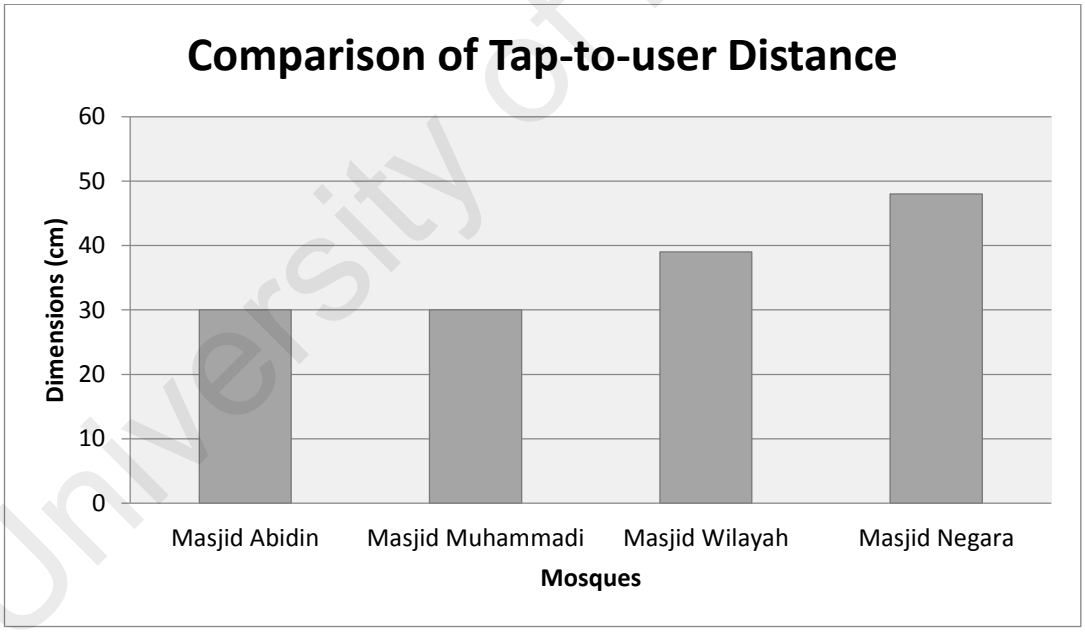


Figure 4. 7: Comparison of tap-to-user distance

The tap-to-user distance can be categorized as one of the important dimensions in designing the wudu' workstation. The farther the distance the more difficult the users to reach the water tap. The water tap must be accessible by users to provide user-friendly facilities and increase the user's satisfaction. The distance must be shorter than

the dimension of arm reach forward. If it is too near, it can cause discomfort and increase the amount water splash to users.

4.3 Anthropometry Measurements of Elderly

For this project, elderly aged above 50 years old is qualified to participate in measuring anthropometry dimensions. There are 15 participants (7 males and 8 females) of elderly involved in this measuring process. However, the data collected had been added up to the existing elderly anthropometry data from (Dawal, 2014) to become 187 for total participants (91 males and 96 females). Table 4.2 presents the 11 anthropometry dimensions of elderly related to ablution workstation.

Table 4. 2: Anthropometry dimensions of elderly

		Male (N=91)					Female (N=96)				
		Mean	**SD**	**5th**	**50th**	**95th**	**Mean**	**SD**	**5th**	**50th**	**95th**
1	Stature	158.81	7.52	145.39	160.00	169.38	147.88	6.91	135.32	148.00	159.02
2	Shoulder height	132.37	6.09	121.53	133.35	141.94	121.81	5.75	111.64	121.60	129.70
3	Elbow height	100.40	9.74	89.48	98.90	115.10	91.36	5.23	83.00	91.40	99.34
4	Kneecap height	45.51	3.33	40.61	45.55	50.92	44.55	4.97	38.10	44.40	51.58
5	Span	160.02	16.35	135.69	163.05	174.02	148.68	10.87	132.00	150.10	163.90
6	Elbow span	81.96	6.05	69.07	83.05	91.05	73.29	7.47	59.72	74.40	82.30
7	Shoulder breadth	21.08	1.97	18.95	22.05	22.83	22.22	4.88	16.21	24.35	27.09
8	Arm reach forward	78.98	7.09	71.19	78.90	86.73	72.69	4.90	64.08	73.40	79.39
9	Forearm-hand length	43.70	4.13	35.73	44.50	47.92	40.46	5.48	26.02	41.70	45.70
10	Hand length	17.74	1.82	15.30	17.90	19.75	16.66	1.13	15.28	16.70	18.33
11	Foot length	23.83	1.30	21.54	24.00	26.22	22.11	1.33	19.64	22.10	24.30

In designing the workstation, anthropometry measurement is important as a guideline to set the best dimension for the workstation. The wrong dimension will cause users experience discomfort and can lead to muscle fatigue. To avoid the users to bend their body, water tap must be placed higher than the standing elbow height and not higher than the shoulder height (in between 90cm to 120cm). Kneecap height is used for placing the lower water tap for foot cleaning purposes. Hence, it should be not exceed 44.5cm (the mean value of female anthropometry). To maintain the comfort environment during performing ablution, ablution point-to-point distance needs to be considered. This distance can be determined by looking at the span dimension of the anthropometry measurements. If the distance is quite close, users may have limited space to move while performing ablution.

Figure 4. 8: Measuring anthropometry of elderly

4.4 User Satisfaction Survey

The survey form had distributed randomly to 50 elderly from different background. The purposes of this survey is to seek opinions for improvements and user's satisfaction about the existing wudu' workstation. It includes the preferable posture, handrail and splash barrier. Questions asked were related to their experiences on corresponding to the ablution workstation and the potential abilities and limitations to the function of the workstation.

4.4.1 Sample Demographic Data

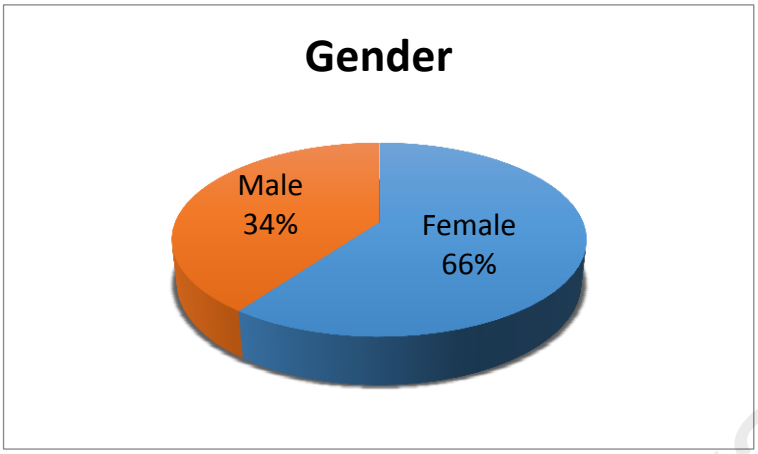


Figure 4. 9: Percentage of respondent's gender

The survey was distributed randomly and as shown in Figure 4.8 female respondent is 66% while 34% is male. Respondent was selected at public area, mosques and residential area. Figure 4.9 shows that the distribution of respondent's age which majority of them are elderly aged 70-79 years old followed by 50-59 years old. Even though elderly in Malaysia is defined as person aged 60 years old and above, in this study persons aged from 50 years old were included as taken from previous study by Dawal et al. (2015) which considered 50 years old and above as elderly.

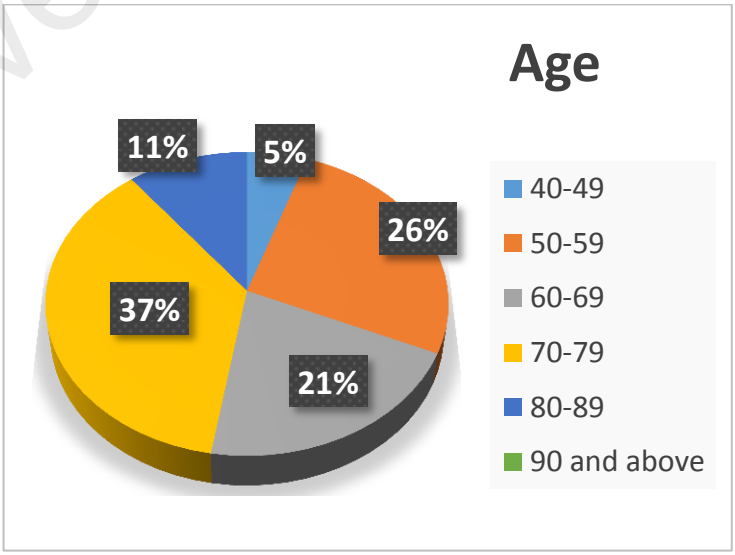


Figure 4. 10: Number of respondents based on their respective ages

Based on the data, 69% of the respondents were aged 60 years old and above and the left are below than 60 years old. About 5% of the respondents are aged above 80 years old and none of them are more than 90 years old involve in this survey.

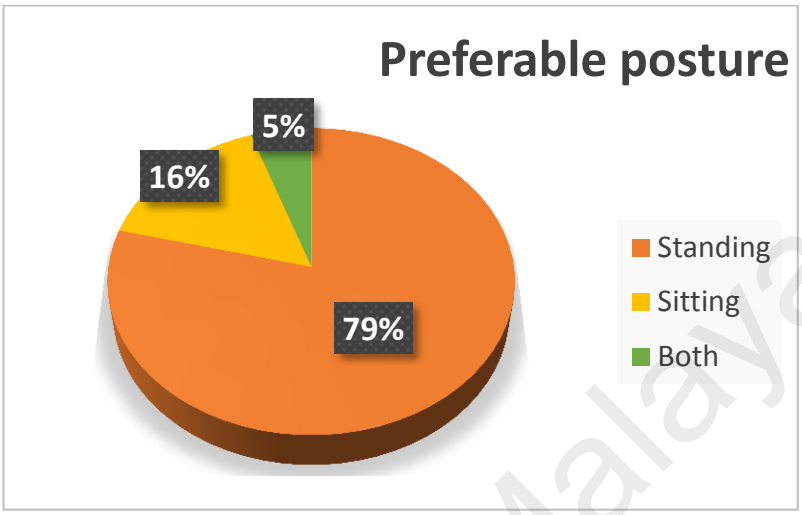


Figure 4. 11: Percentage of preferable posture chosen by elderly

Based on Figure 4.10, respondents are likely to prefer performing their ablution in standing position. 79% of them said that, they are more comfortable to perform ablution while standing instead of sitting, because sometimes the seat provided are not user-friendly. Most of them preferred to sit if they have problem to prolong standing or difficulties to balance their body during ablution.

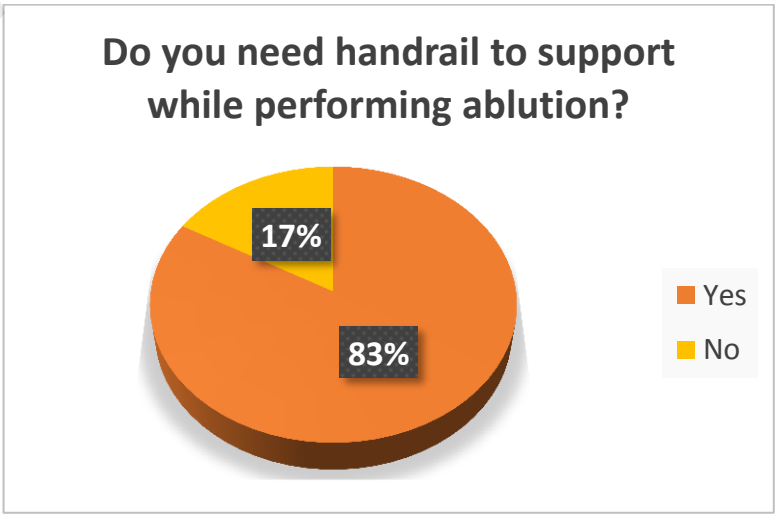


Figure 4. 12: Percentage of elderly who preferred the handrail to support them

Figure 4.11 shows that the percentage of elderly who need handrail as a support while they are performing the ablution. Majority (83%) of them are preferred that they need support materials such as handrail for them to keep balancing during ablution. Some of the ablution areas did not provide any support materials and cause users to fall.

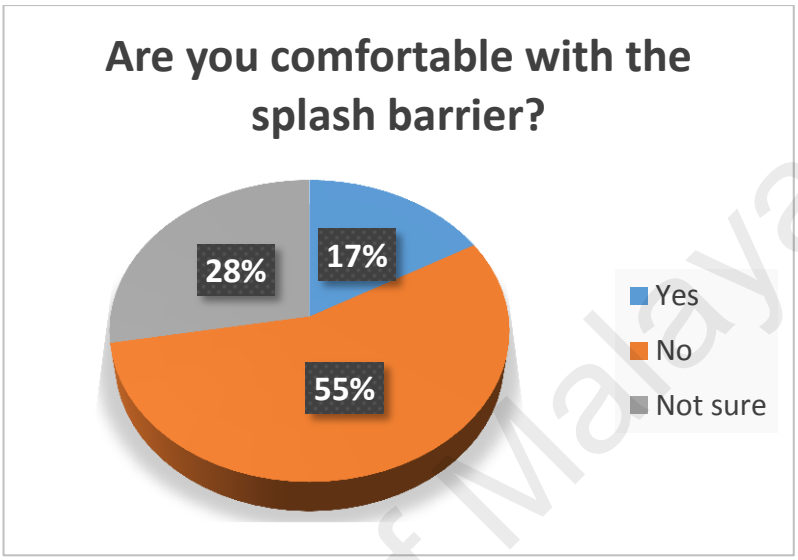


Figure 4. 13: Percentage of the respondents experienced the splash barrier

Many of elderly are not comfortable with the splash barrier. Based on Figure 4.12, 55% of the respondents agreed that they have difficulties with the splash barrier. The long width of splash barrier will cause the users to distance themselves from the water tap and difficult for them to reach the water tap. This condition will lead to awkward posture and causes discomfort to users. However, the presence of the splash barrier is to reduce the amount water splash to users. But, the design and the dimensions of the splash barrier are still inadequate and need to be improved to provide a safe and comfortable wudu' workstation.

CHAPTER 5: PROPOSE THE IMPROVED DESIGN

5.1 Introduction

Another objective in this study is to propose an improved design of an ergonomic wudu' workstation for elderly in Malaysia based on the anthropometry dimensions obtained in this study and previous study by Dawal et al, (2015). Discomfort workstation will lead to health problem related to muscle and body strength. In this chapter, the improved design is proposed and then tested by using RULA analysis in CATIA V5R21. As an initial test, inclinometer was used to record the angle of upper trunk and pelvic of elderly during performing their ablution.

5.2 Improved Design of Wudu' Workstation

Dimension of the wudu' workstation is proposed based on elderly anthropometry dimension discussed in previous chapter. Based on the survey, 79% of the users prefer to stand when to perform their ablution. Hence, the proposed design is focus on the standing wudu' workstation for elderly. The wudu' workstation is divided into two parts which include upper part for face and hand cleaning and lower part for foot cleaning. The sink is designed to reduce water splash to user rather than it falls to the floor. The reduced distance of falling water can reduce the splash to users. The distance between the water tap and the sink is calculated and the dimension is 45cm based on the forearm-hand length. The sink height is referred to the standing elbow height which concluded to be 95cm from the floor. The foot shower should not exceed the dimension of the kneecap height. This is to allow users to wash their feet comfortably with the dimension of 65cm from the floor and the shower head is flexible to give extra comfort to users.

The drain is designed with a slope to prevent maximum splash to users. The slope is about 5˚ from the floor with a splash barrier of 45cm from the wall.

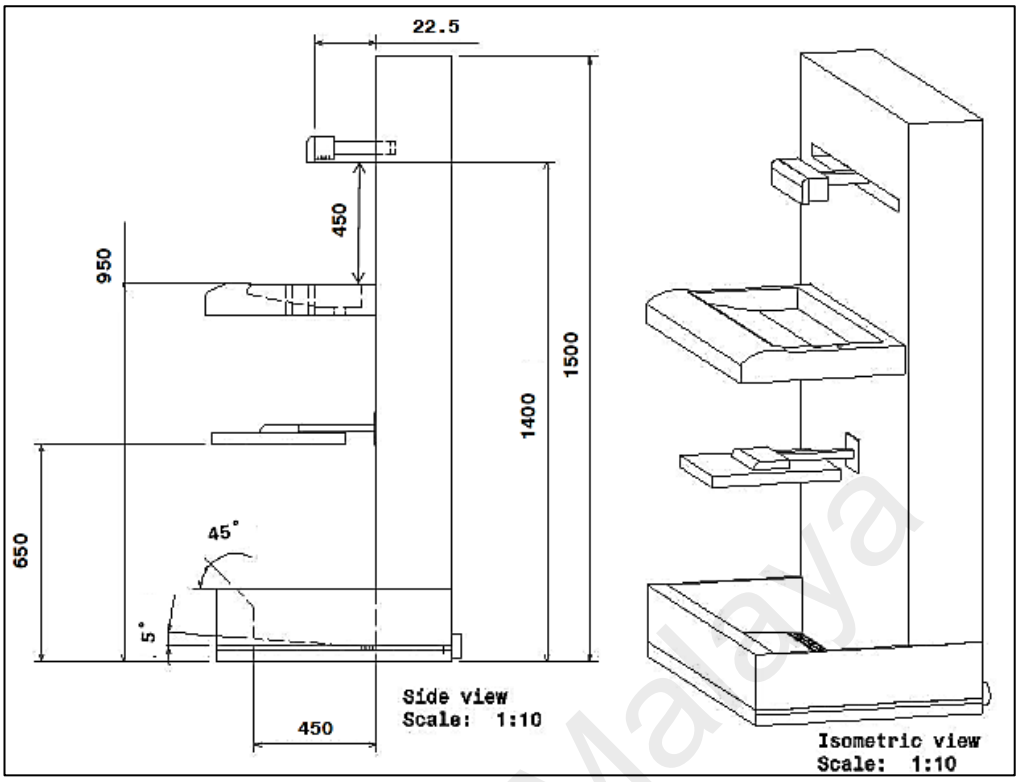


Figure 5. 1: Proposed dimension of the wudu' workstation

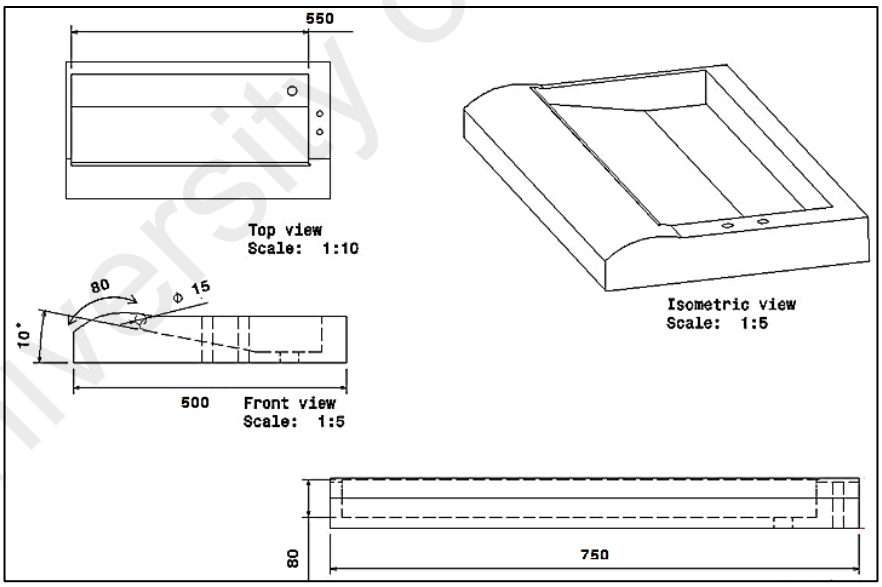


Figure 5. 2: Proposed sink design for the wudu' workstation

The sink is designed also with the slope of 10˚ to reduce wet experienced by users. Figure 5.2 shows the design of the proposed sink with the dimensions. The width of the inner sink is 55cm based on the arm span of the anthropometry measurements. The

curved design at the front of the sink is designed for them to grip well while performing ablution as shown in Figure 5.4. The length of the sink is 50 cm based on the forearm-hand length.

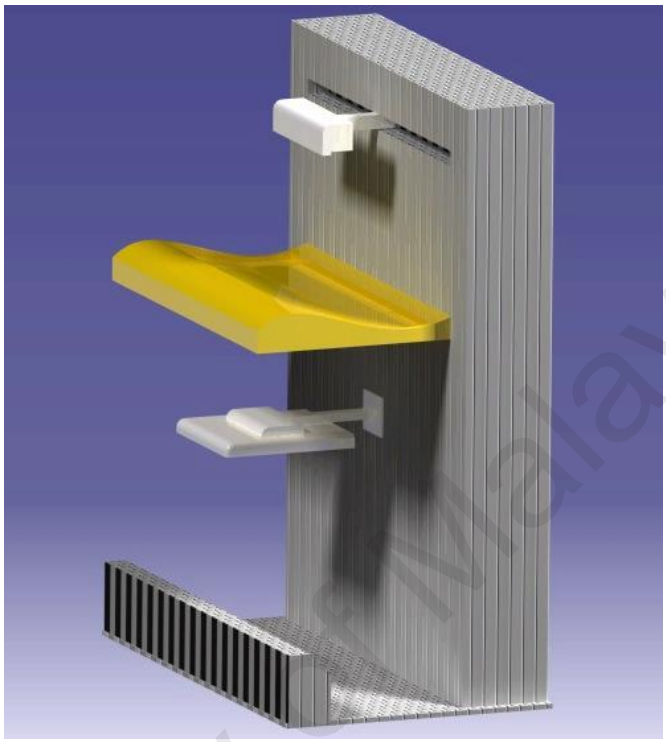


Figure 5. 3: The proposed design of wudu' workstation for elderly

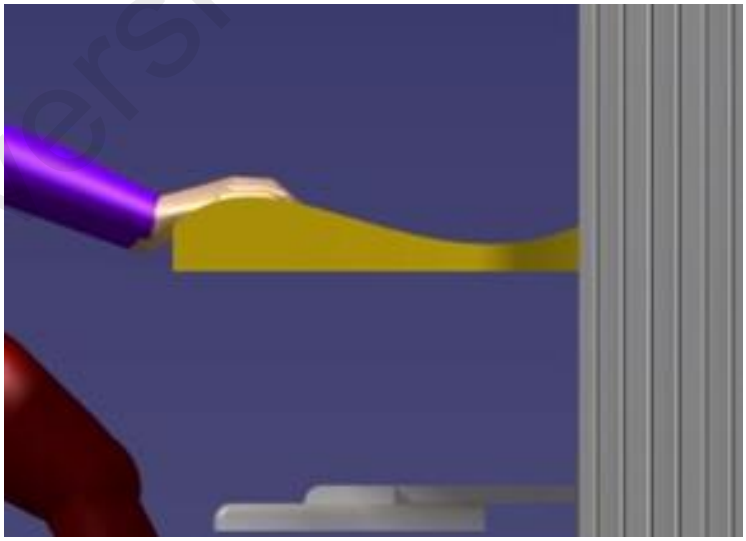


Figure 5. 4: Curved design for extra grip

Figure 5. 5: The prototype of the wudu' workstation

5.3 RULA Analysis of Proposed Design

RULA provides a quick analysis of demands on a person's musculoskeletal system when performing a specific task. It involves assessments on neck and upper limb loading in mainly sedentary tasks (repetitive tasks). The outcome of the analysis presents the exposure of individual workers to risks associated with work-related upper limb disorders. It examines risk factors such as number of movements, static muscle work, force, working posture, and time worked without a break. All these factors combine to provide a final score that ranges from 1(Good) to 7(Worse). In this study, the software used for RULA analysis was CATIA V5R21. The following are the parameters used for RULA analysis:

1) Posture: Intermittent
2) Repeat Frequency: Fewer than 4 times per minute
3) Worker's posture:
    a. Arms are working across midline: No
    b. Check balance: No

4) Load: 0.
5) Manikin: Japanese (Asian, closely resembling to Malaysians (Not listed in software)), male, weight 69 kg and stature 159cm approximately.

According to above parameters, a manikin is built under human builder module in CATIA as shown in Figure 5.6, 5.7 and 5.8. There is no load exerted because no lifting required.

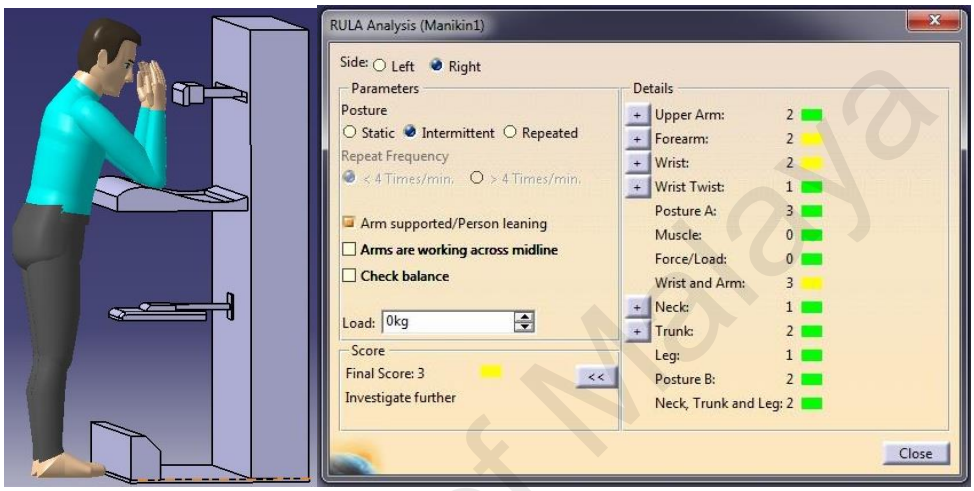


Figure 5. 6: A model posture during face cleaning

This posture shows the step of face cleaning in completing the ablution. The score is 3 and resulted in yellow colour that indicates further investigation is needed and changes may be required. The results show that the posture while performing the wudu' (ablution) is in good condition and further investigation is needed for any changes. The overall analysis indicated that the design is still acceptable but an investigation is needed to improve on the working posture to reduce any discomforts.

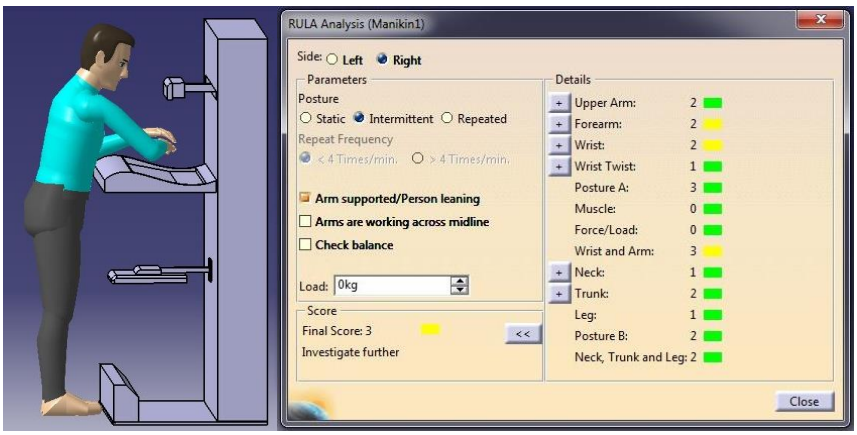


Figure 5. 7: A model posture during hands cleaning

This figure presents the step for hands cleaning. The posture scores the same value, 3 and resulted in yellow colour. The posture will not cause any hazardous and there is no need for immediate investigations and changes. However, the results indicated that further investigation is needed to improve the posture and reduce difficulties for elderly to perform their ablution. The significant body parts that need to be improved are neck, trunk and leg. The results highlighted that the design of the workstation might be the reason of discomfort postures and the anthropometry dimensions should be taken into thorough consideration in planning to improve the design.

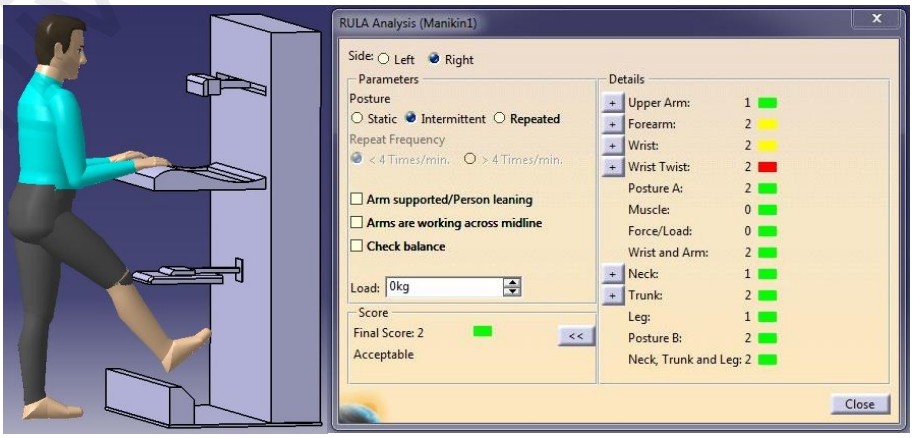


Figure 5. 8: A model posture during foot cleaning

This is the posture for foot cleaning in ablution. It scores 2 which resulted in

green colour. The green colour indicates that the posture is acceptable. It can be maintained or repeated for long periods of time and no changes are required for improvements. This posture will avoid any discomfort of elderly in order for them to perform their ablution.

5.4 Postural Angle Using Inclinometer

Table 5. 1: Angle recorded by inclinometer for upper trunk and pelvic during performing ablution

Upper trunk angle (˚)						
Subjects	Tasks					
	Face Cleaning		Hands Cleaning		Foot Cleaning	
	x	*y*	*x*	*y*	*x*	*y*
1	-0.699	1.955	0.869	6.453	13.736	20.373
2	-3.419	6.148	-3.140	0.799	-0.654	-2.190
3	-6.889	25.257	-10.802	26.622	1.006	28.446
4	16.239	3.654	13.367	7.750	12.298	3.393
Pelvic angle (˚)						
Subjects	Tasks					
	Face Cleaning		Hands Cleaning		Foot Cleaning	
	x	*y*	*x*	*y*	*x*	*y*
1	-6.006	6.943	-10.767	15.127	-2.071	9.892
2	6.763	4.315	5.968	3.765	-18.110	-2.595
3	-2.237	3.357	-8.822	2.875	-11.643	-7.719
4	-17.906	12.273	-15.870	15.712	-41.451	1.764

Table 5.1 presents the recorded angle of the upper trunk (seventh cervical) and pelvic (fifth lumbar) of the four subjects while performing ablution. They are required to perform only three tasks of the ablution which are face cleaning, hands cleaning and foot cleaning. The results show that they experienced more flexion and extension during the foot cleaning. This is because they have to bend their body to reach their feet and rub water all over the skin. Some of them are not able to do that because of the distraction by the sink. A positive value indicates the upper trunk flexion and forward rotation of pelvis, while a negative value indicates upper trunk extension and backward rotation of the pelvis.

CHAPTER 6: CONCLUSION

6.1 Introduction

The number of elderly is kept on increasing year by year which shows 6% increment in 2013 and 2014. The increased population is because of the high awareness of healthy lifestyles and the decline of the fertility and mortality rate. The Muslim population is also increased globally and population of Muslim in Malaysia is the third largest Muslim population in Southeast Asia after Indonesia and Brunei. Therefore, it is crucial to develop an innovative facility such as an ergonomic wudu' workstation to accommodate the elderly especially for Muslim populations. In this study, some suggestions and improvements had been made to provide a comfortable wudu' workstation for elderly especially in Malaysia.

The significant anthropometry measurements in this study are stature, shoulder height, standing elbow height, kneecap height, span, elbow span, shoulder breadth, arm reach forward, forearm-hand length, hand length and foot length. These measurements are very important and need to be considered critically in designing the wudu' workstation. Based on the survey, 79% of the elderly prefer to stand when performing their ablution because it is easier and quicker way.

The improved design of the sink with a curved shape allows the user to have extra grip to hold onto the sink. It can act as a handrail and usually they hold it during foot cleaning to keep balance. The proposed dimension is to provide extra accessibility to the users and to reduce awkward posture during ablution. The inclinometer recorded that user experienced more flexion and extension during foot cleaning because they need to bend down their body to reach their feet.

Finally, anthropometry dimensions are very important in designing the wudu' workstation. The proposed design had followed the mentioned dimensions with additional features to make the workstation more innovative.

6.2 Recommendation

This study can be considered as a preliminary study and guideline for future design of the wudu' workstation. The number of samples for anthropometry measurements can be improved for future studies. Postural angle done in this study can be considered as an initial test and is encouraged to do more testing. The number of the participants must be added up to determine the significant angles and the best posture for ablution. The evaluation of the existing wudu' workstation must include the public area such as highway rest area and shopping complex.

For future design, it can be improved in terms of the mobility and portability of the workstation. Furthermore, it can be considered to facilitate the elderly in hospital as well. The foot shower can be improved so that users can wash their foot without any problems especially when bending their body.

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