Original Article

Development of Normative Data for Grip Strength between Genders of Malaysian Working-Age Population: Preliminary Study

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ABSTRACT: *An increasing number of Musculoskeletal Disorders (MSDs) cases in Malaysia affect work task efficiency. There are many guidelines on the control and prevention of MSDs issues. In this study, the researcher encourages MSDs prevention at an early stage by designing tools or products that ergonomically fit the user to create a comfortable and productive workplace while preventing discomfort. Therefore, this study aims to establish normative data of handgrip strength and pinch grip strength for Malaysian working-age group in both genders. The data is practical to be applied by all designers in developing tools that healthy and ergonomic. For the method, the Baseline Digital Smedley Dynamometer is used to analyze handgrip strength. Baseline Hydraulic Pinch Gauge follows the lateral pinch type method to analyze the pinch grip strength. The result shows that males are significantly stronger than females. Analysis across the age groups found that mean score of female handgrip are equivalent of lower than the lowest 5th percentile value of male handgrip. this study also found that male are at their strongest across the age group, the 5th percentile value of males is greater than the mean score of female handgrip strength, male at their strongest in their thirties while females are strongest at their age below 20 years old. Normative data of grip strength is established in this study.*

Keywords: *Anthropometry, Design, Ergonomics, Gender, Grip Strength, Musculoskeletal Disorder*

1.0 INTRODUCTION

Poor workstation or equipment design may cause musculoskeletal disorders (MSDs) in the area of shoulder, neck, nape, hand, and waist (Kalınkara et al., 2012). According to the Social Security Organization of Malaysia (SOCSO), MSDs cases have increased steadily over the year with 268 cases in 2011, 449 cases in 2012, 517 cases in 2013, and increased to 675 cases year 2011 (Hassan et al., 2015). MSDs are classified into six groups, including 1. Nerve Entrapment Disorders, 2.Occupational Disorders of the Neck and Brachial Plexus, 3.Shoulder disorders, 4.Tendonitis of the Elbow, Forearm, and Wrist, 5.Hand-Arm Vibration Syndrome and 6.Low Back Disorders (Anghel & Lungeanu, 2007). The upper limb was the major part of the body affected primarily involving the hand, wrist, fingers, and shoulder, such as Carpal Tunnel Syndrome (CTS), which has become common work-related injuries to MSDs (Tamrin & Zakaria, 2016). Many of these problems contribute to poor ergonomics. Ergonomics is the science of designing work tasks to fit the worker while considering the human body's capabilities and limitations

(Moriguchi et al., 2013). It is related to the worker's interaction with tools, equipment, environment, jobs, tasks, work methods, work rates and other systems (Bridger et al., 2018; Moriguchi et al., 2013; Bridger, 2009).

The increasing number of MSDs in Malaysia alerted the Department of Occupational Safety and Health (DOSH) and local universities to focus more on MSDs risks (Anwar et al., 2019; SOCSO, 2018). However, many companies still have not considered ergonomics a critical issue (Sirat et al., 2011). Although DOSH has provided some solutions to control hazards, the guidelines were based on industry or task-specific solutions (Sirat et al., 2011), which is not enough to prevent the MSDs issues among workers. Therefore, it is essential to study MSDs risk factors and prevention methods, especially for Malaysians. As suggested by the Occupational Safety and Health Administration (OSHA) ergonomic guideline, a load's weight should be reduced to limit the force exertion to reduce injury chances. Therefore, the tools should be redesigned to fit the workers' ability and encourage a neutral posture to prevent MSDs.

Anthropometry is the science of obtaining systematic measurements of the human body. Ergonomic problems related to fitting the work task or tool to the users can be solved by including the anthropometry element at the design stage to reduce the ergonomic risk factors to the user. Strenuous movements or awkward postures at workplaces are mostly due to incompatible anthropometric data and workstation design (Deros et al., 2011; Seri et al., 2013). Recently in Malaysia, anthropometric studies have become the most significant discussion among ergonomists, anthropometrists, and researchers (Nurul Shahida et al., 2015; Hassan et al., 2015; Hashim & Dawal, 2012; Karmegam et al., 2011; Deros et al., 2011 and Rosnah et al., 2006). Karmegam et al. (2015) conducted a study on anthropometry among adults of different ethnicities in Malaysia. They measured 33 anthropometrical dimensions on 300 respondents for both males and females. They also suggested that designers consider ethnicity when designing for the Malaysian population (Karmegam et al., 2011). Hassan et al. in 2015 developed an anthropometric database for Malaysian workers. They took 23 static anthropometric dimensions of 1134 Malaysian workers and suggested that designers use the database for guidelines in designing for a safer and healthier workplace for Malaysian workers.

Previous studies had included grip strength as one of the anthropometric dimensions (Nikolaos, 2015; Taha and Nazaruddin, 2005). The grip strength data can help the designer to design tools or equipment that will fit the workers. The tools developed by the designer must apply optimum force based on the normative data of the grip strength to prevent overuse injuries. The principle of prevention through design may reduce the risk of MSDs, especially among workers. Taha & Nazaruddin (2005) developed models using an artificial neural network to predict Malaysian industrial workers' grip strength. Their study found that grip strength data is useful to the designer and can be used by the physician to measure the normal grip strength. In 2009, Werle and colleagues conducted a study in an average Swiss population aged 18 to 96 to obtain normative data of grip and pinch strength. They stated that the data could be used for hand assessment parameters to evaluate the hand's functional integrity, determine the effectiveness of different treatment strategies in traumatic hand diseases, and hand strength assessment (Werle et al., 2009). Some studies have endorsed handgrip strength as a tool to measure whole-body strength (Nikolaos, 2015; Taha and Nazaruddin, 2005). Some also used grip strength as a benchmark to evaluate muscle weaknesses.

McCaffrey and LeFebvre (1999) published a protocol on Dynamometer (Grip) and Pinch Gauge use. In the protocol, selected indicators for grip dynamometer include grip weakness and MSDs. Some pinch gauge indicators include suspected weakness of the thumb or fingers and Basilar arthritis of the thumb and ulnar nerve palsy (McCaffrey & LeFebvre, 1999). Anthropometry also considered humans' human mass properties and strength capabilities (Wilson & Desai, 2017). Thus, static strength such as grip strength should be considered essential data to solve the ergonomic issues. Massy-Westropp et al. (2011) conducted a longitudinal cohort study of the Australian population aged 18 and above. Their study aimed to describe normative data for the handgrip. The Australian population showed a lower grip strength in younger participants compared to international hand grip strength norms from the study. The study also reported that the age and gender grip strength values are lower in younger adults than those reported in the international literature (Massy-westropp et al., 2011). It can be concluded that different populations have their normative data for grip strength, and the data also different based on gender and age.

Therefore, this study aims to establish normative data of handgrip strength and pinch grip strength between genders for the Malaysian working-age population. The data might be useful for industrial designers where the MSDs preventions can be done at the design stage. Besides, the data can also be used for the physician for rehabilitation purposes, set realistic treatment goals, and assess the patient's ability to return to work (Gallagher et al., 2000). The previous studies showed that handgrip tests and pinch grip tests are often used to evaluate the hand's physical ability and detect MSDs especially CTS (Maranhao Neto et al., 2017; Dale et al.; Sung et al., 2014). In their study, Dale et al. (2014) found that male and female new workers in high and low intensive handwork have low baseline hand strength compared to normative data of Caucasian adults (Lam et al., 2016). There is no documentation on normative data for grip strength on the Malaysian working age in Malaysia yet. Thus, this preliminary study is significant for ergonomic study in Malaysia.

2.0 METHOD

2.1 Sample Selection

Respondents were voluntarily recruited from all over Malaysia between June 2018 and June 2020. The respondents were given a short briefing before starting the measurements regarding the study's objectives and the measurements. The respondents then fills up the consent form and the demographic data needed for the study. Malaysian with a working-age range between 18 to 69 years old were included in this study. On the day of measurement, respondents must have a healthy body. Respondents were excluded from the study if they are foreigners, out of age range, unhealthy and pregnant. All the respondents were included in this study because had declared that they had no acute pain in their arms, back, and hands, at least six months' post-hospitalization, and can continue to carry on a normal lifestyle without restriction in their activity because of health problem.

2.2 Procedure

2.2.1 Handgrip Strength Test

The Baseline Digital Smedley Dynamometer was used to measure Handgrip strength (Mathiowetz et al., 1985). The handgrip strength test procedure was adapted from the Duke Center for the Study of Aging study (2017). The respondents hold the dynamometer in one hand, standing in an erect position while the same arm extended along the body. The equipment's grip will be adjusted accordingly to ensure that the respondents exerted force by only the last four phalanges to the handle. The respondents perform a maximal strength three times (Dale et al., 2014; Nilsen et al., 2012) for both right and left hand. Both dominant hand and non-dominant hand data will be taken into account for the analysis. The highest strength was recorded.

Figure 1 Respondent Gripping the Baseline Digital Smedley Dynamometer during Hand Grip Strength Test

2.2.2 Pinch Grip Strength Test

For the pinch grip tests, the Baseline Hydraulic Pinch Gauge-Standard-50 lbs (22.6796 kg) Capacity was used using the lateral pinch type to obtain the measurement (Kong et al., 2014). As shown in Fig. 2, the respondents hold the pinch gauge with the thumb, and the index finger's lateral side come into contact. During the test, the researcher would hold the dynamometer's levers so that the respondents's forearm and hand are parallel to the ground (Kong et al., 2014). The test was conducted for both right and left hand for three trials (Dale et al., 2014; Nilsen et al., 2012). Similar to the handgrip strength test, both dominant hand and non-dominant hand data will be taken into account for the analysis. The measurement unit was in kilograms (kg). The highest strength was recorded.

Figure 2 Respondents during Pinch Grip Strength Testing Using Baseline Pinch Gauge Hydraulic Standard 50 lbs

2.2.3 Statistical Test

Independent t-tests were used to determine the statistical differences for weight, height, handgrip strength, and pinch grip strength between male and female respondents. Means and standard deviations were calculated to establish the central tendency and dispersion of all the variables. The 5th and 95th percentile values of the handgrip and pinch grip strength tests were also presented. The study's significance level was set at $\alpha < 0.02$ (Cochran & Wiley, 2017).

3.0 RESULTS

The independent t-tests for age, height, weight, age group, and grip strength for all respondents are shown in Table 1. Height, weight, handgrip strength, and pinch strength were summarized in mean, standard deviation (SD), fifth, and 95th percentile values. A normality test was performed for the data distribution.

Table 1 Normality Test for All Variables

	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
Gender	0.366	1485	0.000	.633	1485	0.000
Age Group	0.186	1485	0.000	.924	1485	0.000
1. Hand grip Dominant	0.070	1485	0.000	.983	1485	0.000
2. Hand grip Non-dominant	0.073	1485	0.000	.753	1485	0.000
3. Pinch grip Dominant	0.096	1485	0.000	.975	1485	0.000
4. Pinch grip Non-dominant	0.091	1485	0.000	.972	1485	0.000

Table 1 shows the normality test for all variables. From the data, all the variables show significant differences between genders, age groups, and grip strength, which indicates the data was not normally distributed.

Table 2 Statistical Analysis for Hand Grip Strength and Pinch Grip Between Genders and Age Groups

	Gender *P* -value ($p < 0.02$)	Age Group *P* -value ($p < 0.02$)
Hand grip Dominant	0.000	0.000
Hand grip Non-dominant	0.000	0.001
Pinch grip Dominant	0.000	0.000
Pinch grip Non-dominant	0.000	0.037

Handgrip dominant, handgrip non-dominant, pinch grip dominant, and pinch grip non-dominant show significant differences between male and female respondents at p-value < 0.02. Handgrip dominant (0.000), handgrip non-dominant (0.001), pinch grip dominant (0.000), and pinch grip non-dominant (0.037) also show significant differences respectively across age group.

Table 3 Mean Score, SD, 5th Percentile and 95th Percentile Value for Hand Grip Strength (Kg) for Both Dominant and Non-dominant Hand, Between Genders Across Age Group

Gender	Hand	Age Group	≤ 19	20-29	30-39	40-49	50-59	60-69
Male	Dominant	Mean (kg)	37.24	40.19	41.07	39.58	36.26	34.96
		Standard Deviation	6.83	8.60	7.52	8.24	8.25	4.24
		Percentile 05 (kg)	27.50	27.50	28.70	27.30	23.40	27.40
		Percentile 95 (kg)	47.50	56.00	53.20	52.90	49.70	41.00
	Non-dominant	Mean (kg)	36.41	39.50	38.82	36.60	35.11	32.15
		Standard Deviation	6.53	19.78	7.01	7.64	7.66	5.20
		Percentile 05 (kg)	28.00	26.70	26.70	25.10	23.75	20.90
		Percentile 95 (kg)	46.50	52.20	50.00	47.70	50.75	40.50
Female	Dominant	Mean (kg)	24.95	24.55	24.54	24.33	21.66	22.37
		Standard Deviation	4.87	5.48	5.68	5.60	5.82	3.06
		Percentile 05 (kg)	17.20	15.20	15.10	15.45	11.60	16.70
		Percentile 95 (kg)	34.10	33.20	33.70	33.10	30.40	25.60
	Non-dominant	Mean (kg)	23.18	23.48	23.08	22.61	20.59	22.07
		Standard Deviation	5.80	5.00	5.03	5.03	4.98	3.73
		Percentile 05 (kg)	17.20	16.90	15.60	14.35	13.00	17.00
		Percentile 95 (kg)	30.40	32.90	31.20	30.75	28.10	28.70

Table 3 presents the results of handgrip strength between males and females across age groups. For males, the mean score for hand dominant is slightly greater than the mean score of non-dominant hand. Both the 5th percentile value and 95th value of hand dominant are more significant than the non-dominant hand. For the dominant hand, the age group 30-39 years old have the highest mean score (41.07 kg) and 95th percentile value, while the non-dominant hand of age group 20-29 years old have the highest mean score (39.50 kg) and 95th percentile (52.2 kg).

Similarly to males, the females mean score for hand dominant for all age is slightly greater than the mean score of non-dominant hand. For the dominant hand, the age group <19 years old have the highest mean score (24.95 kg), 5th percentile value (17.20 kg) and 95th percentile value (34.10 kg), while the non-dominant hand of age group 20-29 years old have the highest mean score (23.48 kg) and 95th percentile value (32.9 kg).

On average, dominant handgrip strength for females was shown to have the same mean scores across an age group (average =24.0 kg) except for the age group 50-59 years old (21.66 kg) and 60-69 years old (22.37 kg). Females of 18-19 years old have the highest value for the 5th percentile (17.20 kg) and 95th percentile (34.10 kg). In comparing genders, males' fifth percentile value is greater than the mean score of female handgrip strength.

Table 4 Mean Score, SD, 5th Percentile and 95th Percentile Value for Pinch Grip Strength (Kg) for Both Dominant and Non-dominant Hand, between Genders Across Age Group

Gender	Hand	Age Group	≤ 19	20-29	30-39	40-49	50-59	60-69
Male	Dominant	Mean (kg)	8.87	8.99	9.24	9.18	8.05	8.35
		Standard Deviation	1.74	1.93	1.99	2.14	2.06	1.92
		Percentile 05 (kg)	6.50	6.00	6.00	6.00	5.00	6.50
		Percentile 95 (kg)	12.00	12.50	12.50	12.70	12.00	12.50
	Non-dominant	Mean (kg)	8.63	8.85	9.08	9.11	8.29	8.25
		Standard Deviation	1.88	2.00	2.18	2.15	1.98	2.16
		Percentile 05 (kg)	6.40	6.00	6.00	6.00	5.00	5.50
		Percentile 95 (kg)	12.00	12.50	13.00	12.50	12.25	13.00
Female	Dominant	Mean (kg)	6.34	6.16	6.20	6.29	5.78	6.29
		Standard Deviation	1.30	1.60	1.78	1.91	1.51	.91
		Percentile 05 (kg)	5.00	4.00	4.00	3.50	3.50	5.50
		Percentile 95 (kg)	8.00	8.50	9.40	8.75	8.90	8.00
	Non-dominant	Mean (kg)	6.32	5.97	6.01	6.20	5.85	6.03
		Standard Deviation	1.88	1.64	1.80	1.81	1.69	1.22
		Percentile 05 (kg)	4.50	3.50	3.50	3.00	3.50	4.00
		Percentile 95 (kg)	9.50	9.00	8.60	8.60	8.00	7.50

From the data above (Table 4), it is apparent that the pinch grip strength score is higher for males than females across all age groups. The 5th percentile value for males is almost similar to the female mean score. The average 95th percentile value for females is slightly the same as the average mean score of the males across the age group. For males, the dominant hand has a more excellent mean score compared to the non-dominant hand. However, for females, the average mean score for both dominant hand and non-dominant hand almost similar.

4.0 DISCUSSION

Overall, 1496 men (822) and women (674) working-age groups from 18 years to 69 participated in this preliminary study. A total of 90.2% (n= 1349) of the respondents showed right-hand dominance whereas 9.8% (n=147) are left-hand dominant. The number of the respondents are not normally distributed across age group, 88 in the age group less than 20 years old, 361 in the age group 20-29 years old, 492 in the age group 30-39, 345 in the age group 40-49, 193 in the age group 50-59 and only 17 in the aged group 60-69 years old. Table 3 and Table 4 show that all group means to have small Standard Deviations (SD), which shows this data is reasonable to be used. Finding from the present study consistent with the findings of previous studies, in which male has greater grip strength compare to female in all age groups (Nilsen et al., 2012; Massy-westropp et al., 2011, Puh, 2020; Faraone et al., 2008; Kamarul, Ahmad and Loh, 2006).

As shown in Table 3, the mean score for the handgrip strength test for the male population steadily increases starting from a group age 18-19 years old to a 30-39 years old, gradually decreasing. The mean handgrip score for the females are highest at their youngest age group (<19 years old) before gradually decreased. This is similar to a study conducted by Kamarul et al. (2006) on handgrip strength in the adult Malaysian population on 200 men and 212 women. Their study found that the right-hand dominant group's grip strength increased with age peaking in respondents aged 18 to 34 years and decreased steadily after that. The present study also shows that females reduce strength at an earlier age than males. It indicates that females have difficulty sustaining hand function due to reduced strength and endurance in grip strength. It shows that females are more vulnerable than males when maintaining daily functions due to lower hand strength and reduced endurance in the handgrip. This view is supported by Nilsen et al. (2012), who writes that due to lower hand strength and weakened stamina in hand gripping, older women are more vulnerable than men when it comes to sustaining function in everyday activities.

Like handgrip strength, males are stronger than females in their pinch strength across all age groups, and the range of strength is more comprehensive for younger than older respondents. Males are at their strongest in their thirties, while females of the age group less than 20 years old have the strongest pinch grip strength. Both males and females aged 50-59 have the lowest mean score for hand dominance. However, for non-dominant hand female in the age group, 50-59 years old also has the lowest mean score while male in the same age group falls the second-lowest. Males have the strongest pinch grip in their thirties. Compared to Nilsen et al., study (2012) found that their respondents have the strongest pinch grip in their forties. Thus might conclude that different populations have different grip strength levels, varying between gender and age. Table 4 shows that pinch grip strength for dominant hands is more muscular than the non-dominant hand, about 0.2kg only. This might affect from training and conditioning effect (Wilson et al., 2013).

This present study aimed to establish normative data of handgrip strength and pinch grip strength for healthy adults of both genders for the Malaysian working-age population. The data are suggested to be used as guidance to design healthier workplaces. When performing work tasks especially that involve tools, workers need to adjust his or her ability to the intense demands which result whether their hand increase tolerance from training and conditioning effect or weakened their hand capabilities, which may contribute to MSDs (Nurul Shahida et al., 2015; Hashim & Dawal, 2012; Karmegam et al., 2011).

Thus, the anthropometric data obtained can be used by the ergonomists, manufacturers, and designers as an indicator to measure optimum strength in design tools, especially those that involve gripping, pulling, push-button, and machine lever. Thus, the tools, products, or machines fit Malaysian workers' capability (Berth, Garfield, and Daryle, 2019). The data also can be used to measure overall hand strength, physical performance, to test the functional index of nutritional status, rehabilitation purpose, and including to evaluate hand function and overall body strength (Nurul Shahida et al., 2015; Kaur, 2009; Taha and Nazaruddin, 2005; Tsunawake et al., 2003). For example, the 5th percentile can be used as a baseline evaluation for the CTS problem's recovery state. For any individual who went CTS surgery, they must achieve 5th value based on their age group category. If they did not archive the value yet, they must continue the physiotherapy program that design for CTS problem until they achieve the targeted value.

One limitation of this study is the gripping trial. In this present study, the respondents performs three trials, and then the average score will be recorded (Dale et al., 2014; Nilsen et al., 2012). This method may result fatigue and pain. Thus it is not necessary to get an advantage. This may also potentially introduce systematic error as there is a risk that participants are better in the second testing due to the learning effect.

In summary, we found that males are stronger than females in all age groups, the 5th percentile value of males is greater than the mean score of female handgrip strength, male at their strongest in their thirties while females are strongest at their age below 20 years old.

5.0 CONCLUSION

The normative data is practical to be applied by all the designers in developing a healthy and ergonomic product, tools, and workstation. In this study, the researcher encourages prevention at an early stage by designing tools or products that ergonomically fit the user. Thus, it can create a comfortable and productive workplace and prevent discomfort and reduce fatigue, resulting in MSDs prevention. Therefore, a good design of the product is the first step in preventing the ergonomic risk problem, which can reduce the employee's medical expenses.

It is recommended for further research to consider the ethnicity and type of work of the respondents. The data quality can also be improved by adding the number of respondents to represent the entire Malaysian working-age population. Finally, this data can be used as a reference for the designer to design hand tools to create a safe working environment and prevent MSDs at an early stage.

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