Analysis of Handgrip Strength and Anthropometric Measurements of Manufacturing Workers in the Philippines

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Abstract

In industrial applications, it is essential to know and estimate the Handgrip Strength (HGS) of workers to accordingly designate them to appropriate job specifications. Most of the manufacturing companies have a manual or semi-automatic product processing unit; thus, it will require an ample amount of dexterity that constitutes to the exertion of grip force. This study aims to assess the relationship between the Anthropometric and Handgrip Strength of the manufacturing workers that can be used both the industrial sector and government implementing agencies. Nine hand dimensions and thirteen body measurements in standing position with the HGS considering both genders were tested among sixty participants. The HGS of both hands were used in developing regression models for Anthropometric Measurements and Demographic Profile. The results show that the gender, age group, tenure, five hand dimensions and nine body measurements in standing position significantly affects the HGS. The findings will provide companies and government labour and safety agencies comprehensive information on the Anthropometric and Handgrip Strength measurements of the manufacturing workers. The results therefore can provide relevant perspectives in terms of the proper designation of workers and improves the ergonomics and safety of the workers employed both in domestic and international workplaces.

Keywords
Handgrip Strength (HGS), Anthropometric Measurement, Hand Dimensions, Body Measurements in Standing Position

1. Introduction
1.1 Background of the Study
Developing countries like the Philippines saw great economic potential in the Manufacturing Industry to drive their economy and to strive to achieve the economic success in China. The Philippines is one of the emerging economies in East Asia and the Pacific Region, and it is poised to become an upper-middle economy in 2020.

Manufacturing workers are therefore viewed as essential factors that drive the country's Manufacturing Industries simply because Philippine manufacturing companies require a lot of manual labour. The execution of tasks such as manual handling, repetitive motion, and movement between the different jobs at irregular periods subtly affects work efficiency (Mengoni et al. 2017). Previous research asserted that the individual performance of manufacturing workers is influenced by several factors in the working environment that includes ergonomics, communication, motivation, and automation. Work efficiency is mostly affected if tasks or tools do not fit the Anthropometric dimensions of a certain individual physique and therefore result in higher exertion of effort. Labour-intensive tasks such as gripping are among the examples that constitute a high ergonomic risk (Narayan 2012).

This kind of process is repeated several times during the workday as a result of repetitive physical load wrist movement at varying power; this may increase the risk of musculoskeletal discomfort (Roquelaure et al. 2001). Handgrip Strength closely correlates with the muscle strength from lower limbs and other muscle groups (Samuel et al. 2012).

Handgrip Strength is associated with primary factors such as age and gender, regardless of race and nationality (Ekşioğlu 2016). In 2018, Trajkov et al. determined a relationship between the Handgrip Strength for both the hands and the physically active indicators for sedentary and physically active older women (Trajkov et al. 2018). The previous study substantiates this claim by saying that muscle strength decreases as a person ages throughout time (Metter et al. 2002). There is, however, a positive correlation between grip strength and decreasing muscle stability. These factors were observed to decline at the age of 50 and is expected to worsen after the age of 65.

In 2018, Smith et al. highlight the weight status for both men and women by saying that these factors have a significant effect on the strength of the handgrip. His study concluded that people who are obese have a lower handgrip force and have a higher risk of reduced physical activity (Smith et al. 2018). The study of Shurrab et al. in 2017, proved a strong correlation between the Anthropometric properties such as the height, weight, and hand-length of the workers with Handgrip Strength (Shurrab et al. 2017).

Many studies have established the relationship between stature and hand anthropometry, such as hand length (Mahakizadeh et al. 2016). Previous research on hand anthropometry showed that hand length and handbreadth affect the results of the one hand dynamometer experiment (Shurrab et al. 2015). Similarly, Fallahi and Jadidian proved significant effects between the hand length and the grip force result based on their experiment samples (Fallahi and Jadidian 2011). HGS values were evaluated based on the average; one possible reason is in maintaining the equilibrium of the force exerted by the two hands to make job and machine operations to run smoothly (Shurrab et al. 2017).

1.2 Motivation of the Study

In a developing country like the Philippines, it is vital to assess the current situation correctly. However, studies regarding the Anthropometric properties, especially for the manufacturing workers, are scarce. Work-related musculoskeletal injuries are common in the workplace; it results in an evident outlay and decreased productivity. One possible reason is that the worker tends to exert more effort to do the job; accordingly, such results were due to worker's capability and job requirements incompatibility, a cause commonly missed due to lack of knowledge on the importance of ergonomics in the workplace (King et al. 1998). Therefore, understanding an individual anthropometric measurement and HGS can be essential factors that might be considered besides physical capabilities. It can be especially useful to those people managing the manufacturing operations in understanding the HGS and anthropometric measurements importance in assigning the right people for the right job.

Many studies have focused on establishing the relationship of stature and hand anthropometry (Mahakizadeh et al. 2016), but there is a limited study relating the body measurements and hand dimensions with HGS. The researchers believe that there is a possibility that body measurements correlate with the HGS since those defined measurements in the study directly affect the movements of the manufacturing workers during the execution of work might as well affects the HGS. To fill this gap, the researcher examined the relationship of the body measurements in standing position and nine hand dimensions with the Handgrip Strength. Furthermore, the research finds a need to address this gap since Handgrip is among the main artilleries in the Manufacturing Industries both in the Philippines and globally, since most manufacturing companies require manual operations.

1.3 Objectives

The purpose of this research is to comprehensively study the Anthropometric and the Handgrip Strength measurements of Filipino manufacturing workers. And to provide companies and government agencies information on the relationship of the Anthropometric measurements and the Handgrip Strength. This research evaluated the relationship between the nine hand dimensions and body measurements in standing position with the Handgrip Strength forces considering both genders. The experiment was conducted in a plastic manufacturing plant to enrich the Literature about Handgrip Strength and make improvements that may be necessary for the comfort, health, and safety of the Filipino manufacturing workers.

2. Methodology

2.1 Subjects

This study was conducted in a plastics manufacturing company, thirty male and thirty female manufacturing workers were selected to participate in the experiment. The samples were divided into two age groups (18-32, and 33-46 years.) using stratified sampling (Han et al. 2019). In this research, participants were asked of their age, years of service in the company, and their respective work departments. Subjects were required to be healthy, and none of the participants reported having any cases of neuromuscular diseases or musculoskeletal injuries of the hand, wrist, elbow, and shoulder within one year before testing. Permission was obtained from a plastics manufacturing company to conduct the Handgrip Strength test, gather Anthropometric data, and demographic information. All the participants gave consent to participate in this study's experiment.

2.2 Apparatus

A digital hand dynamometer CAMRY® was used for measuring the grip strength of the participants (Lin et al. 2018). The said equipment is capable of measuring a maximum strength of 198lbs or 90kgs, has an adjustable gear to get a thorough grasp suitable to the size of hands. A measuring tape was used for measuring the body measurements in standing position, a digital weighing scale for the weight of the participants, and a digital calliper for measuring the nine hand dimensions.

2.3 Procedures

Before the actual experiment, subjects were given demonstrations and a basic understanding of the experiment in general, the grasping procedure, and Anthropometric measurement positions. During the experiment, the researcher observed and presented instructions for the subjects to make sure that the test is performed correctly. Visible sets of photos have been provided for the subjects to guide them throughout the whole experiment consisting of four parts: Demographic Information, Handgrip Strength Test, Nine Hand Dimensions, and Body Measurements in standing position. Moreover, to avoid inter-observer error, all the measurements were taken by one experimenter.

Subjects were shortly interviewed and inquired all the necessary subject information, including their weight in kilograms using a digital weighing scale. Before the actual handgrip experiment, subjects were asked to have one warm-up test, both hands for the tool familiarization. Subjects were instructed to be in an upright standing position with their arms along the side while holding the dynamometer. The unit measurement of the dynamometer was set to kilograms, and the test was done in three consecutive tests; each will last for 3 seconds (Flood et al. 2014) with 15 seconds rest periods (Li K et al. 2010) for each of the trials for both of the subject's hands. The dominant hand of the participants was also identified during the experiment. The handgrip test was done twice at the start and end of the morning shift.

The nine hand dimensions were measured using a digital calliper. The subjects were asked to place their hands on a flat horizontal surface in an abducted position of the thumb and the extended position of the other fingers. Different hand dimensions are illustrated in Figure 1. There are nine hand dimensions identified that include the following: 1. Hand length (HL); 2. Hand breadth (HB); 3. Maximum hand breadth (MHB); 4. Palm length (PL); 5. Thumb finger length (TFL); 6.Index finger length (IFL); 7. Middle finger length (MFL); 8. Ring finger length (RFL); 9. Little finger length (LFL) (Asadujjaman et al. 2019).
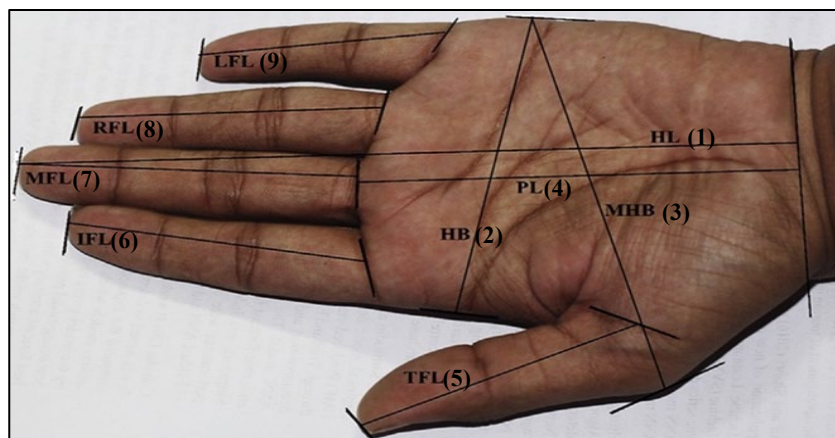
Figure 1. Nine hand dimensions

The body measurements in standing position measurements were also collected during the experiment adapted from the work of Pheasant and Haslegrave. The participants were instructed to be in an upright position without any wear on foot and head. A steel tape meter was used to measure the checkpoints, as shown in Figure 2. That includes the following: 1. Vertical grip reach (standing); 2. Hip height; 3. Knuckle height; 4. Fingertip height; 5. Elbow height (flexed arm); 6. Shoulder height; 7. Eye height; 8. Stature; 9. Span; 10. Elbow span; 11. Upper limb length; 12. Shoulder grip length; 13. Forward grip reach (Pheasant and Haslegrave 2006).
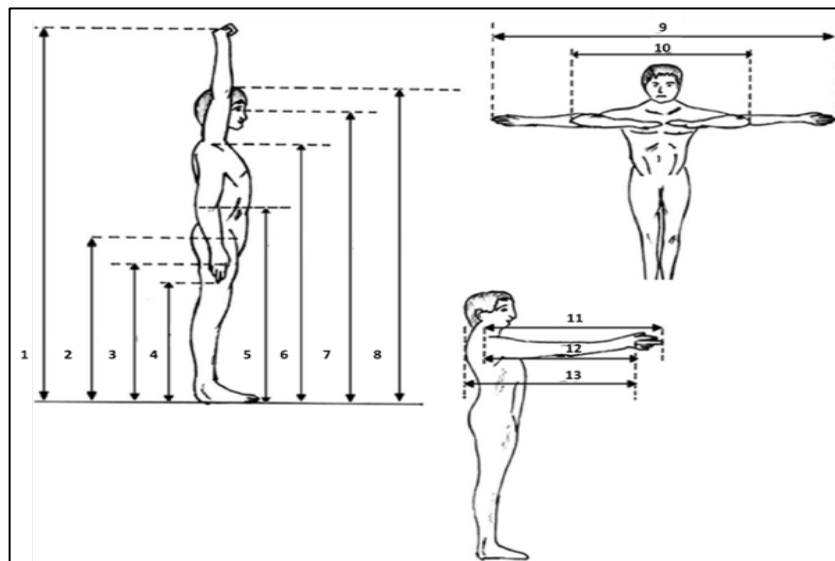

Figure 2. Body measurements in standing position

2.4 Statistical Analysis

Pearson Correlation analysis of significance was used to compare the dependent variable (Handgrip Strength) and the independent variable (hand dimensions). It was also applied in the assessment of the Handgrip Strength for both hands and the body measurement variables. Correlation coefficients of 0.10-0.29, 0.30-0.49, and 0.50-1.0 were interpreted as low, moderate, and strong, respectively (Cohen 1988). Box plot was used to compare the relationship of the Handgrip Strength, age group, and gender.

ANOVA was used to identify the significance between the age group, gender, tenure, and BMI status with the HGS. Multiple ANOVA was performed in determining the relationship between the independent factors (age group and gender) with hand dimensions and body measurements in a standing position as the dependent variable. In estimating the dependent variable (HGS) and the independent variables, the age group, gender, hand dimensions, and body measurements in standing position, multiple regression analysis was utilized. The statistical significance used in the analysis was set at $p < 0.05$ (Dianat et al. 2015). All statistical test was performed using Microsoft Excel and SPSS 23 (Armonk, NY, USA).

3. Results
3.1 Age Group, Gender, Tenure, BMI Status Affects the HGS
To examine the relationship between the age group, gender, tenure, and BMI status on the HGS t-test has been performed. The t-test result can be shown in Table 1. The following were assessed based on the respective ranges and descriptive scales: age range (18-32 years and 33-46 years), gender (male and female), tenure measured in the years of service divided into six groups (0-2, 3-4, 5-6, 7-12, 13-24, 25 above) (Breslin et al. 2008), and BMI status (underweight, normal weight, overweight, and obese). However, in this experiment, the results only show two groups, which are under and normal weight. The age group, gender, and tenure were statistically significant ($p < 0.05$) for dominant, non-dominant, and average Handgrip Strength. In contrast, BMI status has no considerable effect having a p-value higher than 0.05 for all the measures of the Handgrip Strength.

Table 1. ANOVA results to examine the effects on HGS

Variable	Handgrip Strength								
	Dominant			Non-dominant			Average		
	Group	Mean	P-value	Group	Mean	P-value	Group	Mean	P-value
Age									
18–32	A	32.21	0.04**	A	31.04	0.04**	A	31.67	0.04**
33–46	B	27.49		B	26.33		B	26.91	
Gender									
Male	A	37.10	0.00**	A	35.72	0.00**	A	36.41	0.00**
Female	B	22.35		B	21.31		B	21.83	
Tenure									
0–2	A	26.40	0.01**	A B	25.31	0.01**	A	25.85	0.01**
3–4	A	36.42		A B	35.00		A	35.71	
5–6	A	25.83		A	24.69		A	25.25	
7–12	A	36.96		A B	35.61		A	36.28	
13–24	A	26.11		B	25.36		A	25.73	
25+	A	34.72		A B	33.26		A	34.00	
BMI									
Under	A	31.35	0.20***	A	30.00	0.24***	A	30.66	0.22***
Normal	A	28.32		A	27.25		A	27.78	

**Significant ($p < 0.05$).
***Not Significant ($p > 0.05$).

3.2 HGS Significance on Hand Dimensions and Body Measurements
There are five out of nine variables left from the nine hand dimensions through a series elimination of such as normality and test of significance (t-test). And to test the hypothesis that hand dimensions and body measurements significantly affects the HGS, the Pearson correlation was conducted, as shown in Table 2. The index finger length has the lowest correlation of 0.294, middle finger length ($r = 0.375$), and ring finger length ($r = 0.378$) has a moderate correlation, hand length, and maximum handbreadth have the strongest correlation of 0.505 and 0.610, respectively for average

HGS similar results for both the dominant and non-dominant HGS. All of the Pearson R results are positively correlated and statistically significant ($p < 0.05$) with the HGS.

Table 2. Relationship of HGS and hand dimensions

| Hand dimensions | Handgrip Strength | | | | | |
| | Dominant | | Non-dominant | | Average | |
	Pearson R	P – Value	Pearson R	P – Value	Pearson R	P – Value
Hand Length	0.504[c]	0.000**	0.505[c]	0.000**	0.505[c]	0.000**
Maximum hand breadth	0.600[c]	0.000**	0.619[c]	0.000**	0.610[c]	0.000**
Index finger length	0.290[a]	0.030**	0.298[b]	0.026**	0.294[a]	0.028**
Middle finger length	0.372[b]	0.005**	0.376[b]	0.004**	0.375[b]	0.004**
Ring finger length	0.375[b]	0.004**	0.381[b]	0.004**	0.379[b]	0.004**

**Significant ($p < 0.05$).
[a]Low (0.10 – 0.29).
[b]Moderate (0.30 – 0.49).
[c]Strong (0.50 – 1.0).

All body measurement variables were statistically significant with the HGS ($p < 0.05$) and positively correlated, as shown in Table 3. Stature has the strongest correlation (r = 0.661) followed by vertical grip reach (r = 0.635), elbow height (r = 0.439) and shoulder grip length (r = 0.535). The moderately correlated variables are span (r = 0.495), upper limb length (r = 0.495), fingertip height (r = 0.457), and eye height (r = 0.439). The knuckle height was the lowest (r = 0.298) among the nine body measurements in standing position from the average HGS. These results were similar for the dominant and non-dominant HGS.

Table 3. Relationship of HGS and body measurements

| Body measurements in standing position | Handgrip Strength | | | | | |
| | Dominant | | Non-dominant | | Average | |
	Pearson R	P – Value	Pearson R	P – Value	Pearson R	P – Value
Vertical grip reach	0.635[c]	0.000**	0.633[c]	0.000**	0.635[c]	0.000**
Knuckle height	0.296[b]	0.027**	0.299[b]	0.025**	0.298[b]	0.026**
Fingertip height	0.460[b]	0.000**	0.453[b]	0.000**	0.457[b]	0.000**
Elbow height	0.439[b]	0.001**	0.438[b]	0.001**	0.439[b]	0.001**
Eye height	0.583[c]	0.000**	0.592[c]	0.000**	0.588[c]	0.000**
Stature	0.654[c]	0.000**	0.667[c]	0.000**	0.661[c]	0.000**
Span	0.492[b]	0.000**	0.496[c]	0.000**	0.495[c]	0.000**
Upper limb length	0.499[c]	0.000**	0.490[b]	0.000**	0.495[c]	0.000**
Shoulder grip length	0.533[c]	0.000**	0.537[c]	0.000**	0.535[c]	0.000**

**Significant ($p < 0.05$).
[a]Low (0.10 – 0.29).
[b]Moderate (0.30 – 0.49).
[c]Strong (0.50 – 1.0).

3.3 HGS Regression Model

Based on the t-test and ANOVA results, this study showed that age group, gender, hand dimensions, and body measurements all significantly affect the HGS. Hence, the HGS regression model helps in quantifying the handgrip force based on these parameters. The analysis shows that coefficient of correlation (R) of the regression model is 0.912, 0.920, 0.917, and coefficient of determination (R2) is 0.831, 0.846, 0.840 for dominant, non-dominant, and average respectively as shown on Table 4 and Eq. (1,2,3) show the regression model and equation.

$HGS_{Dominant}$ = 67.915 – 16.532 *Gender* – 5.379 *Age group* + 2.713 *Hand length*
 – 0.265 *Vertical grip reach*
$HGS_{Non-dominant}$ = 70.144 – 16.508 *Gender* – 5.192 *Age group* + 2.708 *Hand length*
 – 0.283 *Vertical grip reach*

$HGS_{Average}$ = **69.013 – 16.518** *Gender –* **5.286** *Age group +* **2.712** *Hand length*
– 0.274 *Vertical grip reach*

where "male" is substituted by 1, "female" is substituted by 2, "18-32 years" is substituted by 1, "33-46 years" is substituted by 2.

Table 4. Regression model details for HGS

Model	Unstandardized coefficients		Standard coefficients	T	Sig.
	B	Std. error	Beta		
Dominant					
(Constant)	67.915	21.689		3.131	0.003
Gender	-16.532	1.938	-0.951	-8.532	0.000
Age group	-5.379	1.105	-0.309	-4.868	0.000
Hand length	2.713	0.892	0.271	3.042	0.004
Vertical grip reach	-0.265	0.110	-0.311	-2.399	0.020
Non-dominant					
(Constant)	70.144	20.068		3.495	0.001
Gender	-16.508	1.793	-0.979	-9.208	0.000
Age group	-5.192	1.022	-0.307	-5.078	0.000
Hand length	2.708	0.825	0.279	3.283	0.002
Vertical grip reach	-0.283	0.102	-0.343	-2.774	0.008
Average					
(Constant)	69.013	20.758		3.325	0.002
Gender	-16.519	1.854	-0.966	-8.908	0.000
Age group	-5.286	1.058	-0.308	-4.998	0.000
Hand length	2.712	0.853	0.275	3.177	0.003
Vertical grip reach	-0.274	0.106	-0.327	-2.594	0.012

4. Discussion

The present study determines the relationship between hand force and Anthropometric measurements of Filipino manufacturing workers. The test of hypotheses confirmed that there was a statistically significant effect of hand dimensions and body measurements on Handgrip Strength ($p < 0.05$). There are five positively correlated hand

dimensions with the HGS that include the hand length, maximum handbreadth, index finger length, middle finger length, and ring finger length. This result is consistent with the previous study of Cakmak and Ergul that measures the correlation of the between HGS and Anthropometric data (i.e., handbreadth and hand length) (Cakmak and Ergül 2018). They confirmed that there was a statistical significance between Anthropometric measurements on HGS ($p < 0.05$). In the present study, the five identified hand dimensions were positively correlated with HGS having a strong correlation between the factors. There are nine body measurements remained from the series of normality and significance test, and it confirmed that the identified body measurements are significantly correlated with HGS ($p < 0.05$). And among the body measurements, stature got the strongest correlation, while knuckle height got the lowest correlation with HGS. This study is also confirming the previous research regarding the fact that height was positively correlated ($p < 0.05$) with HGS in both hands (Fink et al. 2010).

The present study finds the relationship between the demographic profiles of the manufacturing workers that significantly affect Handgrip Strength. Tests for the hypothesis that state age group, gender, tenure, and BMI status affect the HGS through ANOVA enabled the researcher to conclude that there is no significant relationship between the BMI status with the HGS. However, there was statistical significance on three of the tested variables (quod est, the age group, gender, and tenure). The result of the present study is similar to the findings of Sosnoff and Newell, which asserts that one of the main factors that affect the stability of grip strength includes age (Sosnoff and Newell 2006). Moreover, middle-aged adults have a weaker grip force than young adults due to age-related degeneration of the neuromuscular system, which results in an inevitably unstable grip force (Lin C-H et al. 2019). Kattel and Fernandez found that gender, the male and female affect the grip strength as a result of their experiment samples in the US population (Kattel and Fernandez 1999). The relationship of tenure with HGS shows a correlation between worker experiences; however, it has a weaker implication on HGS (Cakmak and Ergül 2018). Alternatively, BMI indicates no significance with Handgrip Strength (Shurrab et al. 2015), similar to the results of the previous study on grip force of hand, which supposes that BMI has a very minimal effect on HGS (Hardy et al. 2013).

In the Philippines, the first screening of workers occurs in the human resource department taking all the necessary information, psychological, physical, and health examinations. Mostly, companies are more focused on the physical and health test results of the applicant. However, there were emergent issues concerning workers' efficiency in the designated job they were assigned. The handgrip is one of the factors that should be taken into consideration, especially in the Manufacturing Industry. Wherein it will require a standardized handgrip force depending on the assigned task over some time. It will avoid possible injuries, work-related health illness due to wrong movements, repetitive motions, and inappropriate job assignments due to force movements. In industrial applications, both the dominant and non-dominant hands have an interaction between them. The handgrip force by the two hands is not the same. However, to perform the required job, the two hands need to exert a similar force to maintain equilibrium. So, in this study, the average handgrip force between the dominant and non-dominant hand was also considered together with the dominant and non-dominant grip force to calculate the handgrip force accordingly depending on the job requirements.

The linear regression model shows that gender, age group, hand length, and vertical grip reach are the best estimators of the Handgrip Strength. A similar to the results of the study on the Singaporean body Anthropometric measurements. The research shows that male subjects have larger body dimensions than female subjects. And all the standing posture measurements for all the subjects were significant, having the vertical grip reach as the highest differences among the measures. The sitting posture that includes the hand length shows a significant difference between the genders and the two age groups (Lee Y-C et al. 2019). It proves that there are correlations between the identified variables that most significantly affect the handgrip force value. In 2015, Hartono and Gunawan state that specific body dimensions significantly associated with stature and body weight (Hartono et al. 2015). The study on the Indonesian anthropometry, vertical grip reach is one of the significant dimensions related to estimating the stature. It proves that the present study results are correlated with the Handgrip Strength having the vertical grip reach as a significant factor that could predict the stature, which has been a proven indicator of Handgrip Strength (Hartono 2018).

Although our study reports several significant findings, there are inevitably some noteworthy limitations. First, the sample size for anthropometric analysis was small; there were not enough data points for many weaker correlations to reach significance. Lower numbers also mean that individual subjects can have a more significant effect on averages. Stratified sampling was done to select participants so that a wide range of the HGS and anthropometric levels were represented for both men and women. Second, the experiment was conducted in a plastic manufacturing company, which is one of the numerous types of manufacturing industries; it may induce bias in the representation of the manufacturing workers. Finally, the reliability and accuracy of the HGS result, considering it was done manually

using a commercially available dynamometer. It is difficult to know whether individuals truly gave a maximal voluntary effort for each trial. The individual's different conditions, including pain in joints and other deficiencies, were not shown and could have influenced the HGS result.

5. Conclusion

An experiment was conducted to assess the relationship of the Handgrip Strength with the demographic profile, hand dimensions, and body measurements in the standing position of male and female manufacturing workers. The analysis showed that among the subjects identified demographic profile, the age group and gender were the only variables that are statistically correlated with the Handgrip Strength as well as with hand dimensions and body measurements in standing position. Pearson correlation showed that both the hand dimensions (hand length, maximum handbreadth, index finger length, middle finger length, and ring finger length) and body measurements in standing position (vertical grip reach, knuckle height, fingertip height, elbow height, eye height, stature, span, upper limb height, and shoulder grip length) have a positive correlation with Handgrip Strength.

It is concluded that the age group and gender affect the outcome of the handgrip force. Generally, 18-32 years have a higher grip force than the 33-46 years for both males and females. It also shows that males have a higher variation of grip force than females for both age groups. The multivariate results noticed a significant correlation between HGS and body measurements in standing position with age group and gender. The findings of this study can estimate the handgrip force from the gender, age group, hand dimension, and body measurements in standing position.

This research would be potentially considered as the first comprehensive study in the Philippines with regards to identifying the relationship between the Handgrip Strength and Anthropometric measurements of Filipino manufacturing workers. This study serves as the first step in making an Anthropometric and handgrip standard for a specific job requirement in industrial applications. The study's academic perspectives, therefore, could further improve the efficiency, safety, and health of the manufacturing workers and will eventually improve the company profits.

Future studies could increase the number of participants and age groups to widen the span of the results. And to identify if there are any differences among the work departments handgrip strength values and requirements. And to use structural equation modelling since it could estimate multiple and interrelated dependence in single analysis a more efficient way of evaluating the data.

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