# Developed the Design Parameters of Hand Measurement and Grip Strength for Handbrake and Grip Handle of Motorcycle

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**Abstract.** To achieve mass customization and collaborative product design, human factors and ergonomics should play a key development role. The purpose of this study was to develop the measurement methods and design parameters for handbrake and grip handle of motorcycle. In this study, there is not only anthropometric measurement of hand but also grip strength for design the handbrake and grip handle of motorcycle. New type instruments of handbrake dynamometer and grip circumference were developed. Eighty participants were measured the anthropometric characteristics of both hands as length of hand, breadth of hand, length of thumb, breadth of thumb, grip circumference and grip strength. Further, the effects of gender and the relationship of anthropometric measurements had been evaluated. Results of ANOVA showed that all anthropometric measurements and grip strength were significant difference between genders. Mean female length of hand and breadth of hand are shorter about 20 mm and 10 mm than male, respectively. Mean grip circumference in female and male is about 128 mm and 135 mm, respectively. Mean female grip strength is about 60% of male grip strength. The hand breath is highly correlated with grip strength and handbrake strength. Those parameters could provide for design grip handle of motorcycle.

**Keywords:** Anthropometry, Ergonomics, Product design, Motorcycle, Hand tools

## 1. INTRODUCTION

A hand-operated is defined as any product that is used as a hand-held product, such as a hand-tool, or is a hand-operated product, such as handbrake and grip handle of motorcycle. Workers in many occupations make intensive use of hand-tools, and poor tool design can adversely affect job performance and lead to increased accidents and injuries. Reviewing literatures listed a variety of occupational risk factors associated with common hand and wrist disorders. Prolonged, forceful grip exertions have been strongly associated with tenosynovitis, tendinitis, carpal tunnel syndrome (Armstrong and Silverstein, 1987; NIOSH, 1997). The reported incidence of these types of cumulative disorders represented 25 new cases per 10,000 workers and made up about 3% to 5% of all work-related

injury and illness claims in United States (Brogmus et al., 1996). Analysis of injury data suggested that poor hand–tool design is a significant factor in around 10% of all compensable and disabling injuries among US workers and around 2% of fatalities. Injuries associated with poor hand-tool design cost the USA more than 10 billion (Lewis and Narayan, 1993). Approximately 7 million workers across Europe reported work related problems, over half (52%) of which were reported as musculoskeletal disorders (EUROSTAT, 2002).

Good ergonomics principles for the design of hand-operated devices depend on an understanding of the basic function anatomy of the hand. When ergonomically well designed hand-tools are correctly used, they can reduce the risks of hand, wrist and forearm occupational injuries (Sperling et al., 1993). The ergonomic design of hand-tool handles requires careful consideration of a variety of factors (Lewis and Narayan, 1993). The most important physical factors to improving the ergonomic design and safety of the tool handle are product shape and handle design (Hedge, 1998). The product shape refers to both the overall dimensions of the product and the shape of the product area that will be gripped or operated by the hand. In addition, handle is critical to successful operation. The factors of handle diameter, handle shape, handle length, handle texture, handle material and handle balance should be considered in design of handle. Thus, the size of the handle must fit the hands of those who may use the tool. Handle length should be long enough that handle passes completely across the palm, so that its end cannot cause compression to the palm (Hedge, 1998). Therefore, relevant design dimensions for the human hand should be provided.

The purpose of this study was to develop the measurement methods and design parameters for handbrake and grip handle of motorcycle. In this study, there is not only anthropometric measurement of hand but also grip strength for design the handbrake and grip handle of motorcycle. Those parameters could provide for design of grip handle of motorcycle.

## 2. METHOD

### 2.1 Participants

The study recruited eighty participants (55 male and 25 female) who held driver's license and have experiences with riding motorcycle. Mean height of male is 172.68 cm (SD = 5.59) and mean female height is 158.9 cm (SD = 3.77). Mean body weight of male and female are 69.59 kg (SD = 16.43) and 52.76 kg (SD = 6.43), respectively.

### 2.2 Hand Measurement

The main instrument was the digital caliper for hand measurement. An accuracy of 0.5 mm was the objective and all measurements were recorded in millimeters. Body weight was measured using a portable weighting scale (kg). The grip span measured in relaxing posture (Figure 1). Grip circumference measurement was developed with Takei Scientific Instrument Co., Ltd. (Model S-15077, Figure 2). Measurement range is from 65 mm to 215 mm. Nine anthropometric characteristics of hand were measured as follow:

1. Hand length: the distance from the base of the hand to the top of the middle finger measured along the hand;
2. Hand thickness: the thickness of the metacarpal-phalangeal joint of the middle finger;
3. Hand breath: the breadth of the hand as measures across the distal ends of the metacarpal bone;
4. Thumb length: the distance from the base of the thumb to the top of the thumb;
5. Thumb breath: the breath of the distal phalange of thumb;
6. Forefinger length: the distance from the base of the forefinger to the top of the forefinger;
7. Middle finger breath: the breadth of the distal phalange of the middle finger;
8. Grip span: the distance from the tip of the thumb to the tip of the middle finger with the hand opened as relax as possible.
9. Grip circumference: the diameter of the widest level of a cone which the subject can grasp with his/her thumb and middle finger touching;


Figure 1: The grip span in relaxing posture

Figure 2: Grip circumference measurement

## 2.3 Grip Strength Measurement

Grip strength of each participant measured by grip strength dynamometer (Grip-D, T.K.K. 5401, Takei Scientific Instrument Co., Ltd., Japan). Measurement range is 5.0 to 100 kg and accuracy is ±2 kg. Participant holds the device that the grip meter indicator outward. Turn the knob to adjust the grip width so that the second joint of the pointing finger at a right angle. Participants stand upright and let their arm down naturally. Then, clasping the grip with full force and do not swing the grip meter at this time. In addition, grip strength for handbrake measured by handbrake dynamometer (T.K.K. s-15045, Takei Scientific Instrument Co., Ltd., Japan). The maximum grip strength is achieved when the pliers like handle begins to close at about 80 mm. Thus, the grip span of handbrake dynamometer is 80 mm and handle length is 150 mm (Figure 3). Measurement range is from 0 kg to 100 kg and accuracy is ±2 kg.


Figure 3: Grip strength for handbrake measured by handbrake dynamometer

## 2.4 Data analysis

All data were coded and summarized using SPSS 21.0 software for Windows. Analysis of variance (ANOVA) was utilized to determine the effects of gender on hand dimensions. In addition, correlation analysis was used to assess the relationships between the study variables.

## 3. RESULTS

Table 1 showed that the measurements of left hand between genders. Results of ANOVA revealed that there were significant differences in all hand measurements between genders. The mean measurements of hand are larger in male than in female. The mean hand length (171.3 vs. 153.0 mm), hand thickness (27.9 vs. 22.8 mm), hand breath (79.5 vs. 69.9 mm) are for males and females, respectively. In addition, mean grip span and grip circumference of male and female are 49.9 vs. 43.5 mm and 137.7 vs. 128.0 mm, respectively.

Table 1: Measurements of left hand between genders (mm)

| Measurements | Gender | Mean | SD | Min | Max |
|---|---|---|---|---|---|
| Hand length | Male | 171.3 | 23.7 | 17.9 | 197.0 |
| | Female | 153.0 | 6.6 | 133.0 | 165.0 |
| Hand thickness | Male | 27.9 | 8.2 | 22.1 | 84.0 |
| | Female | 22.8 | 2.2 | 18.2 | 27.8 |
| Hand breath | Male | 79.5 | 5.2 | 70.0 | 89.4 |
| | Female | 69.9 | 2.7 | 64.0 | 74.0 |
| Thumb length | Male | 115.9 | 7.3 | 99.0 | 133.9 |
| | Female | 109.5 | 4.8 | 100.4 | 117.5 |
| Thumb breath | Male | 19.1 | 2.0 | 15.4 | 28.4 |
| | Female | 16.0 | 2.2 | 6.9 | 18.3 |
| Forefinger | Male | 70.8 | 4.3 | 56.1 | 79.0 |
| length | Female | 65.3 | 3.9 | 56.2 | 73.5 |
| Middle finger | Male | 15.4 | 1.7 | 11.0 | 23.0 |
| breath | Female | 13.2 | 0.7 | 12.0 | 14.7 |
| Grip span | Male | 49.9 | 15.4 | 25.1 | 92.0 |
| | Female | 43.5 | 18.6 | 16.7 | 75.0 |
| Grip | Male | 137.7 | 12.0 | 115.0 | 165.0 |
| circumference | Female | 128.0 | 10.7 | 115.0 | 150.0 |

Table 2: Measurements of right hand between genders (mm)

| Measurements | Gender | Mean | SD | Min | Max |
|---|---|---|---|---|---|
| Hand length | Male | 171.6 | 10.4 | 150.0 | 190.0 |
| | Female | 149.6 | 7.4 | 132.0 | 168.0 |
| Hand thickness | Male | 28.7 | 8.3 | 22.4 | 86.0 |
| | Female | 25.2 | 10.1 | 19.2 | 73.2 |
| Hand breath | Male | 80.9 | 4.9 | 70.0 | 92.7 |
| | Female | 70.9 | 3.3 | 64.3 | 77.7 |
| Thumb length | Male | 115.7 | 7.6 | 97.0 | 134.4 |
| | Female | 109.2 | 4.7 | 99.2 | 120.8 |
| Thumb breath | Male | 19.8 | 1.7 | 17.1 | 29.0 |
| | Female | 17.1 | 1.2 | 14.0 | 19.5 |
| Forefinger | Male | 71.3 | 4.5 | 62.2 | 84.0 |
| length | Female | 66.0 | 4.0 | 57.9 | 72.9 |
| Middle finger | Male | 15.9 | 1.9 | 12.0 | 24.0 |
| breath | Female | 13.6 | 0.8 | 11.5 | 15.6 |
| Grip span | Male | 50.2 | 15.0 | 20.3 | 94.0 |
| | Female | 46.8 | 15.8 | 21.3 | 82.2 |
| Grip | Male | 135.4 | 10.2 | 115.0 | 155.0 |
| circumference | Female | 124.0 | 10.7 | 105.0 | 145.0 |

Table 3: Measurements of grip strength and handbrake strength between genders (kg)

| Measurements | Gender | Mean | SD | Min | Max |
|---|---|---|---|---|---|
| Left grip | Male | 36.8 | 6.0 | 24.0 | 51.6 |
| strength | Female | 23.6 | 4.6 | 14.3 | 36.8 |
| Left handbrake | Male | 41.5 | 8.0 | 25.2 | 57.2 |
| strength | Female | 25.1 | 5.8 | 15.6 | 37.5 |
| Right grip | Male | 39.4 | 6.1 | 27.5 | 53.2 |
| strength | Female | 25.3 | 5.1 | 16.9 | 37.9 |
| Right handbrake | Male | 44.2 | 8.1 | 29.0 | 63.8 |
| strength | Female | 27.0 | 6.6 | 14.7 | 42.6 |

For right hand measurements are the same results (Table 2). Further, measurements of grip strength and handbrake strength between genders showed in Table 3. Results of ANOVA revealed that there were significant differences grip strength measurements between genders in both hand ($p < 0.001$). The mean left grip strength of male is about 35% larger than female (36.8 kg vs. 23.6 kg). The mean left handbrake strength of male is about 38% larger than female (41.5 kg vs. 25.1 kg). For right hand measurements are the same results.

Table 4 showed the correlation analysis among measurements. There is higher correlation among stature, body weight, hand breath, grip strength, handbrake strength. In particularly, the hand breath is highly correlated ($r = 0.6$) with grip strength, handbrake strength. Nicolay and Walker (2005) also reported that palm width was the most highly correlated with maximum grip voluntary contraction.

## 4. DISCUSSION

The human hand is a beautifully designed organ, capable of an infinite variety of configurations and functions. Unfortunately, people often require certain types of manual exertions that, when repeated practically daily, can cause a progressive deterioration of support tissues and muscles, resulting in discomfort, pain, and loss of function (Chaffin, Andersson and Martin, 2006). Force gripping and grasping has been associated with the risk of musculoskeletal disorders such as carpal tunnel syndrome (Dong et al., 2005). Maximum voluntary contraction grip force or grip strength should be evaluated as design tool hand-operated tool. Measure of grip strength using a hand dynamometer is a simple and economical test that gives practical information. Ruiz-Ruiz et al. (2002) investigated the grip span on the standard grip dynamometer results in maximum grip strength. Results showed that optimal grip span was identified for both genders and hand size and optimal grip span correlated in women but not in men. Nicolay and Walker (2005) examined the grip strength and endurance and influences of anthropometric variation and gender. Males generated significantly greater maximum grip force than females and there are 39.5 kg and 20.4 kg for male and female in dominant hand. In our study, mean right grip strength is 39.4 kg and 25.3 kg in male and female, respectively.

Since the introduction of the Jamar handle dynamometer more than 50 years ago (Bechtol, 1954), it has become a popular instrument for measuring grip strength. This is partially because of its convenience, but also because the instrument provides a reasonable simulation of the handle shapes of many widely used two-piece handled tools such as pliers, shears, or crimping tools. Wimer et al. (2009) developed a new dynamometer for

measuring maximum grip force or grip strength. This six-arm cylindrical dynamometer provided to be suitable for determining the overall grip strength of a subject, as well as showing the grip distribution around the surface of the handle. The Jamar grip dynamometer may not adequately reflect the fingertip forces at the low and middle spans because the fingertips are not applied in the force measurement plane of the Jamar handle. Therefore, the Jamar dynamometer may not adequately capture changes in the fingertip forces under different grip spans (McDowell et al., 2012). Finneran and O'Sullivan (2013) revealed that grip type (power grip, chuck grip and pinch grip) had a significant effect on muscle activity. Thus, present study developed the new handbrake dynamometer to measure the grip strength while applied the handbrake for motorcycle or bicycle.

In addition, grip strength influenced by grip span. Eastman Kodak (1983) indicated the optimum grip span is 55 mm for power grip. Fransson and Winkel (1991) reported that the optimal grip span was 50 to 60 mm for women and 55 to 65 cm for men. Ruiz-Ruiz et al. (2002) reported that the optimal grip span is a fixed value (55 mm) in the men and is not influenced by hand size. In women the optimal grip span is influenced by hand size. Oh and Radwin (1993) found that the maximum grip force occurred at about 50 mm for small and medium size hands and it occurred at 60 mm for large hands. In results of our study, mean grip span is from 43 mm to 50 mm.

## 5. CONCLUSION

The purpose of this study was to develop the measurement methods and design parameters for handbrake and grip handle of motorcycle. In this study, there is not only anthropometric measurement of hand but also grip strength for design the handbrake and grip handle of motorcycle. New type instruments of handbrake dynamometer and grip circumference were developed. Nine anthropometric characteristics of both hands were measured such as length of hand, breadth of hand, length of thumb, breadth of thumb, grip circumference and grip strength. Results of this study showed that all anthropometric measurements and grip strength were significant difference between genders. Mean female length of hand and breadth of hand are shorter about 20 mm and 10 mm than male, respectively. Mean female grip strength is about 60% of male grip strength. The hand breath is highly correlated with grip strength and handbrake strength. Those parameters could provide for design of grip handle of motorcycle.

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Table 4: Correlation analysis among measurements

| Correlation | A | B | C | D | E | F | G | H | I | J |
|---|---|---|---|---|---|---|---|---|---|---|
| Stature (A) | 1 | .631*** | .154 | .475*** | .686*** | .692*** | .104 | .471*** | .649*** | .665*** |
| Body weight (B) | .631*** | 1 | .006 | .127 | .569*** | .618*** | .037 | .083 | .459*** | .521*** |
| Left hand Breath (C) | .748*** | .644*** | 1 | .328** | .439*** | .670*** | .915*** | .287*** | .618*** | .694*** |
| Left grip Circumference (D) | .475*** | .127 | .069 | 1 | .343** | .291** | -.003 | .849*** | .403*** | .324** |
| Left grip strength (E) | .686*** | .569*** | .146 | .343** | 1 | .820*** | .116 | .338** | .864*** | .816*** |
| Left handbrake strength (F) | .692*** | .618*** | .043 | .291** | .820*** | 1 | -.024 | .268* | .767*** | .845*** |
| Right hand Breath (G) | .787*** | .655*** | .915*** | .359*** | .460*** | .699*** | 1 | .341*** | .661*** | .747*** |
| Right grip circumference (H) | .471*** | .083 | .133 | .849*** | .338** | .268* | .055 | 1 | .389*** | .349** |
| Right grip strength (I) | .649*** | .459*** | .217 | .403*** | .864*** | .767** | .149 | .389*** | 1 | .838*** |
| Right handbrake strength (J) | .665*** | .521*** | .210 | .324** | .816*** | .845*** | .133 | .349** | .838*** | 1 |

* $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$;