

Hand tool handle design based on hand measurements

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Abstract. This study provides a tool handle design guideline based on measurements of hand gripping diameter. Anthropometric measurements on hands of 60 participants were collected with a caliper. The results in the current study concluded the guidelines for handle design, including: (1) a definition of handle design was depended on the users' hand length and hand breadth, (2) different gender would affect the size of tool handle, (3) the handle length at least should be 100mm, (4) the cross-section handle of elliptical shape was better for gripping, and (5) the best ratio of handle cross-section with width and length should be 1:1.25. These findings can serve as references for tool handle design, and improve comfort for users.

1 Introduction

Correct tool design is important for preventing upper-extremity musculoskeletal disorders. Considering the ergonomics of a hand-tool, in addition to its main function, the most important part is the tool's handle. Tool handle design research has been previously limited to the determination of the diameters of cylindrical handles to increase performance and comfort for reducing the chances of CTD (i.e., blisters, inflamed skin, cramped muscles, etc.) [1-4]. Many studies have researched the topic of tool handle design to define the optimal size and shape of a tool handle. Most of the studies have focused on cylindrical [5-7] or elliptical [8-9] shapes of the handles to provide guidelines for determining the optimal diameters to increase finger-force comfort, exertion, and the contact area. According to the previous studies on the related designs of the ergonomic handle, a hand tool design principles are summarized as following:

- Handle diameter: a grip design should consider the hand action when holding the grip [10]. A handle with a diameter of 30 to 40mm is most suitable for a gun or electric tool [5]. Moreover, the handle suitable for both male and female was a cylindrical handle with a diameter of around 40mm [8]. Some studies suggested that the handle diameter should be in a range of 30 to 45 mm [7]. However, some studies argued that the diameter should be in a range of 25 to 50mm [6]. In addition, a suitable handle diameter should be 19.7% of the hand length [11]. The handle shape should be an elliptical shape with a width and length ratio of 1: 1.25 that can be used for the operation of push force and pull force [8].
- Handle length: the minimum handle length should be 100 to 125mm [12]. The palm width of 95% of workers is less than 100mm [7]. Moreover, the average of hand breadth for the males was 87mm, and that for the females was 78mm [13].

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- Handle slope: the pistol-shaped handle should be tilted at 78° [10]. Some studies found that users prefer a slightly curved hammer handle of 10° to replace the straight grip [14]. A hammer handle can reduce wrist damage when it is tilted 20° to 40° [15]. For the hand tool with a normal linear handle, the grip central line and the forearm support shaft form a degree of 110° [16].

The purpose of this study was used anthropometric measurements to develop a handles that fits human-hand and suitable for the most people. The findings can serve as references for the industry and hand tool designers in the design of handles.

2 Methods

2.1 Hand anthropometric measurements

Sixty adult participants (30 male, 30 female; mean age=31.2 y; SD=4.4 y) took part in the experiment. Hand anthropometric measurements were obtained with the participant's right-hand using a caliper.

2.2 Definition of idealized gripping gesture

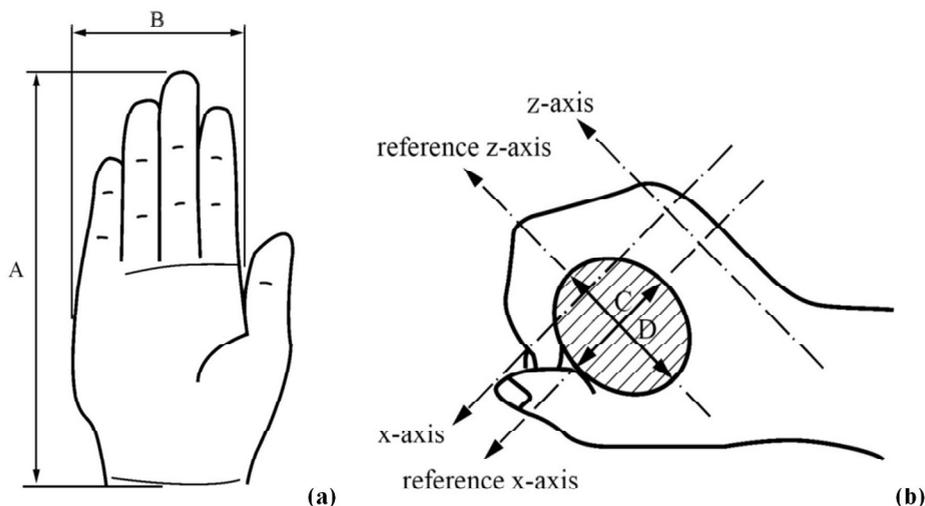


Figure 1. The definitions of the dimensional measurement of hand: (a) A, B, C, and D dimensions were measured with a caliper. (b) The grip gesture was determined by the biodynamic hand coordinate system defined in ISO 8727 [17].

Table 1. Definitions of hand measurements.

item	definition
A hand length	distance from top of the middle finger to the distal crease of the wrist.
B hand breadth	maximum hand breadth where the fingers join the palm.
C grip breadth inside width diameter	inside hand elliptical diameter with the length of major axis measured at grip breadth
D grip breadth inside length diameter	inside hand elliptical diameter with the length of minor axis measured at grip breadth

Figure 1 and Table 1 shows the definitions of the dimensional measurement of hand. The A-D dimensions were measured by using a caliper, as shown in the Fig.1a. In order to obtain the consistency of the gripping gesture, the palm and fingers of the hand needs to be position of the force distribution. The grip gesture were determined by the biodynamic hand coordinate system defined in

ISO 8727 [17] is included in Fig. 1b. The z-axis is passes proximally through the third metacarpal bone when gripping gesture. The x-axis of the system is approximately normal to the palm of the hand, projecting anteriorly from the origin when the hand lies open in the normal anatomical position, i.e. palms facing forward. The axis parallel to the x and z-axis and passing through the center of the handle circle were used as the reference x and z-axis.

3 Results and discussions

3.1 Hand anthropometric data

Table 2 presents the results of anthropometric data. The overall means of hand length was 177.9mm (187.9mm for males and 167.9mm for females). In addition, the average of hand breadth (four fingers) was 79.4mm (83.6mm for males and 75.2mm for females). The measurement results of hand in the current study were close to the anthropometric measurements of Taiwanese aged between 25 to 34 years old [18], suggesting that the anthropometric data in the present study can represent a design reference for related tool manufacturing industries in Taiwan.

Table 2. The results of hand dimensions (unit: mm) (standard deviation of the mean in parentheses).

item		This study	Wang et al. (2002)
male	A hand length	187.9 (7.9)	183
	B hand breadth (four fingers)	83.6 (4.8)	86
	C grip breath inside width diameter	44.5 (5.3)	-
	D grip breath inside length diameter	35.6 (4.9)	-
female	A hand length	167.9 (6.6)	167
	B hand breadth (four fingers)	75.2 (6.2)	75
	C grip breath inside width diameter	32.2 (4.5)	-
	D grip breath inside length diameter	25.7 (5.0)	-
all	A hand length	177.9 (12.4)	175
	B hand breadth (four fingers)	79.4 (6.9)	80.5
	C grip breath inside width diameter	38.3 (7.9)	-
	D grip breath inside length diameter	30.7 (7.0)	-

3.2 Handle length

The handle length was determined by the hand breadth. In the current study, the result of hand breadth (four fingers) was consistent with the findings which suggested that approximately 95% of workers were below 100mm [7]. According to the result of hand breadth, this study therefore considered that the handle length at least should be 100mm. Moreover, the average of hand breadth for the males of American was 87mm, and that for the females was 78mm [13]. It was inferred that the hand breadth of Taiwanese was slightly shorter than that of American.

3.3 Handle diameter

Table 3. The ratio of major-to-minor diameter of handle dimensions.

item	handle diameter of elliptical grip*	
	This study	Cochran & Riley (1986)
male	1:1.25	-
female	1:1.25	-
all	1:1.25	1:1.25

Table 3 illustrates the results of handle diameters for males and females. The grip breath inside width-to-length diameter for all participants was 30.7-to-38.3mm (35.6-to-44.5mm for males and 25.7-to-32.2mm for females). The overall gripping diameter of handle in the present study was consistent with the [5], which suggested that handle diameter should be in the range of 30 to 40 mm. However, this suggested range of handle diameter was small for males, and large for females. Because of the hand length for females in the gripping was smaller than for the males. Moreover, this study agreed the diameter should be in a wider range of 25 to 50mm [6]. It was more suitable for most people, but not clearly for the specific tool handle (i.e. power tool, peeler, or saw). No matter what a tool design should consider the different sizes of handle for different gender used.

3.4 Handle cross-section

The best cross-section of a handle for gripping was elliptical shape. The ratio of cross-section with width and length diameter for males and females were both 1: 1.25, as shown in the Table 3. According to the [8] recommended that the ratio of width and length diameter was 1: 1.25 (28mm for the width diameter and 35mm for the length diameter), suggesting that it is the best ratio for gripping. Moreover, a handle cross-section with the width-to-length diameter for gripping was 17.3-to-21.5% of the hand length (18-to-23.7% for males and 15.3-to-19.2% for females), as shown in the Table 4. The overall results were close to the findings of [11], that the diameter of a suitable handle was 19.7% of hand length. However, this suggested value for a handle was large for females because their hand length was too small that did not enough to completely hold. Thus, a great size of handle cross-section should be depended on the hand length of users.

Table 4. The percentage of handle dimensions to hand length.

item	handle diameter		
	This study		Kong & Lowe (2005)
	width diameter*	length diameter**	
male	18%	23.7%	-
female	15.3%	19.2%	-
all	17.3%	21.5%	19.7%

*width diameter = D grip breath inside width diameter / A hand length

**length diameter = C grip breath inside length diameter / A hand length

4 Conclusion

This study presented a guideline for handle design based on hand anthropometric measurements. The findings in the current study are important for developing a comfortable tool handle to develop and manufacture a best shaped tool handle for users. Thus, our results could provide a handle reference for constructing a new tool handle design.

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