Anthropometric Hand Dimensions of Chinese Adults Using Three-Dimensional Scanning Technique

Qi Chen, Haining Wang(✉), and Kexiang Liu

School of Design, Hunan University, Changsha 410082, China
haining1872@qq.com

Abstract. The purpose of this study is to represent a large-scale Chinese hand anthropometric survey. A total of 937 adults (468 males and 469 females) age between 22 and 60 years-old were involved to be measured from six main areas of China. 3D scanning technology was adopted to capture duplicated models of both left and right hands in the splayed and closed postures respectively. 10 hand dimensions were extracted from the 3D scans. Statistics including mean, standard deviation, and various percentiles were calculated. T-tests were conducted to compare the differences between left and right hands. Moreover, the differences between males and females were analyzed. The results indicate that right hands are generally thicker, broader, and shorter than left hands. Also, males have larger hand measurements than females, as expected. This study provides ergonomic indication for hand related products design.

Keywords: Hand · Anthropometric measurement · Three-dimensional scanning

1 Introduction

Most of human mechanical interactions with the surrounding world are performed by the hands [1]. There are many tools and devices which are used by hands, from everyday life (scissors, hammers, mobile phones, mouses) to areas of expertise (laparoscope, rackets, VR controllers). Extensive research has shown that hand related products and handheld devices would have a poor use experience without good ergonomic design [2–4]. Lack of ergonomic principles in these hand related products have been proved to be a contributing factor in hand diseases, such as tenosynovitis [5–7], neuropraxia [8] and etc.

Anthropometry, as an important branch of ergonomics, collects large amounts of anthropometric dimensions, analyses the measured data, and studies their relationship with the work systems, thus provide indication for the design of products and systems [9–11]. A considerable amount of literature has been published on hand anthropometry of varies countries around the world. Furthermore, different methods have been proposed to obtain hand anthropometric data. Direct measurement is the most traditional and common approach, and it is involved in hand anthropometric study of Czech population [12], Korean [13], Iranian male workers [14], Nigerian farm workers [15], northern

M. M. Soares et al. (Eds.): HCII 2022, LNCS 13322, pp. 377–387, 2022.
https://doi.org/10.1007/978-3-031-05900-1_26

Colombian [11] and Bangladeshi agricultural farm workers [16]. Except this, some researchers developed hand anthropometric database by photogrammetric technique, such as the hand anthropometry of Spain [17], and San Francisco, USA [18]. In recent years, a new progressing method to collect human dimensions data, three-dimensional scanning method, has adopted by several research. For example, the hand anthropometric examinations of Americans [19], and people from Taiwan, China [20].

The 3D scanning technology have been developing over years, which facilitates the investigation of anthropometry. Using a 3D laser or optical scanner, 3D scanning collects surface measurements including not only length and circumference but also complex geometry including shape, surface area, and volume [21–25]. Compared with direct measurement or photogrammetry, 3D scanning shows better reliability if there is good scanning quality [21–23].

On the one hand, data for hand dimensions of Chinese are scarce. On the other hand, there has been a significant rising of indigenous technological companies who have started to explore their own design, including the design of hand related products and handheld devices [26]. There is high demand for these companies to improve the ergonomics of their products to achieve good wearing comfort for hand products. Therefore, a representative and up-to-date hand anthropometric database is needed to help improve the ergonomics design of hand products. In this study, a hand anthropometry survey was created by recruiting 937 participants from 6 main geographic areas of the China (North China, Northeast China, Northwest China, Southwest China, South China, and East China). The aim of this study includes:

- To build a database including scanned hand models and hand dimensions of Chinese;
- To investigate the differences in hand dimensions between left and right hands, and between males and females;
- To compare obtained hand dimensions with corresponding dimensions from other populations.

2 Methodology

2.1 Participants

According to the procedures outlined in the *ISO 15535* [27]*: general requirements for establishing anthropometric databases*, the minimum sample size per region to build a national hand database was calculated to be 100. The accuracy of measurements depends on the sample size. In this study, a larger sample size involving 937 subjects was chosen in order to obtain sufficient data quality and generalization.

The proportional stratified random sampling method was adopted for this survey, through which the population was split into six strata. After the strata were established, a simple random sample was captured from every stratum separately according to proportion. This survey has three demographic variables: gender, age, and geographical area. With the proportional stratified random sampling method, this anthropometric survey is considered to be representative in gender, age and geographical area (Table 1).

Table 1. Basic information of all participants.

Characteristics		Amount			Percentage	
		Total	Male	Female	Male	Female
Age Group	18–29	206	108	98	11.53%	10.46%
	30–39	250	115	135	12.27%	14.41%
	40–49	229	121	108	12.91%	11.53%
	50–65	241	116	125	12.38%	13.34%
	>65	11	8	3	0.85%	0.32%
	Total	**937**	**468**	**469**	**49.95%**	**50.05%**
Living Area	North China	157	78	79	8.32%	8.43%
	Northeast China	156	78	78	8.32%	8.32%
	Northwest China	155	77	78	8.22%	8.32%
	Southwest China	156	78	78	8.32%	8.32%
	South China	156	79	77	8.43%	8.22%
	East China	157	78	79	8.23%	8.43%

2.2 Experiment

In this study, a novel 3D scanning approach was adopted after a pilot scanning trial. This trial was conducted to obtain good hand images, and avoid errors resulted from hidden hand regions and sway of the hand that were found in previous studies [24, 25, 28]. Two methods were used to improve the scanning quality. Firstly, change reflecting angle effectively to avoid the occurrence of hidden hand regions. Secondly, reduce scanning time by using Artec Eva scanner (Artec 3D, Luxembourg), which has a scanning speed with million points per second. Thirdly, enhance the proficiency of operators who were selected by the pilot hand scanning trial. In this way, the required time for scanning was shortened from 8 min to 2 min, result in the decrease of hand sway [21].

Each participant was shown a brief overview on the aim and processes before the experiment. Marking stickers ($\phi = 3$ mm, thickness $= 0.5$ mm) were attached on the hand of each participant as hand identified landmarks. Both hands were scanned in the splayed and closed postures respectively with an accuracy of up to 0.1 mm. Artec Studio 15 (Artec 3D, Luxembourg) was used as the 3D data post-processing software to export high-quality 3D hand models. Geomagic Wrap (Artec 3D, Luxembourg) were chosen to extracted measurements and features of 3D hand scans.

2.3 Measurement

Hand landmarks and dimensions were identified and extracted according to a quantity of literature [11, 13, 16, 17, 29–33]. Definition of 10 dimensions was based on ISO 7250 [32], GBT 5703 [33] and other previous studies [34], as shown in Table 2. All measurements were calculated and extracted using Geomagic Wrap.

Table 2. Definition of hand dimensions.

No	Hand dimensions	Definition
1	Palm length	The distance on the palm of the hand, from a line connecting the radial and ulnar styloid processes to the proximal finger crease of the middle finger, measured parallel to the long axis of the outstretched middle finger
2	Hand thickness	Maximum thickness of the hand, measured across the knuckles
3	Hand length	The distance from the tip of the third finger, along its long axis, to a line connecting the radial and ulnar styloid processes
4	Hand breadth	Projected distance between radial and ulnar metacarpals at the Projected distance between radial and ulnar metacarpals at the level of the metacarpal heads from the second to the fifth metacarpal, measured perpendicular to the long axis of the middle finger
5	Thumb length	Length of the thumb from the proximal thumb crease to the tip of the thumb
6	Middle finger length	The distance from the tip of the third finger to the proximal finger crease on the palm of the hand
7	Thumb breadth	Maximum breadth of the thumb in the region of the joint between the two phalanges
8	Middle finger breadth, proximal	Maximum breadth of the third finger in the region of the joint between middle and proximal phalanges
9	Wrist circumference	Minimum circumference of the wrist at the level of the radial styloid, with the hand outstretched. The tape passes just distal to the ulnar styloid
10	Hand circumference	The superficial distance around the edge of the metacarpal

2.4 Statistical Analysis

SPSS 25 (IBM Corp., Armonk, New York) was used for the statistical analysis of all dimensions for males and females respectively. Statistics like mean value, standard deviation, and various percentiles (5th, 25th, 50th, 75th and 95th) were calculated, as shown in Table 3. All hand measurements were analyzed using Kolmogorov-Smirnov test. Independent sample T-tests was conducted to compare the differences between left and right hands. Besides, to investigate the diversity between males and females, another independent sample T-tests was taken for right hand dimensions. At the aspect of ethnography, T-test were also conducted to compare the hand features from six areas of China. Moreover, differences of hand dimensions between Chinese and other populations were analyzed.

3 Result

The results of anthropometric hand dimensions of left and right including the mean and standard deviation, taken from Chinese male and female of six geographic areas, are shown in Table 3 and Table 4. These two tables also show a matched samples t-test results between left and right hands for male and female respectively. In this paper, hand dimensions comparisons mainly focus on right hands. Tables 5 and 6 lists the 5th, 25th, 50th, 75th, and 95th percentile for right hand measurements. Table 7 depicts a comparison of right hand measurements between male and female.

Table 3. Statistics of left and right hand dimensions of Chinese males.

Hand dimensions	Left hand		Right hand		% diff.	t	P
	Mean	SD	Mean	SD			
1) Palm length	113.38	5.95	113.25	6.20	0.11	0.632	0.527
2) Hand thickness	29.27	1.73	30.50	1.92	−4.21	−18.52	0.000**
3) Hand length	189.17	9.05	189.32	9.13	−0.08	−0.184	0.854
4) Hand breadth	82.46	4.09	83.58	3.89	−1.36	−10.497	0.000**
5) Thumb length	58.23	3.63	58.50	4.02	−0.45	−1.586	0.113
6) Middle finger length	78.82	4.49	78.54	4.62	0.35	2.49	0.013*
7) Thumb breadth	21.16	2.95	21.66	3.65	−2.36	−2.732	0.007*
8) Middle finger breadth, proximal	19.80	2.65	19.99	3.28	−0.97	−1.184	0.237
9) Wrist circumference	172.98	9.46	174.30	9.72	−0.76	−6.021	0.000**
10) Hand circumference	201.25	10.11	203.58	9.70	−1.16	−10.214	0.000**

% diff. = (Left hand mean-Right hand mean)/Left hand mean * 100.
*Statistically significant at $\alpha = 0.05$, ($p < 0.05$) at confidence interval percentage 95%.
**statistically significant at $\alpha = 0.001$, ($p < 0.001$).

Table 4. Statistics of left and right hand dimensions of Chinese females.

Hand dimensions	Left hand		Right hand		% diff.	t	P
	Mean	SD	Mean	SD			
1) Palm length	103.82	5.42	104.30	5.89	−0.46	−2.08	0.04*
2) Hand thickness	26.17	1.58	27.05	1.79	−3.35	−15.08	0.00**
3) Hand length	173.55	8.21	174.85	8.55	−0.75	−4.77	0.00**
4) Hand breadth	74.56	3.65	75.57	3.57	−1.36	−12.70	0.00**
5) Thumb length	54.06	3.43	54.54	3.42	−0.89	−3.09	0.00**
6) Middle finger length	73.82	3.95	73.94	4.05	−0.16	−0.85	0.40
7) Thumb breadth	18.34	3.55	19.20	2.79	−4.74	−4.14	0.00**
8) Middle finger breadth, proximal	17.56	3.38	18.05	2.54	−2.82	−2.59	0.01*
9) Wrist circumference	156.63	10.12	156.94	9.65	−0.20	−1.60	0.11
10) Hand circumference	182.46	9.68	184.61	9.60	−1.18	−12.86	0.00**

% diff. = (Left hand mean-Right hand mean)/Left hand mean.
*Statistically significant at $\alpha = 0.05$, ($p < 0.05$) at confidence interval percentage 95%.
**statistically significant at $\alpha = 0.001$, ($p < 0.001$).

Table 5. Percentiles of right hand dimensions of Chinese males.

Hand dimensions	Percentiles				
	5th	25th	50th	75th	95th
1) Palm length	103.83	108.99	112.77	117.24	123.78
2) Hand thickness	27.62	29.21	30.36	31.64	34.03
3) Hand length	175.22	182.82	189.09	195.36	204.88
4) Hand breadth	77.58	80.99	83.57	86.04	89.97
5) Thumb length	51.52	55.95	58.38	61.21	65.48
6) Middle finger length	70.83	75.58	78.55	81.65	85.53
7) Thumb breadth	19.37	21.10	22.10	23.07	24.83
8) Middle finger breadth, proximal	18.24	19.54	20.39	21.23	22.65
9) Wrist circumference	159.17	167.46	173.90	180.94	191.13
10) Hand circumference	188.43	197.00	203.69	209.88	219.21

Table 6. Percentiles of right hand dimensions of Chinese females.

Hand dimensions	Percentiles				
	5th	25th	50th	75th	95th
1) Palm length	94.65	100.40	104.20	107.70	115.31
2) Hand thickness	24.05	25.88	26.94	28.29	30.16
3) Hand length	161.84	169.07	174.32	179.84	190.33
4) Hand breadth	69.54	73.03	75.43	77.77	81.70
5) Thumb length	49.03	52.20	54.39	56.98	60.22
6) Middle finger length	67.28	71.01	74.02	76.81	81.11
7) Thumb breadth	16.84	18.63	19.46	20.42	21.60
8) Middle finger breadth, proximal	16.38	17.51	18.35	19.04	20.18
9) Wrist circumference	142.10	150.53	155.89	162.92	174.34
10) Hand circumference	169.87	178.26	183.50	190.69	202.21

Table 7. Comparison of right hand measurements between Chinese males and females.

Hand dimensions	Male		Female		% diff.	t	P
	Mean	SD	Mean	SD			
1) Palm length	113.25	6.20	104.30	5.89	7.90	21.99	0.00
2) Hand thickness	30.50	1.92	27.05	1.79	11.31	27.73	0.00
3) Hand length	189.32	9.13	174.85	8.55	7.64	24.29	0.00
4) Hand breadth	83.58	3.89	75.57	3.57	9.58	31.91	0.00
5) Thumb length	58.50	4.02	54.54	3.42	6.77	15.71	0.00
6) Middle finger length	78.54	4.62	73.94	4.05	5.86	15.73	0.00
7) Thumb breadth	21.66	3.65	19.20	2.79	11.36	11.21	0.00
8) Middle finger breadth, proximal	19.99	3.28	18.05	2.54	9.70	9.84	0.00
9) Wrist circumference	174.30	9.72	156.94	9.65	9.96	26.48	0.00
10) Hand circumference	203.58	9.70	184.61	9.60	9.32	27.79	0.00

% diff. = (Left hand mean-Right hand mean)/Left hand mean.
Confidence interval percentage of statistically significant is 95%.

4 Discussion

In this study, ethnic did not be chosen as a criterion in participants recruitment. After 3D hand scanning and data collection, it was found that 98% of the participants are Han nationality. Han Nationality is the largest nationality among the 56 ethnic groups of China, accounting for 91.59% of China's population. So, the sample of this study could be thought to be in accordance with the ethnic group distribution of China.

A three-dimensional scanning method was adopted in this study. Duplicated hand models were obtained through 3D scanning, after which 10 hand dimensions were extracted. Consequently, the result of this study is expandable that more dimensions could be extracted and analyzed according in the future. It is worth noting that unlike conventional direct measurement, 3D scanning doesn't have skin deformation issues resulted from measurement tools, so the figure length dimensions of this study might be smaller than that of conventional direct measurement method, and the figures of width and thickness dimensions might be bigger [21]. With the development of computer-aided design (CAD), more and more products would be developed through CAD technology. Compared with conventional direct measurement method, three-dimension scanning method could match more with CAD, hence might gradually gain its popularity.

The result of this survey could be used to determine dimensions of hand related products and hand-held devices. When designing a dimension-adjustable product which covers 90% of Chinese population, product dimensions should range from the 5^{th} to the 95^{th} percentile. If a glove is developed for Chinese women, then it is not appropriate for the part of palm to be shorter than 94.7 mm (5^{th} percentile value of Chinese female palm length). Besides, percentiles of finger breadth could be used to determine the diameter of rings, and percentiles of hand breadth could provide design reference to the breadth of mouses.

4.1 Left-Right Hand Comparison

Chinese males have significant differences ($p < 0.001$) between left and right hand in the measurement of hand thickness, hand breadth, wrist circumference, and hand circumference. Females have significant differences ($p < 0.001$) between left and right hand in the measurement of hand thickness, hand breadth, hand length, thumb length, thumb breadth, and hand circumference. Males and females both have considerable differences in the measurement of hand circumference, hand thickness and hand breadth. Moreover, for right hands, all length dimensions are shorter than left hand, and all breadth and width dimensions are bigger than left hand. This might be result from higher frequency of right-hand use.

It is also worth noting that although the p values of these measurements are below 0.001, the difference percentages of them only range from 0.1 to 4%. So, when producing products of both hands, whether to consider the differences between left and right hand should base on the specific scenery.

4.2 Male-Female Comparison

T-test results and percentage differences suggest a considerable differences ($p < 0.001$) between Chinese men and women. As expect, males have larger values in all dimensions, and the percentage differences are large (vary from 5.86 to 11.36%). This result indicates a strong necessity to design different product sizes for males and females respectively. For example, mouses for females should be shorter in length at about 7.5% (the percentage difference of hand length between males and females is 7.5%), be narrowed in breadth at about 11.5% (the percentage difference of hand breadth between males and females is 7.5%); straps of wrist-wearing products for females should have 10% shorter than males

(the percentage difference of wrist circumference between males and females is 10%); rings for males and females should have an approximate 10% difference in diameter between them (the finger breadth of females are about 10% less than males).

5 Conclusion

In this study, 937 males and females from six representative cities of China were recruited and 3D scanned. Both hands of them were scanned as 3D models and 10 dimensions were measured and analyzed. The result shows basic hands features and percentiles of Chinese male and female. This is the first large-scale measurement of Chinese hands using 3D scanning, which could provide design references for various types of hand related products aimed for Chinese population.

This study compares the differences of hand dimensions between left and right hands. The result reveals that both male and female hands differ significantly in terms of hand thickness, hand breadth, middle finger middle phalanx length, and hand circumference. However, the percentage differences in these measurements are only between 0.1% and 4%, so it is worth considering whether to ignore the differences between the left and right hands when designing products.

In addition, a comparison of hand dimensions between male and female shows that all values are significantly larger for men compared with women. This suggests that in some hand product designs involving both male and female users, it is important to differentiate between them in separate designs. Furthermore, the hand characteristics of the Chinese differ significantly from those of European and American countries, but not so much from those of Asian countries such as Korea and Jordan. The results of this study can be utilized to design hand related products for other Asian countries.

References

1. León, B., Morales, A., Sancho-Bru, J.: From Robot to Human Grasping Simulation. vol. 19. Springer, Cham (2014). https://doi.org/10.1007/978-3-319-01833-1
2. Goonetilleke, R.S.: Designing to miminize discomfort. Ergon Design **6**(3), 12–19 (1998)
3. Chang, S.R., Park, S., Freivalds, A.: Ergonomic evaluation of the effects of handle types on garden tools. Int. J. Ind. Ergon. **24**(1), 99–105 (1999)
4. Kim, H.K., et al.: Does the hand anthropometric dimension influence touch interaction? J. Comput. Inf. Syst. **59**(1), 85–96 (2019)
5. Li, K.W.: Ergonomic design and evaluation of wire-tying hand tools. Int. J. Ind. Ergon. **30**(3), 149–161 (2002)
6. Andréu, J.-L., et al.: Hand pain other than carpal tunnel syndrome (CTS): the role of occupational factors. Best Pract. Res. Clin. Rheumatol. **25**(1), 31–42 (2011)
7. Kong, Y.-K., Kim, D.-M.: The relationship between hand anthropometrics, total grip strength and individual finger force for various handle shapes. Int. J. Occup. Saf. Ergon. **21**(2), 187–192 (2015)
8. Horgan, L., O'riordan, D., Doctor, N.: Neuropraxia following laparoscopic procedures: an occupational injury. Minim. Invasive Ther. Allied Technol. **6**(1), 33–35 (1997)
9. Chang, J., et al.: Determination of bicycle handle diameters considering hand anthropometric data and user satisfaction. In: Proceedings of the Human Factors and Ergonomics Society Annual Meeting. SAGE Publications Sage CA: Los Angeles, CA (2010)

10. Reis, P.F., et al.: Influence of anthropometry on meat-packing plant workers: an approach to the shoulder joint. Work **41**(Supplement 1), 4612–4617 (2012)
11. Oviedo-Trespalacios, O., et al.: Hand anthropometric study in northern Colombia. Int. J. Occup. Saf. Ergon. **23**(4), 472–480 (2017)
12. Bures, M., Gorner, T., Sediva, B.: Hand anthropometry of Czech population. In: 2015 IEEE International Conference on Industrial Engineering and Engineering Management (IEEM). IEEE (2015)
13. Jee, S.-C., Yun, M.H.: An anthropometric survey of Korean hand and hand shape types. Int. J. Ind. Ergon. **53**, 10–18 (2016)
14. Mirmohammadi, S.J., et al.: Anthropometric hand dimensions in a population of Iranian male workers in 2012. Int. J. Occup. Saf. Ergon. **22**(1), 125–130 (2016)
15. Obi, O.F.: Hand anthropometry survey of rural farm workers in south-eastern Nigeria. Ergonomics **59**(4), 603–611 (2016)
16. Shahriar, M., Parvez, M., Lutfi, M.: A survey of hand anthropometry of Bangladeshi agricultural farm workers. Int. J. Ind. Ergon. **78**, 102978 (2020)
17. Vergara, M., Agost, M.J., Gracia-Ibáñez, V.: Dorsal and palmar aspect dimensions of hand anthropometry for designing hand tools and protections. Hum. Factors Ergon. Manuf. Serv. Ind. **28**(1), 17–28 (2018)
18. Rogers, M.S., et al.: A three-dimensional anthropometric solid model of the hand based on landmark measurements. Ergonomics **51**(4), 511–526 (2008)
19. Griffin, L., Sokolowski, S., Seifert, E.: Process considerations in 3D hand anthropometric data collection. In: Proceedings of 3DBODY. TECH, pp. 121–130 (2018)
20. Lin, C.H., Lin, P.T., Chao, Y.: Hand surface area variation analyzed by 3D laser scan measurement. In: Proceedings of the Second European Academic Research Conference on Global Business, Economics, Finance and Banking. Zurich-Switzerland (2015)
21. Lee, W., et al.: Comparison of a semiautomatic protocol using plastering and three-dimensional scanning techniques with the direct measurement protocol for hand anthropometry. Hum. Factors Ergon. Manuf. Serv. Ind. **27**(3), 138–146 (2017)
22. Chang, C.-C., et al.: Error control and calibration in three-dimensional anthropometric measurement of the hand by laser scanning with glass support. Measurement **40**(1), 21–27 (2007)
23. Lee, W.-S., Yoon, S.-H., You, H.-C.: Development of a 3D semi-automatic measurement protocol for hand anthropometric measurement. IE Interfaces **24**(2), 105–111 (2011)
24. Kim, M.-H., Nam, Y.-J.: Development of three dimensional scanner for anthropometric measurement. J. Ergon. Soc. Korea **20**(3), 77–88 (2001)
25. Li, Z., et al.: Validation of a three-dimensional hand scanning and dimension extraction method with dimension data. Ergonomics **51**(11), 1672–1692 (2008)
26. Zhao, Z., et al.: China's industrial policy in relation to electronics manufacturing. Chin. World. Econ. **15**(3), 33–51 (2007)
27. ISO, I., 15535: General requirements for establishing anthropometric databases. Int. Organ. Stand (2006). https://www.iso.org/standard/57179.html. Accessed on 5 April 2021
28. Choi, H., et al.: Development of hand measurement protocol for glove design. Seoul, South Korea: Size Korea (2006)
29. Hsiao, H., et al.: Firefighter hand anthropometry and structural glove sizing: a new perspective. Hum. Factors **57**(8), 1359–1377 (2015)
30. Mandahawi, N., et al.: Hand anthropometry survey for the Jordanian population. Int. J. Ind. Ergon. **38**(11–12), 966–976 (2008)
31. Cakit, E., et al.: A survey of hand anthropometry and biomechanical measurements of dentistry students in Turkey. Hum. Factors Ergon. Manuf. Serv. Ind. **24**(6), 739–753 (2014)
32. ISO, I.: 7250–1: 2017 Basic human body measurements for technological design—Part 1: body measurement definitions and landmarks. ISO: Geneva, Switzerland (2017)

33. China National Institute of Standardization et al.: Anthropometric project for technical design. General Administration of Quality Supervision, Inspection and Quarantine of the People's Republic of China; Standardization Administration of the People's Republic of China, p. 40 (2011)
34. Li, Z., et al.: An anthropometric study for the anthropomorphic design of tomato-harvesting robots. Comput. Electron. Agric. **163**, 104881 (2019)