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Hand Anthropometry of a Sample of Libyan Young Adults from the City of Benghazi

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***Abstract*—The objective of this study was to collect hand anthropometric data for a sample of Libyan young adults from the city of Benghazi. This study was motivated by the unavailability of such data. Measurements were collected from 400 participants (half males). With an age range of 20-40 years and an average age of 23.8 years. Thirty-two anthropometric hand dimensions were measured. They covered large aspects of hand anthropometry including all five fingers' lengths, breadths and circumferences, hand length, breadth and depth, and wrist breadth and circumference. Mean, standard deviation, 5th percentile and 95th percentile were calculated for each anthropometric hand dimension. Comparison of mean hand dimensions of females and males showed statistically significant differences between all dimensions. Comparisons with data from China and Turkey (the two top exporters to Libya) were also carried out. These comparisons showed significant differences in several hand dimensions with data from both countries.**

Keywords—Hand anthropometry, Libyan, Young adults, Hand tools, Hand garments

I. INTRODUCTION

The process of incorporating anthropometric data in ergonomic design of workplaces and equipment is well established within the field of ergonomic. Engineering anthropometry is the specific scientific field concerned with this process, and is usually part of any general university level course teaching human factors engineering and ergonomic[1]–[3]. The importance of incorporating anthropometric data in ergonomic design comes from the need to design equipment and workplaces that matched human users. Ergonomically designed workplaces and equipment (that matched users' anthropometry) should increase performance, safety and satisfaction [1]–[3].

An important first step in the process requires development of anthropometric data for the potential users' population. One significant role of human factors engineers and ergonomists is the development of such data. This study comes as part of this role; the main objective of this study is to collect anthropometric hand data for a sample of Libyan young adults from the city of Benghazi. The motivation of this study comes from the lack of any anthropometric hand data for the Libyan population. To the best of the authors' knowledge, this study is the first attempt to develop such data.

As many of the developing countries, Libya imports most of industrial goods from the industrialized developed countries. These imported goods may not fit anthropometrics of the Libyan population, since such goods would have been designed to fit body sizes of the population of the industrialized developed countries of origin. Abeysekera and Shahnavaz [4] reveled differences in almost every part of the human body between users form the industrially developing countries and the industrialized developed countries. The use of tools and equipment that do not fit the users' anthropometry could decrease safety, performance and satisfaction. The use of such tools and equipment with repetitive hand and arm exertions could contribute to the development of cumulative trauma disorders (CTD) in the upper extremities [3], [4]. This stress the need for developing anthropometric data for the Libyan population.

Availability of this data could help manufactures who manufactures and sells goods for the Libyan market design their goods according to the anthropometry of the Libyan population.

Many studies aiming at developing hand anthropometric data were published in the related human factors and ergonomics literature. They covered various populations, countries, and professions. The covered countries include Czechia [5], Turkey [6], China [7], [8], the United States [9], Korea [10], [11], Jordan [12], Saudi Arabia [13], Nigeria [14], [15], and Bangladesh [16]. The targeted populations and professions include dentistry students in Turkey [6],

Hong Kong Chinese females [7], Americans of Vietnamese origin [17], Bangladeshis living in America [18], rural farm workers in Nigeria [14], [15], Bangladeshi agricultural farm workers [16], and pianists [19].

Besides collecting hand anthropometric data, other studies also focused on investigating relationships between hand anthropometry and other variables and factors. For examples, Barut et al. [20] investigated relationship between Anthropometric aspects of hand morphology to both sex and body mass in a Turkish population sample. Kong & Kim [21] examined the relationship between hand anthropometrics, total grip strength and individual finger force for various handle shapes. Lee et al. [22] investigated the effect of hand length on bimanual perceived grip comfort in the context of shaping rollable display devices. Nicolay & Walker [23] studied the influence of anthropometric variation on grip strength. Kanchan et al. [24] conducted a study of correlation of hand and foot dimensions for personal identification in mass disasters. Rastogi et al. [25] used hand dimensions to estimate stature of north and south Indians. Shahida et al. [26] investigated the relationship between anthropometry and handgrip strength among elderly Malaysians.

Another group of published studied focused on utilizing hand anthropometric data in designing and evaluating hand tools and gloves. Examples include the use of the data to evaluate machine-guarding standards [27]. Utilization of anthropometric data of female farm workers from northeastern India to design a handle of hand tools [28]. Evaluation of functional fit of chemical protective gloves for agricultural workers [29]. Performing a 2D and 3D anatomical analyses of hand dimensions for custom-made gloves [30].

II. Method

A. Participants

Measurements were collected form 400 participants (half males). All participants were in the age range of 20-40 years, with an average age of 23.8 years and standard deviation of 4.1 years.

All the participants volunteered from students and employees of the University of Benghazi.

All measurements were taken on the right hand and none of the participants reported any hand injury or disability.

B. Anthropometric Hand Measurements

Thirty-two anthropometric hand dimensions were measured in this study. They covered large aspects of hand anthropometry including all five fingers lengths, breadths and circumferences, hand length, breadth and depth, and wrist breadth and circumference. All these 32 dimensions are same as the dimensions defined and measured in [5], [6], [8], [11], [16], [31].

The reason for choosing these 32 dimensions is that they covered large aspects of hand anthropometry as related to designing handles of hand tools (e.g. Hand drills, screwdrivers, pliers … etc.) and hand garments (e.g. Gloves).

All the dimensions were measured using a digital Vernier Caliper (with accuracy of 0.01 mm and range of 0-200 mm) or a flexible measuring tape (with accuracy of 1 mm). The 32 dimensions are listed in the first column of Table I and are shown in Fig. 1 and Fig. 2. The procedure and tool used to measure each dimension are shown in Fig. 3.

III. Results

A. Descriptive Statistics

Table I shows the calculated descriptive statistics for female and male anthropometric hand dimensions. Mean, standard deviation, 5th percentile and 95th percentile were calculated for each anthropometric hand dimension.

The Kolmogorov–Smirnov (KS) test of normality (at a significant level of $\alpha = 0.01$) was carried out for each anthropometric hand dimension for both females and males. Results of KS test are shown next to each dimension's mean in Table I. The KS test results indicated that 13 of the female hand dimensions and 16 of the male hand dimensions are normally distributed.

B. Comparison of Females and Males Measurements

All differences between mean male anthropometric hand dimensions and female anthropometric hand dimensions are statistically significant with p-values $< \alpha = 0.01$ as the hypothesis tests on the means of each dimension showed. The tests were carried out using the two-sample equal variances two-tails t-tests (where the normality assumption was satisfied) and Wilcoxon Rank-Sum tests (in cases where normality assumption was in doubt) [32]. All male anthropometric hand dimensions are larger than female anthropometric hand dimensions. .

C. Comparisons with Populations from Other Countries

The data collected in the current study was compared with data from both China and Turkey, the two top exports to the Libyan market [33]. In order to reduce any possible difference due to generational variability [1], [3]; the selected data from these two countries for comparison have been collected within the last ten years. The range of ages of participants is as close as possible to the range in the current study. In addition, the data has at least three common measured hand dimensions with the current study.

The results of the comparisons of the data of females and males of the current study with data from the selected countries are shown in Table II and Table III respectively.

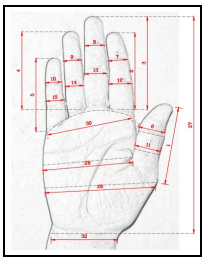

Fig. 1. Illustration of the measured anthropometric hand dimensions.

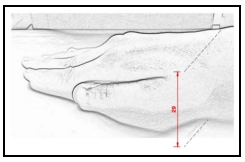

Fig. 2. Illustration of the hand depth dimension

TABLE I. DESCRIPTIVE STATISTICS OF THE ANTHROPOMETRIC HAND MEASUREMENTS (ALL DIMENSIONS IN MM).

No.	Anthropometric Hand Dimension	Female				Male			
		Mean	SD	Percentile Value		Mean	SD	Percentile Value	
				5th	95th			5th	95th
	Age (years)	23.7	3.9	-	-	24.0	4.3	-	-
1	Fingertip to root digit 1	59.6[a]	4.6	52.0	67.3	66.5[a]	5.6	57.3	75.7
2	Fingertip to root digit 2	66.3[a]	5.0	58.1	74.5	72.2[a]	5.3	63.5	80.9
3	Fingertip to root digit 3	73.6[a]	5.4	64.7	82.5	80.1	5.4	71.3	88.9
4	Fingertip to root digit 4	67.4[a]	5.0	59.2	75.6	73.2[a]	5.6	63.9	82.4
5	Fingertip to root digit 5	55.0	5.1	46.6	63.4	60.6[a]	4.7	52.8	68.4
6	Breadth at first joint of digit 1	17.1	1.4	14.7	19.4	19.1[a]	1.6	16.5	21.8
7	Breadth at first joint of digit 2	13.7[a]	1.0	12.0	15.4	15.7[a]	1.1	13.8	17.5
8	Breadth at first joint of digit 3	13.9	1.0	12.3	15.5	16.0[a]	1.1	14.2	17.9
9	Breadth at first joint of digit 4	13.0	0.9	11.5	14.5	15.0	1.1	13.2	16.8
10	Breadth at first joint of digit 5	11.2[a]	0.9	9.8	12.7	13.5[a]	1.1	11.7	15.4
11	Breadth at second joint of digit 1	17.7[a]	2.8	13.1	22.3	19.0[a]	2.4	15.0	22.9
12	Breadth at second joint of digit 2	16.1[a]	1.1	14.4	17.9	18.4[a]	1.2	16.4	20.3
13	Breadth at second joint of digit 3	16.5	1.0	14.8	18.1	18.6[a]	1.1	16.8	20.5
14	Breadth at second joint of digit 4	15.4[a]	1.0	13.8	17.0	17.6[a]	1.2	15.6	19.6
15	Breadth at second joint of digit 5	13.3[a]	1.1	11.4	15.1	15.6[a]	1.1	13.8	17.5
16	Circumference at first joint of digit 1	54.5	4.6	46.9	62.0	61.8	4.8	53.8	69.7
17	Circumference at first joint of digit 2	45.2	3.5	39.5	51.0	51.4	4.3	44.3	58.5
18	Circumference at first joint of digit 3	45.9	3.5	40.2	51.6	52.4	3.7	46.3	58.5
19	Circumference at first joint of digit 4	43.7	3.1	38.5	48.8	50.2	3.8	43.9	56.5
20	Circumference at first joint of digit 5	39.6	3.0	34.7	44.4	46.1	3.6	40.2	52.0
21	Circumference at second joint of digit 1	60.2	4.2	53.3	67.2	68.2	4.6	60.6	75.8
22	Circumference at second joint of digit 2	52.8	4.4	45.6	60.1	59.8	5.0	51.5	68.0
23	Circumference at second joint of digit 3	52.8	3.9	46.4	59.2	60.5	5.4	51.7	69.4
24	Circumference at second joint of digit 4	49.3	3.8	43.1	55.6	56.7	5.2	48.1	65.3
25	Circumference at second joint of digit 5	44.5	3.2	39.2	49.8	51.9	4.6	44.3	59.5
26	Handbreadth across thumb	81.7[a]	6.0	71.7	91.6	94.9	10.1	78.3	111.6
27	Hand length	173.8	10.5	156.4	191.1	185.9	18.3	155.9	216.0
28	Palm breadth	74.6[a]	4.4	67.4	81.8	85.4[a]	5.5	76.3	94.5
29	Hand depth	34.4	6.0	24.5	44.3	39.9	6.0	30.1	49.7
30	Handbreadth at metacarpals	69.6[a]	4.1	62.9	76.2	76.7[a]	4.6	69.1	84.2
31	Wrist circumference	153.6	11.6	134.5	172.6	170.7	13.2	148.9	192.4
32	Wrist breadth	50.6[a]	3.5	44.9	56.3	56.5[a]	3.6	50.6	62.4

[a.] Normally distributed (KS test p-value > $\alpha = 0.01$).

Fig. 3. Illustration of the procedure and tool used to measure each anthropometric hand dimension.

TABLE II. COMPARISONS OF ANTHROPOMETRIC HAND DATA OF FEMALES OF THE SAMPLE OF THE CURRENT STUDY WITH FEMALE DATA FROM CHINA AND TURKEY (ALL DIMENSIONS IN MM).

No.	Anthropometric Hand Dimension	Country	Libya (Current study)		China [8]			Turkey [6]		
		Sample size	200		2000			73		
		Age range (y)	(20-40)		(18-60)			(18-30)		
			Mean	SD	Mean	SD	Difference[b]	Mean	SD	Difference[b]
1	Fingertip to root digit 1		59.6	4.6	65.9	3.9	-6.2	59.4	3.7	0.2
2	Fingertip to root digit 2		66.3	5.0				68.3	3.5	-2.1
3	Fingertip to root digit 3		73.6	5.4				74.4	3.9	-0.8
4	Fingertip to root digit 4		67.4	5.0				68.3	3.5	-0.9
5	Fingertip to root digit 5		55.0	5.1				55.6	3.3	-0.6
6	Breadth at first joint of digit 1		17.1	1.4	17.2	0.9	-0.1	17.2	1.4	-0.2
8	Breadth at first joint of digit 3		13.9	1.0				14.4	0.6	-0.4
10	Breadth at first joint of digit 5		11.2	0.9				12.0	0.6	-0.7
13	Breadth at second joint of digit 3		16.5	1.0				16.7	0.7	-0.2
15	Breadth at second joint of digit 5		13.3	1.1				13.7	0.8	-0.4
27	Hand length		173.8	10.5	170.4	7.6	3.3	172.2	8.1	1.6
29	Hand depth		34.4	6.0				37.3	3.4	-2.9
30	Handbreadth at metacarpals		69.6	4.1	75.7	3.8	-6.1	69.9	3.2	-0.3
32	Wrist breadth		50.6	3.5				49.9	2.8	0.7

[b] Difference = (mean dimension of Libya – mean dimension of the other country). Underlined values are significant at $\alpha = 0.01$.

TABLE III. COMPARISONS OF ANTHROPOMETRIC HAND DATA OF MALES OF THE SAMPLE OF THE CURRENT STUDY WITH MALE DATA FROM CHINA AND TURKEY (ALL DIMENSIONS IN MM).

No.	Anthropometric Hand Dimension	Country	Libya (Current study)		China [8]			Turkey [6]		
		Sample size	200		2000			92		
		Age range (y)	(20-40)		(18-60)			(18-30)		
			Mean	SD	Mean	SD	Difference[c]	Mean	SD	Difference[c]
1	Fingertip to root digit 1		66.5	5.6	69.3	4.1	-2.8	65.7	4.6	0.8
2	Fingertip to root digit 2		72.2	5.3				74.7	4.8	-2.5
3	Fingertip to root digit 3		80.1	5.4				81.9	5.2	-1.8
4	Fingertip to root digit 4		73.2	5.6				75.6	5.3	-2.4
5	Fingertip to root digit 5		60.6	4.7				62.4	4.6	-1.8
6	Breadth at first joint of digit 1		19.1	1.6	19.0	1.0	0.1	19.8	1.7	-0.6
8	Breadth at first joint of digit 3		16.0	1.1				16.5	0.9	-0.5
10	Breadth at first joint of digit 5		13.5	1.1				14.0	0.8	-0.4
13	Breadth at second joint of digit 3		18.6	1.1				19.3	1.0	-0.6
15	Breadth at second joint of digit 5		15.6	1.1				16.1	0.9	-0.5
27	Hand length		185.9	18.3	182.9	8.0	3.1	190.4	9.7	-4.5
29	Hand depth		39.9	6.0				42.9	3.4	-3.0
30	Handbreadth at metacarpals		76.7	4.6	82.0	4.0	-5.3	78.4	4.5	-1.8
32	Wrist breadth		56.5	3.6				56.3	3.3	0.2

[c] Difference = (mean dimension of Libya – mean dimension of the other country). Underlined values are significant at $\alpha = 0.01$.

Two-sample unequal variances two-tails t-tests were used to complete the comparison. Results of the comparisons showed statistically significant differences in several dimensions between the Libyan sample of the current study and the Chinese and Turkish data reported in their respective studies. From results of comparisons, one can note that on average:-

- Turkish females have longer index fingers (digit 2), wider fingers, and thicker hands than Libyan females.
- Libyan females have longer hands than Chinese females. While Chinese females have longer thumbs (digit 1) and wider hands than Libyan females.
- Turkish males have longer and wider fingers, and longer, thicker and wider hands than Libyan males.
- Libyan males have longer hands. While Chinese males have longer thumbs (digit 1) and wider hands.

IV. CONCLUSIONS

This study was motivated by the lack of any anthropometric hand data for the Libyan population. The purpose of this study was to develop anthropometric hand data for a sample of Libyan young adults from the city of Benghazi. The data was collected from 400 participants (half males) of 20-40 years old.

The collected data included 32 hand dimensions. The data was analyzed using descriptive statistics and percentiles. Statistically significant differences were found between all hand dimensions of females and males.

The collected data in this study was compared with data of populations from both China and Turkey. The comparisons showed that Libyan females of the sample of the current study seem to have longer and narrower hands than Turkish and Chinese females. While Libyan males of the sample of the current study seem to have smaller hands than Turkish and longer and narrower hands than Chinese. These differences should be considered when designing hand tools and hand garments that would be manufactured and exported to the Libyan market; especially as China and Turkey are the two top exports to the Libyan market [33].

The data collected in this study can be very useful for designing hand tools (e.g. handles of any hand tools like hand drills and screwdrivers) and hand garments (e.g. gloves) for the Libyan population. However, since the sample collected in this study cover only one region in Libya, its results may not apply to all regions of Libya. Nevertheless, this study could be considered a first step in developing a database for the anthropometric hand dimensions of the Libyan population. The next steps should collect measurements from a wider Libyan population; covering both hands, wider age rang and all regions of Libya.

REFERENCES

[1] R. Bridger, Introduction to Human Factors and Ergonomics, Fourth Edition. Boca Raton FL: CRC Press Taylor & Francis Group, 2018.

[2] K. H. E. Kroemer, Fitting the Human: Introduction to Ergonomics / Human Factors Engineering, Seventh Edition. CRC Press, 2017.

[3] J. D. Lee, C. D. Wickens, Y. Liu, and L. N. Boyle, Designing for People: An Introduction to Human Factors Engineering. CreateSpace Independent Publishing Platform, 2017.

[4] J. D. A. Abeysekera and H. Shahnavaz, "Body size variability between people in developed and developing countries and its impact on the use of imported goods," Int. J. Ind. Ergon., vol. 4, no. 2, pp. 139–149, 1989, doi: 10.1016/0169-8141(89)90040-1.

[5] M. Bures, T. Gorner, and B. Sediva, "Hand anthropometry of Czech population," IEEE Int. Conf. Ind. Eng. Eng. Manag., vol. 2016-Janua, pp. 1077–1082, 2016, doi: 10.1109/IEEM.2015.7385814.

[6] E. Cakit, B. Durgun, O. Cetik, and O. Yoldas, "A survey of hand anthropometry and biomechanical measurements of dentistry students in Turkey," Hum. Factors Ergon. Manuf., vol. 24, no. 6, pp. 739–753, 2014, doi: 10.1002/hfm.20401.

[7] A. J. Courtney, "Hand anthropometry of hong kong chinese females compared to other ethnic groups," Ergonomics, vol. 27, no. 11, pp. 1169–1180, 1984, doi: 10.1080/00140138408963598.

[8] J. Zhao, G. Wu, C. Zhao, H. Wang, W. Ding, and F. Zhang, "Research on the Characteristic and Gender Differences in Adult Hand Shape in China," in Advances in Intelligent Systems and Computing, Jul. 2019, vol. 789, pp. 161–169, doi: 10.1007/978-3-319-94484-5_17.

[9] Garrett J. W., "The adult human hand. Some anthropometric and biomechanical considerations," Hum. Factors, vol. 13, no. 2, pp. 117–131, 1971, doi: 10.1177/001872087101300204.

[10] S. C. Jee, Y. S. Lee, J. H. Lee, S. Park, B. Jin, and M. H. Yun, "Anthropometric classification of human hand shapes in Korean population," Proc. Hum. Factors Ergon. Soc., pp. 1199–1203, 2016, doi: 10.1177/1541931213601281.

[11] S. C. Jee and M. H. Yun, "An anthropometric survey of Korean hand and hand shape types," Int. J. Ind. Ergon., vol. 53, pp. 10–18, 2016, doi: 10.1016/j.ergon.2015.10.004.

[12] N. Mandahawi, S. Imrhan, S. Al-Shobaki, and B. Sarder, "Hand anthropometry survey for the Jordanian population," Int. J. Ind. Ergon., vol. 38, no. 11–12, pp. 966–976, 2008, doi: 10.1016/j.ergon.2008.01.010.

[13] M. A. A. Mansour, "Hand anthropometric data for Saudi Arabia engineering students of aged 20-26 years at King Khalid university," Am. J. Eng. Appl. Sci., vol. 9, no. 4, pp. 877–888, 2016, doi: 10.3844/ajeassp.2016.877.888.

[14] O. O. Okunribido, "A survey of hand anthropometry of female rural farm workers in ibadan, western nigeria," Ergonomics, vol. 43, no. 2, pp. 282–292, 2000, doi: 10.1080/001401300184611.

[15] O. F. Obi, "Hand anthropometry survey of rural farm workers in south-eastern Nigeria," Ergonomics, vol. 59, no. 4, pp. 603–611, 2016, doi: 10.1080/00140139.2015.1073796.

[16] M. M. Shahriar, M. S. Parvez, and M. Lutfi, "A survey of hand anthropometry of Bangladeshi agricultural farm workers," Int. J. Ind. Ergon., vol. 78, no. May, p. 102978, 2020, doi: 10.1016/j.ergon.2020.102978.

[17] S. N. Imrhan, M. T. Nguyen, and N. N. Nguyen, "Hand anthropometry of Americans of Vietnamese origin," Int. J. Ind. Ergon., vol. 12, no. 4, pp. 281–287, 1993, doi: 10.1016/0169-8141(93)90098-X.

[18] S. N. Imrhan, M. D. Sarder, and N. Mandahawi, "Hand anthropometry in Bangladeshis living in America and comparisons with other populations," Ergonomics, vol. 52, no. 8, pp. 987–998, 2009, doi: 10.1080/00140130902792478.

[19] C. Wagner, "The pianist's hand: Anthropometry and biomechanics," Ergonomics, vol. 31, no. 1, pp. 97–131, 1988, doi: 10.1080/00140138808966651.

[20] C. Barut, A. Dogan, and M. C. Buyukuysal, "Anthropometric aspects of hand morphology in relation to sex and to body mass in a Turkish population sample," HOMO- J. Comp. Hum. Biol., vol. 65, no. 4, pp. 338–348, 2014, doi: 10.1016/j.jchb.2014.03.004.

[21] Y. K. Kong and D. M. Kim, "The relationship between hand anthropometrics, total grip strength and individual finger force for various handle shapes," Int. J. Occup. Saf. Ergon., vol. 21, no. 2, pp. 187–192, 2015, doi: 10.1080/10803548.2015.1029726.

[22] S. Lee et al., "Shaping Rollable Display Devices: Effects of Gripping Condition, Device Thickness, and Hand Length on Bimanual Perceived Grip Comfort," Hum. Factors, vol. 62, no. 5, pp. 770–786, 2020, doi: 10.1177/0018720819855225.

[23] C. W. Nicolay and A. L. Walker, "Grip strength and endurance: Influences of anthropometric variation, hand dominance, and gender," Int. J. Ind. Ergon., vol. 35, no. 7, pp. 605–618, 2005, doi: 10.1016/j.ergon.2005.01.007.

[24] T. Kanchan, K. Krishan, A. Sharma, and R. G. Menezes, "A study of correlation of hand and foot dimensions for personal identification in mass disasters," Forensic Sci. Int., vol. 199, no. 1–3, pp. 112.e1-112.e6, 2010, doi: 10.1016/j.forsciint.2010.03.002.

[25] P. Rastogi, K. R. Nagesh, and K. Yoganarasimha, "Estimation of stature from hand dimensions of north and south Indians," Leg. Med., vol. 10, no. 4, pp. 185–189, 2008, doi: 10.1016/j.legalmed.2008.01.001.

[26] M. S. Nurul Shahida, M. D. Siti Zawiah, and K. Case, "The relationship between anthropometry and hand grip strength among elderly Malaysians," Int. J. Ind. Ergon., vol. 50, pp. 17–25, 2015, doi: 10.1016/j.ergon.2015.09.006.

[27] A. J. Courtney and M. K. Ng, "Hong Kong female hand dimensions and machine guarding," Ergonomics, vol. 27, no. 2, pp. 187–193, 1984, doi: 10.1080/00140138408963476.

[28] K. N. Dewangan, C. Owary, and R. K. Datta, "Anthropometric data of female farm workers from north eastern India and design of hand tools of the hilly region," Int. J. Ind. Ergon., vol. 38, no. 1, pp. 90–100, 2008, doi: 10.1016/j.ergon.2007.09.004.

[29] J. F. Tremblay-Lutter, E. M. Crown, and K. B. Rigakis, "Evaluation of functional fit of chemical protective gloves for agricultural workers," Cloth. Text. Res. J., vol. 14, no. 3, pp. 216–224, 1996, doi: 10.1177/0887302X9601400307.

[30] A. Yu, K. L. Yick, S. P. Ng, and J. Yip, "2D and 3D anatomical analyses of hand dimensions for custom-made gloves," Appl. Ergon., vol. 44, no. 3, pp. 381–392, 2013, doi: 10.1016/j.apergo.2012.10.001.

[31] B. T. Davies, A. Abada, K. Benson, A. Courtney, and I. Minto, "A comparison of hand anthropometry of females in three ethnic groups," Ergonomics, vol. 23, no. 2, pp. 179–182, 1980, doi: 10.1080/00140138008924731.

[32] D. C. Montgomery, Design and Analysis of Experiments, Ninth Edition, John Wiley & Sons, Inc. 2017.

[33] "Libya (LBY) Exports, Imports, and Trade Partners | OEC - The Observatory of Economic Complexity." https://oec.world/en/profile/country/lby (accessed Mar. 10, 2022).