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Anthropometric characteristics of the hand based on laterality and sex among Jordanian

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Abstract

Human laterality is considered to be one of the most important issues in human factors engineering. In this context, hand anthropometric data can help in the proper designing of hand tools for better efficiency and less human fatigue. In the present study hand dimensions of right- and left-handed individuals were collected based on Jordanian subjects. Results indicated that there were significant differences in hand measurements between right- and left-handed individuals as well as between males and females subjects. Percentile values for right-handed, left-handed, males and females subjects were also calculated. It was found that the hand tools should be designed separately to fit left and right handers. Further, where precise control is needed, hand tools should be designed separately to fit the hand of males and females.

Relevance to Industry: Hand anthropometric data have indicated differences between right- and left-handed individual and between males and females. This finding should affect the hand tool design. Accordingly, designers of the hand tool for Middle East market in general and for Jordan markets in particular should take these findings into consideration.

Keywords: Anthropometry; Laterality; Hand tool design

1. Introduction

Anthropometric data provides information on static dimensions of the human body in standard postures. For years, anthropometry has been used in national sizing surveys as an indicator of health status (Marks et al., 1989). Standard anthropometric tools have been used since Richer first used calipers in 1890 (Anthropometry, 2000). Anthropometric measurement of human limbs plays an important role in design of workplace, clothes, hand tools and many products for human use. To design any product for human use, human factors engineers/ergonomists have to rely on anthropometric data, otherwise the output product may turn out to be non-ergonomically designed product or the product may turn out to be ergonomically incompatible (Haslegrave, 1986). Many

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studies have been conducted in the past to study the hand anthropometry. Kamal and Samuel (2001) studied differences between elderly and young adult dimensions for Australian people. Results indicated that both elderly males and females are significantly heavier than the young ones, but elderly males and females were significantly shorter than the young group. The depth and breadth of each segment of the hand were measured at points that were spaced at equal distance between the joints of the hand (Buchholz and Armstrong, 1991). Data on the mean length of the proximal and middle phalangeal segments for the fingers was published by An et al. (1979). The interaction of handle size and shape with the kinematics and anthropometry of the hand have a great effect on hand posture and grip strength (Buchholz et al., 1992). Anthropometric survey measuring 18 dimensions of the right hand female workers living in Western Nigeria was conducted (Okunribido and Olajire, 1999) and the means of the collected data were compared with those females from USA, UK and Hong Kong. Grip tasks for six subjects were studied using the hand measurement system (Yun, 1993). The results showed that the flexion angle for the five fingers decreased with increasing grip span.

Human has used tools to perform a variety of objectives. In the last decade, tremendous strides have been made in design and development of hand tools in an attempt to reduce the problems and potential injuries to the workers and also to increase tool efficiency. Today, there is a growing demand among professional hand tool users to have ergonomically designed product (Snow and Newby, 1984). These improved hand tools are often labeled and marketed as ergonomic hand tools. The process of designing and selecting the hand tools to provide a better fit for the user lies on the shoulders of human factor/ergonomists engineers. Poor ergonomic hand tool design is a well known factor contributing to biomechanical stresses and increasing the risk of cumulative trauma and carpal tunnel syndrome disorders of workers (Claudon, 2000; Loslever and Ranaivosoa, 1993). In this context the hand dimensions is required. Hand anthropometry is useful for determining various aspects of industrial machinaries (Imrahan et al., 1993) so as to design the equipment and machines for better efficiency and more human comfort.

On other hand studies on limitation and capabilities of human performance through split brain research revealed that humans may be right or left handed, similarly they may be right or left footed, right or left eared and right or left eyed. Such a characteristic of humans are referred to as human laterality. There are asymmetrical behaviors in human beings leading to an efficient use of either right or left sided part of the body (Porace et al., 1980). Asymmetrical hand function was examined in the context of expert sports performance (Grondin et al., 1999). Results indicated that left handers were more likely to hit with power and to strike out than right handers. The connection between lateral dominance and force of handgrip among school children was investigated by Krombholz (1989). The results indicated that 52% of the children attained best performance on handgrip with the right hand and 39% with the left hand. So far as the laterality versus human fatigue is concerned, Annet (1972) has studied the effect of hand preference asymmetry on human fatigue. In a task of tapping and dotting it was found that 35% of the left handers did better on tapping with the right hand, while 6% showed no difference. On the other hand 12% showed better tapping with their non-preferred left hand and 1% showed no difference (Satz et al., 1967). Hand skill and hand preference in blind and sighted children was studied by Ittyerah (2000). Results showed that there were no differences between the left and right hands for any of the tasks for either group. Imrhan and Jenkins (1999) studied flexion-extension of hand torque strength. Result of this study indicated that right-handed torques was 1.10 as strong as left hand ones.

Literature reviewed indicated that either no or very few studies have been conducted in the past to study the body measurement for Jordanian people in particular and for the Middle Eastern subjects in general. Further, literature reviewed revealed that laterality was yet not being considered as an important parameter in human factors engineering in general and in the design of hand tools in particular.

In the present study an attempt has been made to develop an anthropometry for right and left handed and for males and females for the Jordanian subjects in particular and for the Middle Eastern young peoples, in general. Further, an effort was made to study the impact of the collected anthropometric data on hand tool design.

2. Methodology

2.1. Participants

Participants for this study were randomly selected from the general public places in the capital (Amman) of the country. The capital was chosen in the light of the fact that the population of the capital is around 25% of the population of Jordan. Further, population of Amman can be considered as a mixed population from different parts of the country. Four hundred subjects (200 males, 200 females) were chosen for this study. Most of the sample study (94%) was born in Jordan and the rest from different countries like USA (1%), UK (1%) and 4% from other countries.

Annet's questionnaire (Annet, 1970) was introduced to all subjects chosen for this study. Preference index (PI) was measured for all the subjects. Subjects having PI greater than 0.85 was considered to be right-handed individuals, whereas an ideal value for PI is +1.0, a value that represents perfectly right-handed people. Those having negative PI were considered to be left-handed, whereas an ideal value for PI is –1.0, a value that corresponds to represent a perfectly left motor-sided feature of laterality. Any negative score in the latter category was taken to be an index of left motor sidedness due to shortage of left motor-sided people in the Jordanian society. All subjects selected were of normal physical health and were active in their society. Subjects selected were chosen from 19 to 50 years of age. All the subjects chosen were experienced in varieties of hand tools which were available in the market. Table 1 shows the number and characteristics of the subjects participated in this study. Participants were explained about the objective of the study. All the participants were unpaid. A rest of 10 min was given to all the subjects in between the measurement session. Measurements were conducted daily between 09:30 to 16:30.

2.2. Apparatus

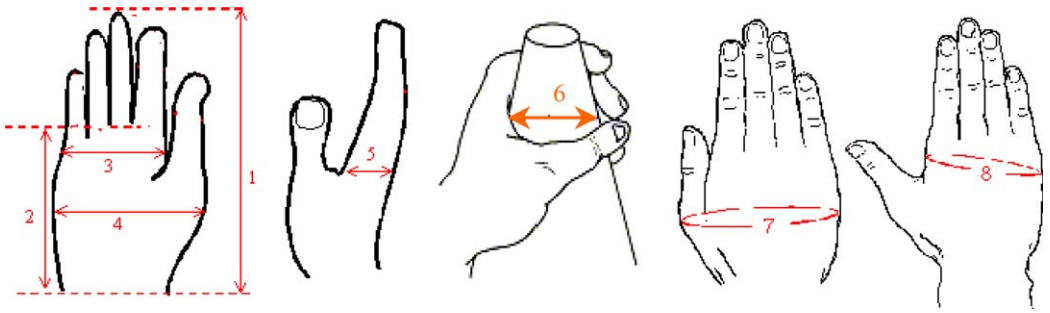
A wooden cone designed locally and specially to measure the internal grip diameter of the hand was used. Sliding caliper and a steel measuring tape were also used. All statistical parameters were computed by making use of computerized statistical analysis software (SPSS).

2.3. Measurements

The techniques of measurements were as per guidelines in NASA-1024 (1978). Totally eight hand dimensions have been identified which were considered to be useful for hand tool design (Fig. 1). The hand dimensions were: hand length: the distance between root of the palm (the distal crease of the wrist) and the tip of the middle finger; palm length: the distance between root of the palm and root of the middle finger; hand breadth: the breadth of the palm measured at the level of maximum buldge of the palm excluding thumb, maximum hand breadth: the breadth of the hand measured at the level of maximum bulge of the palm including thumb; hand thickness: the thickness of the hand at the level of middle portion

Table 1
Characteristics and number of the participants

Subject gender	Number	Mean age	Right-handed	Left-handed	Stature (mm)
Male	200	31.23±6.7	100	100	1708±54
Female	200	29.07±8.3	100	100	1628±89



1. Hand Length
2. Palm Length
3. Hand Breadth
4. Maximum Hand Breadth
5. Hand Thickness
6. Grip Diameter
7. Maximum Hand Circumference
8. Hand Circumference

Fig. 1. 1. Hand length, 2. Palm length, 3. Hand breadth, 4. Maximum hand breadth, 5. Hand thickness, 6. Grip diameter, 7. Maximum hand circumference, 8. Hand circumference.

(circumference passing over the metacarpal joints) of the palm transversely; hand circumference: the close measurement that follow a hand contour at the maximum palm level; maximum hand circumference: the closed measurement that follows a hand contour at the maximum feast (maximum bulge of the palm including the thumb) level and grip diameter: maximum inner curvature of the hand at the touching level between tip of the middle finger and thumb.

Measurements were made on right handed, left handed, males and females. All measurements were taken using proper landmarks (Ermacova et al., 1985). Breadth, length and thickness were measured with a sliding caliper. Circumference was measured with a steel tape and wooden cone was used to measure the grip diameter. A great care was made so as to use, read and to record the readings from the apparatus as accurately as possible.

3. Results

The anthropometric data for eight hand dimensions of the 400 participants were measured and recorded as shown in Tables 2 and 3. The statistical analysis (t-test) of the data indicated that there was a significant difference in hand dimensions between males and females ($P<0.01$). Further, there was statistically significant difference between right- and left-handed individuals ($P<0.01$) for males and females Subjects. It was noted that the percentage difference between hand dimensions of males and females was varied from 0.64% to 3.31% for males and 0.37% to 1.76% for females. It was also observed that the percentage difference between right-handed individuals of males and females was ranged from 2.32% to 8.97% for right hand and from 1.55% to 6.58% for left hand. Moreover, the difference between left handers dimensions was ranged between 0.25% to 2.4% for males and from 0.4% to 2.29% for females. The percentage difference between males and females of left-motor-sidedness individuals was ranged between 0.38% and 7.16% for right hand and between 1.15% and 7.63 for left hand.

Percentiles values (5th, 50th, and 95th) of different hand dimensions (right and left handed) of males and females individuals have been calculated and presented Table 4. Further, The percentage difference, mean, standard deviation

Table 2
Mean, standard deviation and percentage difference of different hand dimensions in millimeters for males and females of right-handed individual participated in the study

Hand dimension	Males ($n = 100$)			Females ($n = 100$)			% difference between males and females of right-handed individuals	
	Right-motor-sidedness			Right-motor-sidedness				
	Right hand	Left hand	% difference	Right hand	Left hand	% difference	Right-handed	Left-handed
Hand length	178.3±6.4	173.1±8.60	2.91	162.3±5.4	161.7±4.9	0.37	8.97	6.58
Palm length	98.4±5.3	97.3±5.8	1.12	92.1±5.1	91.2±5.4	0.98	6.40	6.27
Hand breadth	83.1±4.7	81.2±3.7	2.28	79.5±3.7	78.1±2.6	1.76	4.33	3.82
Max. hand breadth	99.7±6.3	96.4±5.6	3.31	95.7±4.1	94.9±2.3	0.83	4.01	1.55
Hand thickness	29.4±1.7	28.9±2.1	1.7	27.1±3.2	26.8±3.1	1.10	8.84	7.27
Hand circumference	196.8±8.9	195.9±9.9	0.46	191.7±6.2	189.6±4.9	1.09	2.59	3.21
Max. hand circumference	271.1±11.4	268.9±12.7	0.81	264.8±9.7	263.1±7.4	0.64	2.32	2.16
Grip diameter	54.7±3.5	53.5±2.6	2.91	51.1±2.9	50.4±3.2	1.37	6.58	5.79

Table 3
Mean, standard deviation and percentage difference of different hand dimensions in millimeters for males and females of left handed individual participated in the study

Hand dimension	Males ($n = 100$)			Females ($n = 100$)			% difference between males and females of left-handed individuals	
	Left-motor-sidedness			Left-motor-sidedness				
	Right hand	Left hand	% difference	Right hand	Left hand	% difference	Right-handed	Left-handed
Hand length	172.1±3.7	172.8±5.30	0.40	161.5±4.9	161.9±5.4	0.25	6.15	6.31
Palm length	97.8±2.8	98.3±5.1	0.51	90.3±4.9	90.8±6.1	0.55	7.16	7.63
Hand breadth	83.8±4.7	85.1±3.9	1.53	81.6±4.2	82.2±3.7	0.73	1.91	3.41
Max. hand breadth	98.2±5.8	99.1±6.1	0.91	94.1±5.2	94.9±2.7	0.84	4.17	4.24
Hand thickness	29.9±2.3	30.6±1.9	2.29	28.3±4.6	29.0±5.2	2.4	5.35	5.23
Hand circumference	192.8±8.6	194.8±8.6	1.03	188.5±7.1	189.9±6.2	1.00	2.23	2.51
Max. hand circumference	272.4±12.6	275.7±10.8	1.20	249.6±8.6	252.0±8.2	0.95	8.37	8.60
Grip diameter	52.3±3.8	53.1±2.7	1.51	52.1±3.7	52.3±3.1	0.38	0.38	1.51

and percentile values (5th, 50th, and 95th) of different hand dimensions of right and left handed.

Individuals irrespective of the gender of the participants have been calculated and presented in Table 5.

4. Discussion and conclusion

This study highlights significant differences between right and left hand of males and females, between left- and right-handed individuals when the anthropometry of hand was concerned. These differences should be very important and should be taken into consideration in designing the hand tools or equipment that should be controlled by hands. In this study, it was concluded that there was a significant difference of hand dimensions between males and females. Further, there was a significant difference between the hand dimensions of left-handers and right-handed individuals. Many researchers support these findings. For

Table 4
Values of different percentiles for different hand dimensions (mm) for males (right-handed "RH" and left-handed "LH") and females (right-handed and left-handed) participated in this study

Hand dimensions	5th				50th				95th			
	Male		Female		Male		Female		Male		Female	
	RH	LH	RH	LH	RH	LH	RH	LH	RH	RH	RH	LH
Hand length	165	165	156	153	174	172	165	165	191	190	183	183
Palm length	88	86	80	78	99	97	91	90	110	110	105	105
Hand breadth	81	80	77	77	93	92	88	86	101	99	99	98
Maximum hand breadth	92	91	89	86	104	101	98	96	113	112	106	104
Hand thickness	27	26	25	25	31	31	28	27	36	35	31	31
Hand circumference	189	186	172	171	111	109	191	188	234	229	215	212
Maximum hand circumference	263	252	247	235	287	280	269	261	312	307	291	289
Grip diameter	51	51	48	47	62	62	58	57	69	67	63	62

Table 5
Mean, standard deviation, percentage difference and percentile values of different hand dimensions for right and left-handed individuals irrespective of the gender of the participant

Hand dimensions	Right-handed	Left-handed	% difference	5th		50th		95th	
				RH	LH	RH	LH	RH	LH
Hand length	183.3±11.3	180.9±9.7	1.30	160	158	174	173	198	195
Palm length	98.5±6.2	97.1±4.1	1.42	95	94	118	114	127	124
Hand breadth	86.4±4.7	83.9±6.1	2.89	84	82	93	90	109	106
Maximum hand breadth	107.4±9.2	105.5±8.1	1.77	98	95	114	111	124	121
Hand thickness	29.7±4.7	28.9±5.9	2.69	29	27	38	35	43	41
Hand circumference	206.4±14.9	203.3±11.6	1.5	181	179	202	198	228	226
Maximum hand circumference	278.3±19.5	271.5±13.7	2.44	236	234	268	266	299	297
Inside grip diameter	57.2±5.7	55.9±7.1	2.27	56	55	63	61	74	72

example, hand dimensions was studied by many investigators (Schmidtke, 1984; Snow, 1984). Differences in hand measurement were recorded within a country and between rural and urban areas (Majumder et al., 1986).

Due to the fact that people differ significantly in their anthropometric characteristics (Okunribido, 2002), the percentile values of different hand dimensions for males and females and for right- and left-handed individuals have been presented in Table 2. The computed percentile values (5th, 50th and 95th) may be used as a guide for designing the hand tools and control panel in different work-stations design for Middle Eastern people in general and for the Jordanians in particular. Developing a "single standard" for ergonomic hand tool design is difficult because of the variation in human anthropometry (branch of human science that deals with body measurements, human performance, work environments, and tasks). Therefore, investigation of appropriate tool design and of using hand tools while utilizing proper ergonomic principles continues to evolve.

According to this study, hand tools and many other equipment which are controlled by means of operator hand, tools and equipment should be designed separately for both males and females workers. Both males and females were using the hand tools that are available in the market. These tools are made outside of the country like USA, Japan, UK, Taiwan and China. As a part of the present study, a survey was conducted to study the

dimensions of different hand tools that are available and being used in the market. The survey revealed that a significant difference in dimensions and design of the hand tools was recorded among the five different countries from which the hand tools were originated. As previously mentioned no one hand tool is perfect for every job, and no one hand tool is perfect for every user.

The literature reviewed indicated that anthropometric data have indicated difference among age groups (Martin and Soldo, 1997), occupational groups (Mebark and Davies, 1990) and among different countries (Fernmandez et al., 1989). Accordingly, it is very necessary for the hand tools designers to take these findings into consideration while designing the hand tools for Middle Eastern subjects in general and for Jordanians in particular.

Another important findings of this study revealed that there was a significant differences in hand dimensions and hand performance between left- and right-handed individuals. This result was supported by many researchers (Li et al., 2000; Laeng and Park, 1999; Masin and Agostini, 1991). Recently, a special computer keyboard was designed separately for right- and left-handed individuals. In this context, designing a separate hand tools for right- and left-handed ones may resolve many types of injuries and disorders associated with the usage of the hand tools. The finding of the present study may be generalized to suggest that in all the tasks that need to be controlled by operator's hands, laterality has a role to play in designing that hand tools.

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References

Annet, M., 1970. A classification of hand preference by association analysis. British Journal of Psychology 61, 303–321.

Annet, M., 1972. The distribution of manual asymmetry. British Journal of Psychology 3, 343–358.

An, K.N., Chao, E.Y., Cooney, W.P., Linscheid, R.L., 1979. Normative model of human hand for biomechanical analysis. Journal of Biomechanics 12, 775–788.

Anthropometry, 2000. Anthropometry available on line: http://www.sameint.it/dietosys/diets/englboro/bro03.htm

Buchholz, B., Armstrong, T.J., 1991. An ellipsoidal representation of human hand anthropometry. Human Factors 33, 429–441.

Buchholz, B., Armstrong, T.J., Goldstein, S.A., 1992. Anthropometric data for describing the kinematics of human hand. Ergonomics 35, 261–273.

Claudon, L., 2000. Ergonomics hand tool design: Interview of users. Ergonomics and safety for global business quality and productivity. In: Podgorski, D., Karwowski W. (Ed.). Proceeding of the second international conference ERGON-AXIA 2000. 19–21 May 2000, Warsaw, Poland. Central Institute for Labour Protection, Warsaw.

Ermacova, S.V., Podstavkina, T.P., Strokina, A.N., 1985. Anthropometric Atlas, Recommendation and Methods. Amerind Publishing Company, New Delhi, India.

Fernmandez, J.E., Malzahn, D.E., Eyada, O.K., Kim, C.H., 1989. Korean female industrial workers. Ergonomics 32, 491–495.

Grondin, S., Guiard, Y., Ivry, R.B., Koren, S., 1999. Manual laterality and hitting performance in major league baseball. Journal of Experimental Psychology: Human Perception and Performance 25 (3), 747–754.

Haslegrave, C.M., 1986. Characterizing the anthropometric extremes of the population. Ergonomics 29, 281–301.

Imrhan, S.N., Jenkins, G.D., 1999. Flexion extension hand torque strengths: Application in maintenance tasks. International Journal of Industrial Ergonomics 23, 359–371.

Imrahan, S.N., Nguyan, M., Nguyen, N., 1993. Hand anthropometry of Americans of Vietnamese origin. International Journal of Industrial Ergonomics 12, 281–287.

Ittyerah, M., 2000. Hand skill and hand preference in blind and sighted children. Laterality 5 (3), 221–235.

Kamal, K., Samuel, T., 2001. Anthropometry for design for the elderly. International Journal of Occupational Safety and Ergonomics 7 (1), 15–34.

Krombholz, H., 1989. Laterality and force of hand grip during the first two years of school. Perceptual and Motor Skill 68 (3), 955–962.

Laeng, N., Park, A., 1999. Handedness effects on playing a reversed or normal keyboard. Laterality 4 (4), 363–377.

Li, S., Danion, F., Latash, M.L., Li, Z.M., Zatsiorsky, V.M., 2000. Characteristics of finger force producing during one and two hand tasks. Human Movement Science 19 (6), 923–987.

Loslever, P., Ranaivosoa, A., 1993. Biomechanical and epidemiological investigation of carpal tunnel syndrome at workplaces with high risk factors. Ergonomics 36 (5), 537–555.

Marks, G.C., Habicht, J.P., Mueller, W.H., 1989. Reliability, dependability and precision of anthropometric measurement. American Journal of Epidemiology 130 (3), 578–587.

Martin, L.G., Soldo, B.J., 1997. Racial and Ethnic Differences in the Health of Older Americans. National Academy Press, Washington DC, pp. 285–296.

Majumder, P.P., Gupta, R., Mukhopadyay, B., Bharati, P., Ray, S.K., Masali, M., Sloan, A.W., Basu, A., 1986. Effects of altitude, ethinicity religion geographical distance and occupation on adult anthropometric characters of Eastern Himalayan population. American Journal of Physical Anthropometry 70, 377–393.

Masin, S.C., Agostini, A., 1991. Handedness and space errors. Bulletin of the Psychonomic Society 24 (4), 301–303.

NASA, 1978. Anthropometric Source Book, vol. II. National Aeromatics and Space Administration, Washington.

Okunribido, O.O., 2002. A survey of hand anthropometry of female rural farm workers in Ibadan. Western Nigeria Ergonomics 43, 282–292.

Mebark, B., Davies, B.T., 1990. Anthropometry of Algerian women. Ergonomics 33, 1487–1494.

Okunribido, O.O., Olajire, K.A., 1999. A survey of hand anthropometry of female rural workers in Ibadan, Western Nigeria. Ergonomics SA 11, 2–6.

Porace, C., Coren, S., Duncan, P., 1980. Human laterality: A multidimensional approach. Canadian Journal of Psychology 34, 311–321.

Satz, P., Achenbach, K., Fennel, E., 1967. Corelation between assessed manual laterality and predicted speech laterality in a normal population. Neuropsychology 5, 295–310.

Schmidtke, H., 1984. Ergonomics and equipment design. NATO conference series, Series III: Ergonomic data for equipment design. Human Factors 25, 19–23.

Snow, N.A., Newby, T.J., 1984. Ergonomically designed job aids. Performance and Instruction Journal 28, 26–30.

Yun, M.H., 1993. Designing for diversity. Proceeding of the human factors and ergonomics society. 37th Annual Meeting, Seattle, Washington, 11–15 October 1993. The Human Factors and Ergonomics Society, Sanata Monica, California, vol. 2, 754–758.