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A Survey of Hand Anthropometry and Biomechanical Measurements of Dentistry Students in Turkey

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Abstract

The objectives of this study were 1) to determine various hand dimensions and biomechanics measurements for Turkish dentistry students, 2) to evaluate the differences between males and females and between the right and left hand, and 3) to compare these data with similar data for other populations (Thai, Indian, Malaysian, British, Jordanian, Nigerian, Mexican, Bangladesh, and Vietnamese). The present study was undertaken to generate hand anthropometric and biomechanics data of 92 male and 73 female students studying at dentistry faculty. Sixty-seven anthropometric and 26 biomechanics measurements were taken in both hands. The means, standard deviations, and percentile values were tabulated and compared with other populations. The results suggest that the Turkish female fingers are thinner than those of other females except Indians, and that the Turkish male fingers are wider than those of the other males. Furthermore, the results also suggest that the Turkish female strength in handgripping is greater than that of other females except British females, and the Turkish male handgrip strength is greater than that of other males except Americans. This study provides insights about Turkish hand dimensions and biomechanics; it can be a basis for future studies and the design of dental tools meant for the Turkish market. © 2012 Wiley Periodicals, Inc.

Keywords: Hand anthropometry and biomechanics; Turkish; Dental tools

1. INTRODUCTION

The current state of the dental industry shows an increasing number of dentists who are reducing hours and retiring early because of the injuries sustained while working. These injuries, or cumulative trauma disorders, can be reduced by applying ergonomics in dental tool design (Ahern, 2010). There are many considerations that need to be addressed while redesigning dental tools. The first is assessing gender shifts in the industry and looking into the diverse anthropometric

dimensions related to females versus males. Another guideline for hand tool design is that the tools should be able to be used by either hand (Konz & Johnson, 2008). As of now, dental tools are designed for both hands. Most dentists and hygienists use their dominate hand to clean the teeth while holding the mirror in their nondominate hand (Ahern, 2010). To design any hand tool, engineers have to rely on hand anthropometric data; otherwise, the resulting tool may turn out to be ergonomically incompatible. Both males and females use the hand tools available in the market. These tools are made outside of the country, such as the United States, Japan, the United Kingdom, Taiwan, and China. As a part of the present study, a survey was conducted to study the dimensions of different hand tools available and used in the market.

The survey revealed that a significant difference in dimensions and design of hand tools was recorded among the five different countries from which the

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hand tools originated. As previously mentioned, no one hand tool is perfect for every job, and no one hand tool is perfect for every user (Mohammad, 2005). As new ergonomically friendly designs are tested, it is important that the people in the industry who will be using the tools on a daily basis have input in the process. Students will become the first generation of dentists to use them in practice. If more students are aware of the current issues, the urgency for change will become more apparent for future generations in the dental industry (Ahern, 2010). If better-fitted hand tools are to be produced for dentistry students, knowledge of hand dimensions is required. It is evident that mismatch or incompatibility can exist between hands and tools' characteristics.

Various studies exist in the literature to point out the importance of anthropometric measurements for equipment design. Wagner (1988) has compiled data on 20 hand dimensions from pianists and pointed out the significance of these measurements for keyboard design. Okunribido (2000) has compiled data on 18 hand dimensions from rural farmworkers in Nigeria to enable better-fitting manual farming equipment. Nag, Nag, and Desai (2003) have compiled data on 51 right-hand dimensions from Indian women in their study and used these measurements for ergonomic hand tool design. Mandahawi, Imrhan, Al-Shobaki, and Sarder (2008) have compiled data on 24 hand dimensions relevant to hand tool design compared with other populations. Besides these studies, hand anthropometry measurements relevant to design of hand tools and other manual devices have been published for various nationalities, such as British females (Davies, Abada, Benson, Courtney, & Minto, 1980), Chinese females (Courtney, 1984), Indian workers (Karunanithi, Tajuddin, & Kathirvel, 2001), and Mexicans (Imrhan & Contreras, 2005). In the present study, different hand dimensions and biomechanical measurements of the right and left hand of dentistry students have been collected. The collected data were compared with the data of abroad.

2. MATERIAL AND METHODOLOGY

2.1. Participants

Measurements were taken from all students at the Faculty of Dentistry (92 males and 73 females). Thus, we didn't need to do random selection. The population was aged between 18 and 30 years. According to the

dominant hand, of the 165 participants, only 12 were left-handed, the remaining 153 were right-handed. The participants were informed about the study, and each indicated his or her willingness to participate by signing a consent to participate form. At the time of the study, none of the participants reported a hand injury or disability. Three experimenters were trained to take measurements in this survey by practicing on themselves. They started data collection only after their measurements were considered accurate and consistent. Measurements were taken daily between 08:00 to 17:00, and data were collected over a period of 2 months.

2.2. Apparatus and Measurements

Weight and height were measured using a digital scale. Twenty hand dimensions (finger dimensions; hand, palm, and wrist breadth; hand depth) were measured using an electronic digital caliper, with an accuracy of 0.01 mm/0.0005 inch. Ten hand dimensions were measured using a finger circumference gauge, with an accuracy of 0.0625 inch and then converted to millimeters. Hand length and forearm length were measured using a digital tape measure, with an accuracy of 1 mm. Wrist circumference was measured using a tape measure (Figures 1, 2, and 3). Grip and pinch strength were measured using digital handgrip dynamometer and mechanical pinch gauge (Baseline Corp., Irvington, NY), respectively. Participants were seated, with the elbow against the side of the body and the lower arm at a right angle to the body. For grip strength, the hand was parallel to the body and the wrist was bent slightly backward. Participants performed three grip tests with each hand. For pinch strength, the hand was parallel to the floor, and measures were taken in two positions: 1) lateral pinch strength: the thumb tip to the side of the middle portion of the index finger, and 2) chuck pinch strength: the thumb tip to the middle portion of both the index and middle fingers. Three pinch tests were performed in each position with each hand. For both grip and pinch strength, measurements were recorded in kilograms. The averaged grip and pinch strength measures were analyzed.

All these measurements were selected because most of them are relevant to the design of hand tools and other manual equipment, and they have been measured in previous research studies in different populations. Some definitions and technique of measurements correspond to the guidelines in NASA 1024 (1978) and ISO 7250 (1996). The remaining definitions and the



Figure 1 Hand measurements; refer to definitions in Table 1.

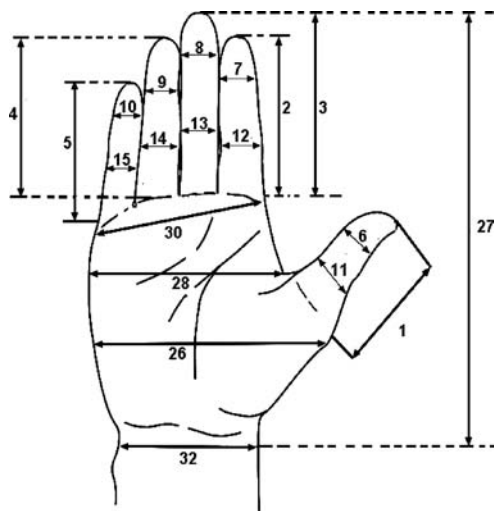


Figure 2 Hand measurements as a diagram.



Figure 3 Hand depth.

methods for hand dimensions were derived from previous research papers by Davies et al. (1980); Courtney and Ng (1984), Imrhan, Nyugen, and Nyugen (1993);

and Mandahawi et al. (2008). These definitions are summarized in Tables 1 and 2.

2.3. Statistical Analysis

The data were statistically analyzed by a software package, SPSS (Version 15.0 for Windows), to determine the normality of data and the percentile values of hand dimensions. The descriptive statistics were summarized in terms of mean, standard deviation (*SD*), and percentile values. Kolmogorov-Smirnov test results indicated that the finger length, fingerbreadth, hand depth, handbreadth, handgrip strength, and abduction angles were approximately normally distributed. Significance *t*-tests for determining the difference between means were performed to compare male versus female, right hand versus left hand, and Turkish versus other populations for existing anthropometric and biomechanics measurements in literature. The levels of statistical significance were reported as 5% or 1%.

3. RESULTS

Tables 3 and 4 show the percentile values (5th and 95th) for all the measurements according to genders and both hands. These percentiles may also be used for comparison with those published for other populations. Tables 5 and 7 present the summary data for all the

TABLE 1. Hand Dimension Definitions

Hand Dimension	Definition
Fingertip to root digit	Hand is extended and the palm is facing up; the distance along the vertical axis of digit from the tip of digit to the root of the hand
Breadth at first joint of digit	Hand is extended and palm is facing down; maximum breadth of the first joint of digit
Breadth at second joint of digit	Hand is extended and palm is facing down; maximum breadth of the second joint of digit
Circumference at first joint of digit	Hand is extended and palm is facing down; maximum circumference of the first joint of digit
Circumference at second joint of digit	Hand is extended and palm is facing down; maximum circumference of the second joint of digit
Hand breadth across thumb	The breadth of the hand measured at the level of the distal end of the first metacarpal of the thumb
Hand length	The distance from the base of the hand to the top of the middle finger measured along the long axis of the hand
Palm breadth	Hand is extended and palm is facing down. This dimension is measured across the palm of the hand at the junction between the palm and the fingers, not including the thumb. The hand and fingers must be held flat, palm uppermost
Maximum depth of the hand	Hand is extended with palm facing down; fingers are close together with the thumb held against the side of the hand. This measurement is the maximum depth from the volar side of the thenar pad to the dorsal surface of the hand
Hand breadth at metacarpals	The breadth of the hand as measured across the distal ends of the metacarpal bones
Wrist circumference	This dimension is measured using a cloth tape measure, which is wrapped around the bony part of wrist, snug but not tight
Wrist breadth	Maximum breadth from the outside projection of the distal part of the ulna to the radius at the wrist joint
Elbow-wrist length	The distance from the tip of the elbow to the tip of the styloid process of the radius

TABLE 2. Biomechanics Measurements Definitions

Biomechanics	Measurements Definition
Wrist angle (°)	The angle between a vertical through that joint and lines joining ulna styloid and the head of the fifth metacarpal
Flexion angle at second joint of each digit (°)	Align the fulcrum of the goniometer with the anatomical fulcrum of the joint being measured. Place the flat arm of goniometer that is attached to the dial indicator of the center of the limb; hold both arms of goniometer and move the joint through the entire range of motion
Abduction angles between digits (°)	The angular excursion at the level of both metacarpalphalangeal and proximal interphalangeal joints for each pair of adjacent digits (thumb index, index middle, middle ring, and ring little)
Hand grip strength (kg)	The shoulder is adducted and neutrally rotated, the elbow flexed to 90°, and the forearm and wrist is in a neutral position
Lateral pinch strength (kg)	The maximum force generated by a person squeezing between the tips of thumb and index finger
Chuck pinch strength (kg)	Thumb pad to pads of the index and middle fingers

TABLE 3. Percentiles Value for Both Hand Dimensions (mm) of Turkish Male and Female Dentistry Students

Hand Dimension	Males (<i>n</i> = 92)				Females (<i>n</i> = 73)			
	Right Hand		Left Hand		Right Hand		Left Hand	
	5th	95th	5th	95th	5th	95th	5th	95th
(1) Fingertip to root digit 1	56.90	73.50	58.79	73.59	53.44	65.63	53.26	65.46
(2) Fingertip to root digit 2	66.58	82.26	66.92	83.49	62.40	75.03	62.05	74.99
(3) Fingertip to root digit 3	73.00	91.29	72.91	91.89	68.31	81.07	67.90	80.87
(4) Fingertip to root digit 4	66.65	85.20	66.79	84.72	63.31	74.60	62.06	74.77
(5) Fingertip to root digit 5	53.95	70.79	54.00	70.50	49.58	61.07	50.48	62.08
(6) Breadth at first joint of digit 1	16.28	22.63	15.92	22.19	14.74	19.44	14.04	18.90
(7) Breadth at first joint of digit 2	14.54	17.83	14.09	17.44	13.13	15.32	12.33	14.75
(8) Breadth at first joint of digit 3	14.91	18.21	14.40	17.51	13.22	15.19	12.69	14.62
(9) Breadth at first joint of digit 4	13.90	16.92	13.68	16.54	12.32	14.59	12.05	14.08
(10) Breadth at first joint of digit 5	12.50	15.23	12.07	15.25	10.90	13.01	10.70	12.74
(11) Breadth at second joint of digit 1	18.26	22.63	18.09	22.26	16.13	19.21	15.77	18.64
(12) Breadth at second joint of digit 2	17.40	21.23	16.85	20.41	15.25	17.93	14.79	17.33
(13) Breadth at second joint of digit 3	17.72	20.96	17.09	20.46	15.60	17.84	15.03	17.27
(14) Breadth at second joint of digit 4	16.39	19.63	16.13	19.40	14.46	16.99	14.18	16.50
(15) Breadth at second joint of digit 5	14.50	17.66	13.89	17.33	12.29	14.82	12.26	14.63
(16) Circumference at first joint of digit 1	53.41	68.26	53.41	68.26	47.62	59.91	45.56	56.03
(17) Circumference at first joint of digit 2	44.44	57.15	44.44	55.56	39.68	49.21	38.09	47.62
(18) Circumference at first joint of digit 3	45.48	57.15	44.44	56.11	39.21	49.68	38.09	47.62
(19) Circumference at first joint of digit 4	42.86	53.97	42.30	52.38	38.09	46.03	36.51	44.44
(20) Circumference at first joint of digit 5	39.13	49.76	38.09	48.18	32.86	43.33	31.75	41.27
(21) Circumference at second joint of digit 1	60.32	73.02	59.76	71.43	53.97	63.97	52.38	61.91
(22) Circumference at second joint of digit 2	58.73	68.81	57.15	67.23	51.91	60.32	50.80	58.73
(23) Circumference at second joint of digit 3	59.76	68.81	57.15	69.85	52.38	59.21	51.91	59.21
(24) Circumference at second joint of digit 4	53.97	65.08	53.97	65.08	47.62	57.62	47.14	56.03
(25) Circumference at second joint of digit 5	49.21	58.73	47.62	57.15	42.86	50.80	42.38	49.68
(26) Handbreadth across thumb	172.30	207.40	176.30	208.70	159.00	186.00	160.70	172.00
(27) Hand length	94.05	115.69	95.05	112.04	83.45	99.52	81.41	98.25
(28) Palm breadth	79.95	94.40	78.30	94.94	68.78	84.10	67.98	82.83
(29) Hand depth	36.60	47.82	36.75	49.06	32.62	44.03	30.17	42.69
(30) Handbreadth at metacarpals	71.12	85.54	69.41	86.34	64.90	74.85	63.18	73.97
(31) Wrist circumference	15.19	18.13	14.96	18.03	13.57	16.00	13.37	16.00
(32) Wrist breadth	51.62	62.34	51.01	62.04	45.49	54.92	45.05	55.04
(33) Elbow-wrist length	244.60	302.70	249.00	305.35	220.40	275.00	223.00	275.60

measurements of Turkish male and female dentistry students.

Tests for normality of distribution showed that most of the data came from normally distributed populations. The Kolmogorov-Smirnov Test (at the 5% level of significance) was used to test normality. Tables 6 and 8 show the tabulated result of *t*-test and percentage differences in genders and hands. Between Turkish genders, highly significant differences were found in all dimensions except in some flexion and abduction angles.

The differences in most of the fingerbreadths, finger circumferences, and handgrip strength were found to be highly significant between right hand and left hand for both genders. Tables 9 and 11 present the comparison of hand dimensions between Turkish males and females with other males and females populations, respectively. Some hand dimensions for females obtained from this study were used to compare with Thai (*n* = 150; Saengchaiya & Bunternghit, 2004), Indian (*n* = 95; Nag et al., 2003), Malaysian (*n* = 55; Balakrishnan & Yeow, 2008), British (*n* = 181; Salvendy, 1971),

TABLE 4. Percentiles Value for Biomechanics Measurements of Turkish Male and Female Dentistry Students

Biomechanics Measurements	Males (<i>n</i> = 92)				Females (<i>n</i> = 73)			
	Right Hand		Left Hand		Right Hand		Left Hand	
	5th	95th	5th	95th	5th	95th	5th	95th
Wrist angle (°)	110.00	140.00	115.00	140.00	106.75	137.50	107.50	135.00
Flexion angle at second joint of digit 1 (°)	80.00	115.87	79.12	117.50	78.50	118.25	80.00	115.75
Flexion angle at second joint of digit 2 (°)	65.00	98.37	65.00	100.00	65.00	106.50	65.00	100.00
Flexion angle at second joint of digit 3 (°)	62.50	90.00	61.62	96.75	62.50	94.75	61.75	100.75
Flexion angle at second joint of digit 4 (°)	61.62	90.00	61.62	98.37	60.00	91.50	61.75	98.25
Flexion angle at second joint of digit 5 (°)	65.00	115.87	67.50	120.00	61.75	115.00	62.50	115.00
Abduction angle between digits 1 and 2 (°)	57.00	107.35	56.90	105.35	57.40	88.00	56.00	96.00
Abduction angle between digits 2 and 3 (°)	21.65	41.05	20.65	42.00	20.00	44.20	21.70	48.30
Abduction angle between digits 3 and 4 (°)	15.00	35.70	18.00	40.35	16.00	39.00	17.70	39.00
Abduction angle between digits 4 and 5 (°)	24.00	46.70	28.00	50.00	23.70	44.60	27.00	50.00
Handgrip strength (kg)	31.10	53.92	29.23	51.24	21.01	34.61	18.28	31.38
Lateral pinch strength (kg)	3.50	8.55	3.71	9.00	2.50	7.00	2.00	6.50
Chuck pinch strength (kg)	5.00	11.50	5.00	11.66	3.11	8.66	3.33	8.38

Jordanian (*n* = 120; Mandahawi, Imrhan, Al-Shobaki, & Sarder, 2008), and Nigerian (*n* = 37; Okunribido, 2000) populations. For males, some hand dimensions also were used to compare with Mexican (*n* = 25; Imrhan & Contreras, 2005), Bangladesh (*n* = 40; Imrhan, Sarder, & Mandahawi, 2006), Jordanian (*n* = 115; Mandahawi et al., 2008), and Vietnamese (*n* = 41; Imrhan et al., 1993) populations.

The observed differences between Turkish females and other populations were found statistically significant. Between Turkish and Thai females, highly significant differences were found ($p < .01$); most involve the fingerbreadth. Between Turkish and Indian females, highly significant and significant differences were found except two dimensions (finger length, digit 5 and second joint circumference, digit 2). Similarly, the differences between Turkish and Nigerian females were found highly significant except one finger length. The differences in three dimensions were found to be significant between Turkish females and Jordanian females, and three are highly significant (Table 10).

The differences between Turkish and other male participants were found statistically significant for most of the dimensions. Between the Turkish males and males from Mexican, highly significant differences were found in all the finger and hand dimensions. Between the Turkish males and males from Bangladesh, significant and highly significant differences were found in all the finger and hand dimensions. Similarly, highly sig-

nificant differences were found between Turkish and Vietnamese males in all dimensions except in one dimension, handbreadth at metacarpals. The differences in seven hand dimensions were found to be highly significant between Turkish males and Jordanian males ($p < .01$), five breadth dimensions, the depth of the hand, and one finger length (Table 12).

Handgrip strength and lateral and chuck pinch strength were used to compare with Indian (*n* = 95 female; Nag et al., 2003), South Indian (*n* = 128 male; Fernandez & Uppugonduri, 1992), Jordanian (*n* = 120 female, *n* = 115 male; Mandahawi et al., 2008), American (*n* = 26 female, *n* = 29 male; Mathiowetz et al., 1985), and British, Malaysian, and Israeli populations (Tables 13 and 14).

The differences between Turkish and other female participants except British females were found statistically significant and highly significant in grip strength. Between Turkish males and males from other populations except two nations (Jordanian and Malaysian), highly significant differences were also found in grip strength (Tables 15 and 16).

4. DISCUSSION

4.1. Gender and Right-/Left-Hand Differences

Males are known to have large physical dimensions and an ability to exert higher grip forces than females

TABLE 5. Descriptive Statistics for Both Hand Dimensions (mm) of Turkish Male and Female Dentistry Students

Hand Dimension	Males (<i>n</i> = 92)				Females (<i>n</i> = 73)			
	Right Hand		Left Hand		Right Hand		Left Hand	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
(1) Fingertip to root digit 1	65.66	4.57	66.12	4.41	59.42	3.72	59.21	3.37
(2) Fingertip to root digit 2	74.69	4.82	75.06	5.05	68.34	3.47	68.36	3.52
(3) Fingertip to root digit 3	81.86	5.15	81.92	5.49	74.41	3.91	74.20*	4.08
(4) Fingertip to root digit 4	75.59	5.26	75.46	5.24	68.30*	3.47	67.84	3.90
(5) Fingertip to root digit 5	62.43	4.63	62.46	4.83	55.58	3.28	55.59	3.40
(6) Breadth at first joint of digit 1	19.75	1.74	19.35	1.77	17.21	1.43	16.73	1.42
(7) Breadth at first joint of digit 2	16.22	0.95	15.70	0.96	14.27	0.72	13.69	0.68
(8) Breadth at first joint of digit 3	16.52	0.89	15.94*	0.93	14.35	0.62	13.86*	0.62
(9) Breadth at first joint of digit 4	15.35	0.88	15.14	0.87	13.41*	0.73	13.11*	0.61
(10) Breadth at first joint of digit 5	13.95	0.77	13.62	0.88	11.97	0.63	11.72	0.65
(11) Breadth at second joint of digit 1	20.27*	1.15	20.07	1.18	17.64	0.93	17.17	0.91
(12) Breadth at second joint of digit 2	19.01	0.99	18.56	1.04	16.61*	0.83	16.20	0.73
(13) Breadth at second joint of digit 3	19.25	1.01	18.82	1.06	16.67	0.72	16.27	0.68
(14) Breadth at second joint of digit 4	18.16	0.96	17.78	0.97	15.69	0.73	15.36	0.70
(15) Breadth at second joint of digit 5	16.11	0.87	15.63*	0.91	13.70	0.76	13.41	0.69
(16) Circumference at first joint of digit 1	61.44*	4.45	60.96*	4.05	53.84	3.75	52.10*	3.41
(17) Circumference at first joint of digit 2	51.05*	3.56	49.78*	3.83	44.77*	3.41	42.79*	3.06
(18) Circumference at first joint of digit 3	51.47*	3.35	49.93*	3.63	44.90*	3.13	43.23*	2.61
(19) Circumference at first joint of digit 4	48.28*	3.09	43.84*	3.69	41.55*	2.62	40.73*	2.39
(20) Circumference at first joint of digit 5	44.41*	3.20	47.53*	3.18	38.05*	3.19	37.18*	2.60
(21) Circumference at second joint of digit 1	66.03*	3.64	65.12*	3.49	58.66*	3.07	57.08*	2.66
(22) Circumference at second joint of digit 2	63.17*	3.22	62.20*	3.39	56.43*	2.65	54.77*	2.26
(23) Circumference at second joint of digit 3	64.06*	2.97	62.80*	4.27	56.32*	2.36	55.25*	2.44
(24) Circumference at second joint of digit 4	60.42*	3.28	59.35*	3.26	53.06*	2.90	51.99*	2.72
(25) Circumference at second joint of digit 5	53.90*	2.74	52.85*	3.09	46.79*	2.63	45.66*	2.31
(26) Handbreadth across thumb	190.40*	9.69	191.38*	9.72	172.16*	8.14	172.89	7.86
(27) Hand length	104.30	6.01	102.89	5.49	91.45	5.09	90.08	4.59
(28) Palm breadth	87.32	4.67	86.52	5.11	76.06	4.66	75.17	4.73
(29) Hand depth	42.89	3.40	41.62	3.72	37.32*	3.44	35.95	3.78
(30) Handbreadth at metacarpals	78.44	4.52	77.75	4.71	69.91*	3.23	68.95	3.16
(31) Wrist circumference	16.68*	0.78	16.61*	0.84	14.87*	0.75	14.79	0.75
(32) Wrist breadth	56.31	3.30	56.68	3.31	49.86*	2.84	49.59*	4.40
(33) Elbow-wrist length	273.28	16.92	273.57	16.07	248.90*	15.39	247.81	14.55

Note: The dimensions with superscript (*) are not normally distributed.

(Hallbeck, 1994). The results suggest that mean values of hand dimensions and forces are significantly larger in males when compared with females in both hands ($p < .01$). This difference is quite important because there has been an increase in the number of female dentists entering the industry. In 2008, the Turkish Dental Association (TDA) reported 59% active female dentists versus only 40% in 2004.

Because dentists are performing tasks that require precision, it is important that the tools fit a va-

riety of anthropometric dimensions, especially with the differences between genders (Ahern, 2010). It may imply that gender difference should be considered in the design of hand tools. A power grip tool, designed for the male hand, for example, may result in excessive muscular handgrip forces when used by many females and may, thus, contribute to lower productivity from discomfort, muscular fatigue, or cumulative traumas (Mandahawi et al., 2008).

TABLE 6. Comparison of Hand Dimensions for Each Gender and Hand

Hand Dimension	Males (<i>n</i> = 92)		Females (<i>n</i> = 73)		Right Hand		Left Hand	
	Right vs. Left		Right vs. Left		Male vs. Female		Male vs. Female	
	<i>t</i>	% Diff	<i>t</i>	% Diff	<i>t</i>	% Diff	<i>t</i>	% Diff
(1) Fingertip to root digit 1	0.69	−0.70	0.35	0.35	9.44**	9.50	11.06**	10.45
(2) Fingertip to root digit 2	0.50	−0.49	0.03	−0.02	9.47**	8.50	9.62**	8.92
(3) Fingertip to root digit 3	0.07	−0.07	0.31	0.28	10.23**	9.10	10.01**	9.42
(4) Fingertip to root digit 4	0.16	0.17	0.75	0.67	10.20**	9.64	10.35**	10.09
(5) Fingertip to root digit 5	0.04	−0.04	0.01	−0.01	10.68**	10.97	10.29**	10.99
(6) Breadth at first joint of digit 1	1.54	2.02	2.03*	2.78	10.06**	12.86	10.28**	13.54
(7) Breadth at first joint of digit 2	3.69**	3.20	5.00**	4.06	14.53**	12.02	15.12**	12.80
(8) Breadth at first joint of digit 3	4.32**	3.51	4.77**	3.41	17.69**	13.13	16.42**	13.04
(9) Breadth at first joint of digit 4	1.62	1.36	2.69**	2.23	15.14**	12.63	16.90**	13.40
(10) Breadth at first joint of digit 5	2.70**	2.36	2.35*	2.08	17.75**	14.19	15.40**	13.95
(11) Breadth at second joint of digit 1	1.16	0.98	3.08**	2.66	15.85**	12.97	17.30**	14.44
(12) Breadth at second joint of digit 2	3.00**	2.36	3.16**	2.46	16.59**	12.62	16.43**	12.71
(13) Breadth at second joint of digit 3	2.81**	2.23	3.45**	2.39	18.42**	13.40	17.84**	13.54
(14) Breadth at second joint of digit 4	2.67**	2.09	2.78**	2.10	18.19**	13.60	17.92**	13.61
(15) Breadth at second joint of digit 5	3.65**	2.97	2.41*	2.11	18.67**	14.95	17.26**	14.20
(16) Circumference at first joint of digit 1	0.76	0.78	2.93**	3.23	11.66**	12.36	14.95**	14.53
(17) Circumference at first joint of digit 2	2.32*	2.48	3.69**	4.42	11.46**	12.30	12.70**	14.04
(18) Circumference at first joint of digit 3	2.99**	2.99	3.50**	3.71	12.87**	12.76	13.27**	13.41
(19) Circumference at first joint of digit 4	8.84**	9.19	1.97	1.97	14.84**	13.93	6.23**	7.09
(20) Circumference at first joint of digit 5	6.63**	−7.02	1.80	2.28	12.69**	14.32	22.47**	21.77
(21) Circumference at second joint of digit 1	1.73	1.37	3.32**	2.69	13.82**	11.16	16.28**	12.34
(22) Circumference at second joint of digit 2	1.98*	1.53	4.07**	2.94	14.42**	10.66	16.09**	11.94
(23) Circumference at second joint of digit 3	2.32*	1.96	2.69**	1.89	18.17**	12.08	13.45**	12.02
(24) Circumference at second joint of digit 4	2.21*	1.77	2.29*	2.01	15.06**	12.18	15.47**	12.40
(25) Circumference at second joint of digit 5	2.43*	1.94	2.75**	2.41	16.85**	13.19	16.54**	13.60
(26) Handbreadth across thumb	0.62	−0.51	0.59	−0.42	12.87**	9.57	13.18**	9.66
(27) Hand length	1.76	1.35	1.70	1.49	14.58**	12.32	15.98**	12.45
(28) Palm breadth	1.10	0.91	1.14	1.17	15.39**	12.89	14.64**	13.11
(29) Hand depth	2.41*	2.96	2.29*	3.67	10.39**	12.98	9.65**	13.62
(30) Handbreadth at metacarpals	1.01	0.87	1.81	1.37	13.59**	10.87	13.69**	11.31
(31) Wrist circumference	0.58	0.41	0.64	0.53	15.05**	10.85	14.48**	10.95
(32) Wrist breadth	0.75	−0.65	0.44	0.54	13.25**	11.45	11.81**	12.50
(33) Elbow-wrist length	0.12	−0.10	0.43	0.43	9.53**	8.92	10.66**	9.41

Note: *Statistically significant ($p < .05$); **Statistically significant ($p < .01$).

% difference = $100 \times (\text{Mean for Turkish} - \text{Mean for Comparison Nationality}) / \text{Mean of Turkish}$.

On the other hand, the mean values of finger-breadths, finger circumferences, and hand depths are significantly larger in the right hand when compared with the left hand in genders. The mean value of handgrip strength is significantly larger in the right hand when compared with the left hand. It is believed that this dissimilarity arises from hand dominance (Geschwind & Galaburda, 1985; Ulijaszek & Mascie-Taylor, 1994). Since 92% of participants were right

handed in this study, the difference might be relevant to laterality.

4.2. Differences between Populations

One of the most fundamental problems in hand tool design is to optimize the dimensions of the tool in relation to the hand anthropometry of the population under study (Bridger, 2003). The results suggest

TABLE 7. Descriptive Statistics for Biomechanics Measurements of Turkish Male and Female Dentistry Students

Biomechanics measurements	Males (<i>n</i> = 92)				Females (<i>n</i> = 73)			
	Right Hand		Left Hand		Right Hand		Left Hand	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Wrist angle (°)	125.76*	8.31	126.54*	8.18	121.37	8.66	121.57	8.27
Flexion angle at second joint of digit 1 (°)	97.90*	11.11	96.87*	11.17	100.68*	12.19	98.63*	11.12
Flexion angle at second joint of digit 2 (°)	76.76*	10.30	75.59*	10.24	78.49*	11.75	78.39*	11.03
Flexion angle at second joint of digit 3 (°)	74.34*	9.10	74.67*	11.02	75.64*	9.48	75.20*	11.34
Flexion angle at second joint of digit 4 (°)	72.68*	10.21	73.15*	10.02	73.49*	9.93	74.54*	10.59
Flexion angle at second joint of digit 5 (°)	82.88*	15.28	83.69*	15.63	88.87*	16.28	86.50*	16.01
Abduction angle between digits 1 and 2 (°)	80.96	14.18	80.96	15.02	73.27	9.76	74.90	12.44
Abduction angle between digits 2 and 3 (°)	31.62	6.22	30.11	6.60	32.11	7.33	32.53*	7.99
Abduction angle between digits 3 and 4 (°)	24.89	6.04	27.89*	6.84	27.07	6.51	28.84	5.92
Abduction angle between digits 4 and 5 (°)	34.13*	6.69	38.05	6.80	35.22	6.05	38.29	6.98
Handgrip strength (kg)	43.21	6.42	40.18	6.94	26.99	4.31	24.95	3.85
Lateral pinch strength (kg)	6.45*	1.45	6.22*	1.42	4.25*	1.22	3.87*	1.20
Chuck pinch strength (kg)	8.23*	1.78	7.96*	1.82	5.90	1.44	5.55	1.55

Note: The dimensions with superscript (*) are not normally distributed.

TABLE 8. Comparison of Biomechanics Measurements for Each Gender and Hand

Biomechanics Measurements	Males (<i>n</i> = 92)		Females (<i>n</i> = 73)		Right Hand		Left Hand	
	Right vs. Left		Right vs. Left		Male vs. Female		Male vs. Female	
	<i>t</i>	% Diff	<i>t</i>	% Diff	<i>t</i>	% Diff	<i>t</i>	% Diff
Wrist angl (°)	0.65	−0.62	0.19	−0.16	3.30**	3.49	3.85**	3.92
Flexion angle at second joint of digit 1 (°)	0.07	1.05	1.02	2.03	1.52	−2.83	1.00	−1.81
Flexion angle at second joint of digit 2 (°)	0.77	1.52	0.05	0.12	1.00	−2.25	1.68	−3.70
Flexion angle at second joint of digit 3 (°)	0.22	−0.44	0.25	0.58	0.89	−1.74	0.30	−0.70
Flexion angle at second joint of digit 4 (°)	0.31	−0.64	0.61	−1.42	0.51	−1.11	0.86	−1.90
Flexion angle at second joint of digit 5 (°)	0.35	−0.97	0.88	2.66	2.42*	−7.22	1.13	−3.35
Abduction angle between digits 1 and 2 (°)	0.00	0.00	0.88	−2.22	3.94**	9.49	2.77**	7.48
Abduction angle between digits 2 and 3 (°)	1.59	4.77	0.33	−1.30	0.46	−1.54	2.13*	−8.03
Abduction angle between digits 3 and 4 (°)	3.15**	−12.05	1.71	−6.53	2.22*	−8.75	0.93	−3.40
Abduction angle between digits 4 and 5 (°)	3.94**	−11.48	2.83**	−8.71	1.08	−3.19	0.22	−0.63
Handgrip strength (kg)	3.07**	7.01	3.01**	7.55	18.52**	37.53	16.85**	37.90
Lateral pinch strength (kg)	1.08	3.56	1.89	8.94	10.37**	34.10	11.29**	37.78
Chuck pinch strength (kg)	1.01	3.28	1.41	5.93	9.07**	28.31	9.01**	30.27

Note: *Statistically significant ($p < .05$); **Statistically significant ($p < .01$).

% Difference = $100 \times (\text{Mean for Turkish} - \text{Mean for Comparison Nationality}) / \text{Mean of Turkish}$.

that Thai females were particularly wider and longer in their finger dimensions than Turkish females. Indian females were particularly narrower but longer in their finger dimensions than Turkish females. Moreover, Indian females have larger finger circumference

than Turkish females. British, Jordanian, and Nigerian female populations have wider and longer finger dimensions than Turkish females. The female Turkish hand was longer than that of Indian and Jordanian but shorter than that of Thai and Nigerians nationals. The

TABLE 9. Summary Data of Hand Dimensions of Turkish Female Dentistry Students and Other Populations (mm)

Hand Dimension	Turkish		Thai		Indian		Malaysian		British		Jordanian		Nigerian	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Fingertip to root digit 1	59.42	3.72			64.1	6.3	54	6.5	58.2	7.5				
Fingertip to root digit 2	68.34	3.47			69.2	5.5			70.6	7.4				
Fingertip to root digit 3	74.41	3.91	76.77	3.24	76	5.7			79	7.3	75.15	3.62	74.20	5.49
Fingertip to root digit 4	68.30	3.47			70.2	5.4								
Fingertip to root digit 5	55.58	3.28	55.89	3.34	56.3	5.4					56.63	3.40	54.21	4.93
Breadth at first joint of digit 2	14.27	0.72			10.4	1.6			16.8	1.8				
Breadth at first joint of digit 3	14.35	0.62	15.53	0.94	10.4	1.5			16.9	1.9	15.83	0.99	14.84	2.05
Breadth at first joint of digit 5	11.97	0.63	12.85	0.68							13.54	0.96	13.19	1.71
Breadth at second joint of digit 1	17.64	0.93							19.7	1.8				
Breadth at second joint of digit 2	16.61	0.83			13	1.7								
Breadth at second joint of digit 3	16.67	0.72	18.02	0.82	13.3	1.5					18.11	1.10	17.89	1.95
Breadth at second joint of digit 5	13.70	0.76	15.21	0.69							15.30	1.05	14.50	1.77
Circumference at first joint of digit 1	53.84	3.75					54	5.8						
Circumference at first joint of digit 2	44.77	3.41			48	4.2								
Circumference at first joint of digit 3	44.90	3.13			49.1	2.5								
Circumference at second joint of digit 2	56.43	2.65			57	3.1								
Circumference at second joint of digit 3	56.32	2.36			59.2	3.6								
Hand length	172.16	8.14	177.22	7.04	169.6	9.4					171.27	7.44	175.05	11.07
Handbreadth across thumb	91.45	5.09	89.95	4.02							93.99	5.63	87.94	4.99
Palm breadth	76.06	4.66	71.96	3.36										
Hand depth	37.32	3.44	35.63	2.53	34.2	5.2					40.35	4.26		
Handbreadth at metacarpals	69.91	3.23	70.16	3.29	68	5.1	73	4			77.82	3.92	75.75	5.17
Wrist breadth	49.86	2.84			46.1	4.8								

TABLE 10. Comparison of Hand Dimensions between Turkish Female Dentistry Students and Other Nationalities

Hand Dimension	Turkish vs. Thai		Turkish vs. Indian		Turkish vs. Malaysian		Turkish vs. British		Turkish vs. Jordanian		Turkish vs. Nigerian	
	<i>t</i>	% Diff	<i>t</i>	% Diff	<i>t</i>	% Diff	<i>t</i>	% Diff	<i>t</i>	% Diff	<i>t</i>	% Diff
Fingertip to root digit 1			-10.73**	-7.87	12.43**	9.12	2.79**	2.05				
Fingertip to root digit 2			-2.09*	-1.25			-5.54**	-3.30				
Fingertip to root digit 3	-5.13**	-3.17	-3.45**	-2.13			-9.99**	-6.16	-1.60	-0.99	0.47	0.28
Fingertip to root digit 4			-4.66**	-2.78								
Fingertip to root digit 5	-0.79	-0.55	-1.85	-1.29					-2.71**	-1.88	3.57**	2.46
Breadth at first joint of digit 2			45.73**	27.11			-29.82**	-17.72				
Breadth at first joint of digit 3	-16.59**	-8.22	54.09**	27.52			-34.83**	-17.77	-20.19**	-10.31	-6.65**	-3.41
Breadth at first joint of digit 5	-11.72**	-7.35							-20.96**	-13.11	-16.27**	-10.19
Breadth at second joint of digit 1							-18.89**	-11.67				
Breadth at second joint of digit 2			37.15**	21.73								
Breadth at second joint of digit 3	-15.94**	-8.09	39.88**	20.21					-17.01	-8.63	-14.40**	-7.31
Breadth at second joint of digit 5	-16.91**	-11.02							-17.92	-11.67	-8.95**	-5.83
Circumference at first joint of digit 1					-0.35	-0.29						
Circumference at first joint of digit 2			-8.05**	-7.21								
Circumference at first joint of digit 3			-11.42**	-9.35								
Circumference at second joint of digit 2			-1.82	-1.01								
Circumference at second joint of digit 3			-10.37**	-5.11								
Hand length	-5.31**	-2.93	2.68*	1.48					0.93	0.51	-3.03**	-1.67
Handbreadth across thumb	2.52*	1.64							-4.24	-2.77	5.89**	3.83
Palm breadth	7.51**	5.39										
Hand depth	4.21**	4.52	7.75**	8.36					-7.48	-8.11		
Handbreadth at metacarpals	-0.64	-0.35	5.06**	2.73	-8.14**	-4.41			-20.89	-11.31	-15.41**	-8.35
Wrist breadth			11.28**	7.54								

Note: * Statistically significant ($p < 0.05$); ** Statistically significant ($p < .01$).

% Difference = $100 \times (\text{Mean for Turkish} - \text{Mean for Comparison Nationality}) / \text{Mean of Turkish}$.

TABLE 11. Summary Data of Hand Dimensions of Turkish Male Dentistry Students and Other Populations (mm)

Hand Dimension	Turkish		Mexican		Bangladesh		Jordanian		Vietnamese	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Fingertip to root digit 3	81.86	5.15	78.50	4.40	76.40	3.27	81.26	7.14	78.20	4.50
Fingertip to root digit 5	62.43	4.63	57.90	3.20	58.10	3.45	61.12	4.69	67.90	12.10
Breadth at first joint of digit 3	16.52	0.89	17.00	1.40	17.30	1.78	17.65	1.06	17.50	2.40
Breadth at first joint of digit 5	13.95	0.77	15.00	1.20	14.20	1.24	15.40	1.15	14.80	2.50
Breadth at second joint of digit 3	19.25	1.01	20.00	1.20	19.50	1.47	20.41	1.41	20.30	2.40
Breadth at second joint of digit 5	16.11	0.87	17.30	1.20	17.10	1.80	17.40	1.34	16.90	2.50
Hand length	190.40	9.69	185.50	7.10	174.00	8.65	191.20	10.20	177.00	12.00
Handbreadth across thumb	104.30	6.01	102.60	6.50	98.40	9.12	104.20	10.94	100.30	5.90
Hand depth	42.89	3.40	48.20	5.10	46.60	4.25	43.90	3.93	45.80	5.90
Handbreadth at metacarpals	78.44	4.52	85.30	4.90	80.10	7.12	87.70	4.82	79.20	6.90

TABLE 12. Comparison of Hand Dimensions between Turkish Male Dentistry Students and Other Nationalities

Hand Dimension	Turkish vs. Mexican		Turkish vs. Bangladesh		Turkish vs. Jordanian		Turkish vs. Vietnamese	
	<i>t</i>	% Diff	<i>t</i>	% Diff	<i>t</i>	% Diff	<i>t</i>	% Diff
Fingertip to root digit 3	6.25**	4.10	10.15**	6.66	1.11	0.73	6.81**	4.47
Fingertip to root digit 5	9.38**	7.25	8.97**	6.93	2.72**	2.09	-11.30**	-8.76
Breadth at first joint of digit 3	-5.10**	-2.90	-8.30**	-4.72	-12.04**	-6.84	-10.44**	-5.93
Breadth at first joint of digit 5	-12.88**	-7.52	-2.98**	-1.79	-17.83**	-10.39	-10.40**	-6.09
Breadth at second joint of digit 3	-7.00**	-3.89	-2.29*	-1.29	-10.86**	-6.02	-9.83**	-5.45
Breadth at second joint of digit 5	-12.93**	-7.38	-10.74**	-6.14	-14.03**	-8.01	-8.56**	-4.90
Hand length	4.84**	2.57	16.22**	8.61	-0.78	-0.42	13.25**	7.03
Handbreadth across thumb	2.71**	1.62	9.41**	5.65	0.16	0.09	6.38**	3.83
Hand depth	-14.94**	-12.38	-10.43**	-8.65	-2.93**	-2.35	-8.18**	-6.78
Handbreadth at metacarpals	-14.54**	-8.74	-3.51**	-2.11	-19.63**	-11.80	-1.60	-0.96

Note: *Statistically significant ($p < .05$); **Statistically significant ($p < .01$).

% Difference = $100 \times (\text{Mean for Turkish} - \text{Mean for Comparison Nationality}) / \text{Mean of Turkish}$.

TABLE 13. Summary Data of Biomechanics of Turkish Female Dentistry Students and Other Populations ($n = 73$)

Biomechanics Measurements	Turkish		Indian		British		American		Jordanian		Malaysian		Israeli	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Handgrip strength (kg)	26.99	4.31	20.36	3.24	27.9	4.42	20.4	5.4	24.21	7.24	25.90	6.71	20.30	1.00
Lateral pinch strength (kg)	4.25	1.22											3.40	0.10
Chuck pinch strength (kg)	5.90	1.44											3.80	0.10

female Turkish hand was also broader than the Thai and Nigerian except Jordanian nationals. The handgrip strengths of Turkish females were significantly stronger than other populations except British females. The

lateral and chuck pinch strengths of Turkish females were significantly stronger than Israeli females.

For male participants, 1) Mexican, Jordanian, and Bangladesh males had particularly shorter and wider

TABLE 14. Summary Data of Biomechanics of Turkish Male Dentistry Students and Other Populations ($n = 92$)

Biomechanics Measurements	Turkish		Jordanian		Malaysian		South Indian (dominant hand)		American	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Handgrip strength (kg)	43.21	6.42	43.05	11.6	42.00	7.81	32.05	3.43	54.88	9.34
Lateral pinch strength (kg)	6.45	1.45							9.34	1.36
Chuck pinch strength (kg)	8.23	1.78							12.06	2.40

TABLE 15. Comparison of Hand Biomechanics between Turkish Female Dentistry Students and Other Nationalities

Biomechanics Measurements	Turkish vs. Indian		Turkish vs. British		Turkish vs. American		Turkish vs. Jordanian		Turkish vs. Malaysian		Turkish vs. Israeli	
	<i>t</i>	% Diff	<i>t</i>	% Diff	<i>t</i>	% Diff	<i>t</i>	% Diff	<i>t</i>	% Diff	<i>t</i>	% Diff
Handgrip strength (kg)	13.14**	24.56	−1.79	−3.37	13.06**	24.41	5.51**	10.30	2.16*	4.03	13.26**	24.78
Lateral pinch strength (kg)											5.96**	20.00
Chuck pinch strength (kg)											12.43**	35.59

Note: *Statistically significant ($p < .05$); **Statistically significant ($p < .01$).

% Difference = $100 \times (\text{Mean for Turkish} - \text{Mean for Comparison Nationality}) / \text{Mean of Turkish}$.

TABLE 16. Comparison of Hand Biomechanics between Turkish Male Dentistry Students and Other Nationalities

Biomechanics Measurements	Turkish vs. Jordanian		Turkish vs. Malaysian		Turkish vs. South Indian		Turkish vs. American	
	<i>t</i>	% Diff	<i>t</i>	% Diff	<i>t</i>	% Diff	<i>t</i>	% Diff
Handgrip strength (kg)	0.24	0.37	1.80	2.80	16.67**	25.82	−17.59**	−27.00
Lateral pinch strength (kg)							−11.35**	−44.80
Chuck pinch strength (kg)							−20.74**	−46.53

Note: *Statistically significant ($p < .05$); **Statistically significant ($p < .01$).

% Difference = $100 \times (\text{Mean for Turkish} - \text{Mean for Comparison Nationality}) / \text{Mean of Turkish}$.

finger dimensions than Turkish males; 2) Vietnamese males had particularly wider finger dimensions than Turkish males; and 3) Mexican, Bangladesh, and Vietnamese males had shorter hand length and narrower handbreadth than Turkish males. The handgrip strength of Turkish males were significantly stronger than South Indian males. The handgrip strength, lateral pinch strength, and chuck pinch strength of Turkish males were significantly weaker than American males. These differences have implications for use of hand tools that have been designed based on the anthropometry of the industrialized countries' (ICs') home population and exported for local use in Turkey.

It is well known that various other factors, apart from gender and nationality, affect body dimensions (Mandahawi et al., 2008). Age group is one of the most important. Our results may be affected by this factor. We do not have enough subjects in our study to reliably test for this factor effect.

5. CONCLUSION

This study was conducted to provide hand anthropometric and biomechanics information of Turkish dentistry students from 18 to 30 years old. Thirty-three hand anthropometric and 13 hand biomechanics

measurements are listed in the forms of mean, standard deviation, and percentile values. The data showed those significant differences between right hand and left hand, between genders, and between Turkish and other populations. The results showed that the differences between genders were highly significant. Based on the study, Turkish female hand dimensions seem to be shorter than other populations. Except Indian females, all other populations have wider finger dimensions than Turkish females. The handgrip strengths of Turkish females and males seem to be stronger than other populations except for British females and American males. Turkish male hand dimensions seem to be longer than other nations. Such differences have practical implications for the ergonomic design of tools and implements meant for the Turkish market. As a result, this study will be considered as an important database. A larger sample of data, such as dentists, might be considered as a future work. In this context, it is hoped that this study would be a good reference for future studies and would be used in basic hand tool design.

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