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Research Article

Quantification and analysis of human hand anthropometry: an iraqi study

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Abstract
Anthropometric measurements of the hand are commonly used to measure height for growth and nutrition assessments, calculate body surface area for burn patients and drug dosing, and identify individuals in forensic medicine. This study focused on Iraqi populations and conducted a bilateral analysis of hand measurements to establish a quantified relationship between males and females and between right- and left-hand dimensions using a population-specific approach. Dominant hand anthropometric measures of the Iraqi population with selected Middle Eastern populations were compared. This study found statistically significant differences in all anthropometric hand measures and stature between male and female groups, with male mean values being larger than female mean values. These findings are consistent with earlier studies that reported smaller female hand dimensions than male hand dimensions in many human communities. Moreover, the study showed that all hand anthropometric measurements were significantly and positively correlated with stature, with hand length, maximum breadth, and palm length having the highest correlation compared to other dimensions. The comparison analysis also revealed that the dominant hand length and breadth measurements of the Iraqi population were consistent with those of Middle Eastern populations. Based on these results, it is concluded that individuals aged 18-69 years old could use hand anthropometric measurements to estimate their height, and further research could include individuals outside of that age range. This study provides a valuable database for diverse demographics and serves as a significant source of information for scientific research.

Keywords
Anthropometry, Hand dimensions, Iraqi population, Personal identification, Stature.

1.Introduction
The science of measuring and the art of application that determines the physical geometry, mass characteristics, and strength capacities of the human body are known as anthropometry. In addition to being used in forensic medicine for identifying dismembered remains [1, 2], accurately recording a person's stature from hand anthropometric measurements is crucial for evaluating growth and nutrition [3] and calculating body surface area [4, 5] as in the case of burn patients and drug dosing. Gender and stature are essential factors in determining personal identification. When gender and stature cannot be inferred from fundamental anatomical features, anthropometric approaches are applied [6].

Anthropometric measures were widely employed before DNA research for personal identification, and when paired with other approaches, they decreased the pool of persons for identification, which was beneficial in terms of human resources and money.

When these strategies are customized for a certain community, they are useful. In addition to forensic reconstruction benefits, anthropometry may give a reliable statistical estimate of limb component measurements for use in reconstructive post-traumatic orthopedic or plastic procedures, as well as prosthesis selection [7]. Several studies have shown that anthropometric measures such as hand lengths, breadths, and other factors have a role in determining stature. Anthropometric dimensions are also demographic, racial, ethnic, and gender specific, according to studies. Hand measurements have also been utilized in a variety of clinical applications, including estimating foetal gestational age, burn surface area, and body weight [8].

Anthropometric research generally and anthropometric data of particular segments of the population, such as women, children, and disabled persons, are extremely uncommon if not nonexistent in the developing countries where ergonomic ideas as well as applications are unstructured and constrained.

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Every population anthropometric database should be built, updated, and maintained as a result. There are no hand anthropometric statistics currently available for the Iraqi population. Therefore, the objectives of motivation of this study are to conduct an anthropometric analysis of hand database among Iraqi populations in the 18-69 years age range, to quantify the variations according to the gender and hand dominancy, and to compare these findings to those of other groups in the Middle East region.

The connection between the measured hand dimensions was investigated for the reconstruction of the original stature, which may be efficiently calculated using linear regression formulae to give population-specific guidelines for the reconstruction of other body parts based on these measurements. Methodologies and regression formulae developed for one community may not be appropriate for another. Therefore, disparities in population and ethnicity between this study population and those in earlier studies can be ascribed to the findings. The findings of this study can be used to create a valuable database for diverse demographics and aid scientific research and serve as a significant source of information for scientists.

The human hand is a complicated structure that performs a variety of tasks in daily life and in the workplace. It is made up of the thenar eminence, hypo thenar eminence, and creases, and is made up of a thumb, index finger, middle finger, ring finger, little finger, and palm. There are 19 distal phalanges and metacarpal bones in the fingers. Metacarpophalangeal (MCP), proximal interphalangeal (PIP), and distal interphalangeal (DIP) joints are found in the fingers, whereas carpometacarpal (CMC), MCP, and interphalangeal (IP) joints are found in the thumb. More than 25 degrees of freedom are provided by such a complicated structure, allowing it to execute a wide range of duties [9].

Figure 1 illustrates an anterior and posterior view of the hands with corresponding labels. Anterior view labels read (from top): middle finger, ring finger, index finger, little finger, thumb, phalanges (distal, proximal), metacarpals, carpals, ulna, and radius. Posterior view labels read (from top): Phalanges (distal, middle, proximal), head shaft and base of proximal phalange, head shaft and base of metatarsal, metatarsals 1-5, carpals, ulna, radius [10].

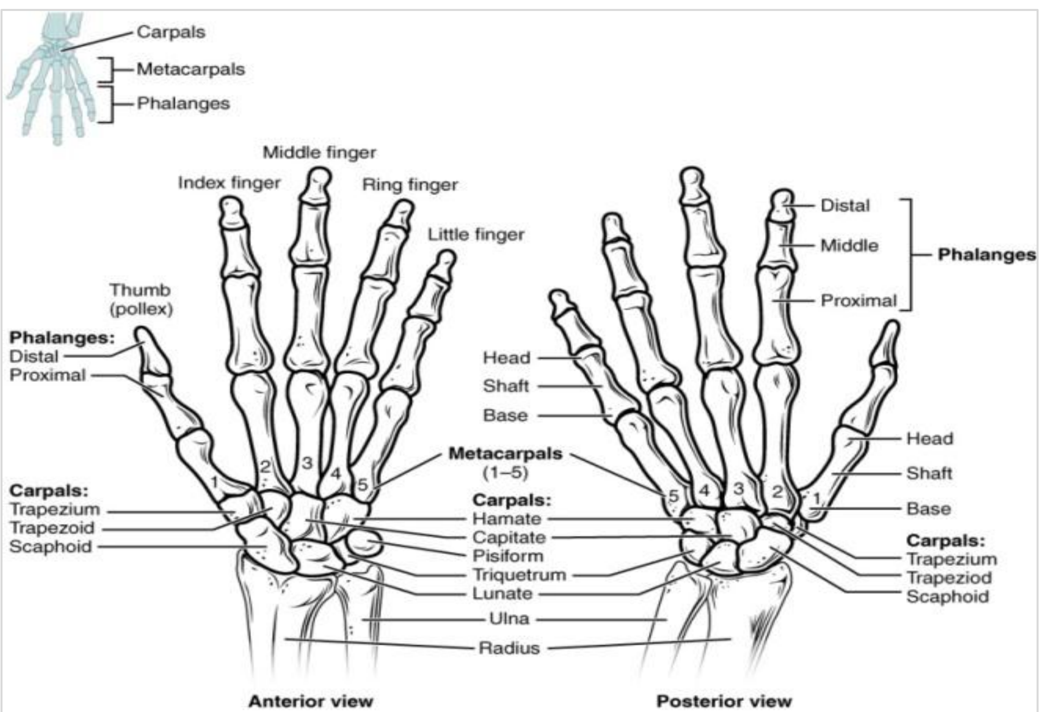


Figure 1 Right hand bones; anterior view (left) and posterior view (right) [10]

Due to the varying nature of labor, living styles, environments, nutritional condition, and ethnic mix of communities, human body dimensions differ significantly across gender, race, nationality, and age.

Numerous nations from across the world, including those in Asia and the Pacific, North America and Europe, have hand anthropometry data. Hand anthropometric statistics on the Iraqi people, however, have not been published.

The remaining sections of the paper are organized as follows: Section 2 provides a literature review, Section 3 outlines the methodology, Section 4 presents the results, Section 5 provides a discussion and highlights the impact of the results, and Section 6 presents the conclusion.

2.Literature review

Earlier literatures have been carried out on hand anthropometric dimensions in different communities. Anthropometric hand measurements in both developed and developing communities, anthropometric have long been accessible. Some of the related studies that have been compiled globally are included below. The majority of studies on this topic focused on Asian groups. An examination of these literatures reveals that there have been few investigations into hand anthropometry. In their 1993 research of Americans of Vietnamese origin populations, Imrhan et al. [11] discovered that the average male hand length was 177.0 mm, the average female hand length measured 165.0 mm, and the average hand breadth was 79.2 mm and 71.0 mm, respectively.

Hu et al. [12] in their studies in 2007 on a Chinese community revealed that the average male hand length measured 179.0 mm and the average female hand length was 168.0 mm. Males' hands were 87.0 mm wide and females' hands were 78.0 mm wide. In a population of Filipinos in 2007, Del [13] discovered that males' and females' hands were, respectively, 197.5 mm and 179.5 mm in length and 98.0 mm and 92.3 mm in width. According to a research by Chuan et al. [14] conducted in 2010 on Indonesian and Singaporean populations, the average male hand was 190.0 mm in length and 90.0 mm in width for both ethnicities, whereas the average female hand length measures was 180.0 mm and 170.0 mm for Indonesian and Singaporean females respectively. While the average female hand width measures was 80.0 and 70.0 mm for Indonesian and Singaporean females respectively. Dey and Kapoor [15] in their research in 2015 on an Indian population found that males' hands measured 192.3 mm in length and females' hands measured 173.3 mm. Indian males' hands measured 83.0 mm in breadth and Indian females' hands measured 75.7 mm. While in a Pakistani community, Qayyum et al. (2016) [16] estimated that male and female average hand lengths were 185.9 mm and 176.9 mm respectively. In their investigations on a Malaysian community, Abd et al. 2018 [17] revealed that the average male hand length measured 183.0 mm and the average female hand length was 170.0 mm. Males' hands were 81.0 mm wide and females' hands were 72.0 mm wide. In a Bangladeshi population in 2019, Asadujjaman et al. [18] have reported hand length to be 184.4 mm for males and 167.1 mm for females and hand breadth to be 82.9 mm for males and 75.1 mm for females. While in a population of Sri Lanka, Nanayakkara et al. [19] in 2021 revealed that the average male hand length measured 183.81 mm and the average female hand length was 169.4 mm. Males' hands were 82.0 mm wide and females' hands were 72.5 mm wide. Kaewdok et al. [20] in their studies in 2022 on a Thai population revealed that the average hand length was 182.0 mm for males and 170.0 mm for females. And hand breath was 87.0 mm for males and 81.0 mm for females.

A study by Khazri et al. (2023) [21] was conducted on hand anthropometric measurement among Malay and Chinese populations in Sabah region, showing males more prolonged hands in both ethnicities with 186.3 mm and 184.8 mm than females with 169.2 mm and 171.4 mm respectively. Also, measured males of Malay and Chinese ethnicities hands were broader with 82.6 mm and 82.9 mm than female counterparts with 73.4 mm and 73.3 mm respectively. Some studies have compiled data on hand dimensions from elderly males and females in the Asian Pacific region according to the highly life expectancy rate. In their 2001 research in Australia, Kothiyal and Tettey [22] presented that the average male hand length was 184.0 mm, the average female hand length measured 170.0 mm, and the average hand breadth was 86.0 mm and 79.0 mm, respectively. Lin et al. [23] in their study in 2004 compared the anthropometric data among Taiwanese, Chinese, Japanese and Korean people. For males, the mean hand lengths were estimated as 192.0 mm, 183.00 mm, 182.00 mm and 189.0 mm respectively, while the females' data were 174.0 mm, 171.0 mm, 168.0 mm and 175.0 mm respectively.

For the North American communities, in their investigation on a Mexican community, Contreras and Imrhan (2005) [24] found that males' and females' hand lengths were measured as 185.5 mm and 171.8 mm respectively. According to Guan et al. research on US population in 2012 [25], the average measured male hand length was 197.0 mm and the average measured female hand length was 177.0 mm. Males' hands were 90.0 mm wide and females' hands were 79.0 mm wide. Meanwhile, a study by Massiris et al. (2015) [26] was conducted on hand anthropometric measurement among Colombian Caribbean populations, showing mean anthropometric measurements of 177.13 mm for the hand length and 84.48 mm for the hand breadth.

Moreover, European studies about hand anthropometrics have been conducted. According to Molenbroek [27], hand anthropometrics of male elderly from Germany and the Netherlands were investigated in 1987 as 183.0 mm and 184.0 mm for hand length and 85.0 mm and 83.0 mm for hand breadth respectively. In a similar manner, Macleod (2000) [28], the mean anthropometric hand lengths of elderly British males and females were 190.0 mm and 175.0 mm respectively, whereas their mean hand breadths were 85.0 mm and 75.0 mm respectively. While for a Spanish community, Carmona's study in 2001 [29] revealed that the average male hand length measured 188.18 mm and the average female hand length was 172.99 mm. Males' hands were 89.3 mm wide and females' hands were 77.65 mm wide. In 2008, Hanson et al. [30] described the anthropometrics of the Swedish workforce discovered that males' and females' hands were, respectively, 194.0 mm and 181.9 mm in length and 86.0 mm and 78.0 mm in width. Bures et al. [31] per their research in 2015 on various age groups in the Czech Republic's population found that males' hands measured 192.0 mm in length and females' hands measured 176.0 mm. Czech males' hands measured 89.0 mm in breadth and Czech females' hands measured 79.0 mm. For Serbian population, Spasojević-Brkić et al. in 2020 [32] have reported hand length to be 186.64 mm and hand breadth of 91.9 mm. Therefore, we may assume that hand anthropometrics are essentially the same across Asia and nearby regions, but variances are more obvious in Europe. In all of these investigations, male's hands were larger than female's hands, as was to be expected. With the application of statistical models, these variations in hand dimensions across genders are exploited to confirm gender. Studies have also used a variety of indices to categorize gender using hand measures that were proportionate with one another. The current study has demonstrated once more how anthropometric measures are extremely population-specific. The size of the hand is regarded to be helpful for gender verification, just as the bones and many other body parts. We think the information gathered from this study will be useful for studies on Iraqi population identification and gender verification.

3.Methods

A total of 128 healthy individuals (64 females and 64 males) with a mean age of 36.01 ± 18.14 years old, height 163.20 ± 16.73 cm, mass 74.51 ± 21.96 kg, and body mass index (BMI) of 28.73 ± 1.96 kg/m^2 were selected at random from general community to participate in this study after giving their informed consents in accordance with the ethical approval obtained from Al-Nahrain University's College of Engineering (02/2020). Participants had to be able-bodied and have no prior history of hand diseases or physical abnormalities to be considered for this research. They ranged in age from 18 to 69 years old, as there was no age restriction in this study. The anthropometric information of the participants was gathered after they signed the permission form. Using a Seca Ltd. wall-mounted measuring tape, each participant's height (m) was measured. For both dominant and non-dominant sides, hand lengths, hand breadth, and phalange lengths were measured with a measuring tape (cm) with the participants were seated in a chair and holding their hand supinated (palms facing up) and maintained on a horizontal platform while the measures were obtained. The fingers were completely extended (not hyperextended) and maintained close to one another, [33]. Linear measurements were taken on both hands with the long axis of the forearm parallel to the hand axis. Descriptive statistics were performed using the Statistical package for the social sciences (SPSS) version 28.0 software for Windows. *Figure 2* demonstrates a block diagram of the complete experimental procedure of hand anthropometric measurements performed per this study.

The following *Table 1* illustrates the measurement description of the hand dimensions [34].

Table 1 Hand anthropometric measurements

Anthropometric measurement	**Description**
Finger length	The measured straight distance along a straight line between the palmar digital creases of the finger to the tip of the corresponding finger.
Hand length	The measured straight distance between the distal crease of the wrist joint and the tip of the middle finger.
Palm length	The measured straight distance

Anthropometric measurement	Description
	from the midpoint of the distal crease of the wrist and the palmar digital crease of the middle finger.
Hand breadth	The measured straight distance between the most remote points on the heads of the second and the fifth metacarpal bones.
Maximum hand breadth	The measured straight distance between the most remote points on the heads of the first and the fifth metacarpal bones.

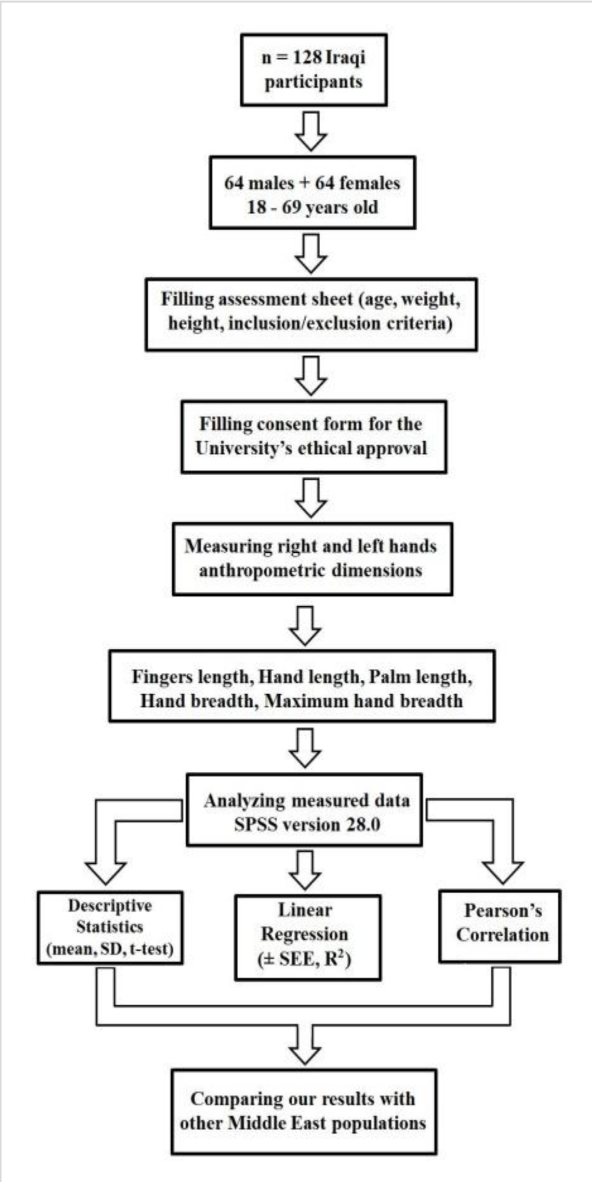


Figure 2 Block diagram of the complete experimental procedure performed per this study

Figure 3 illustrates a schematic description of the hand landmarks and measured anthropometric dimensions.

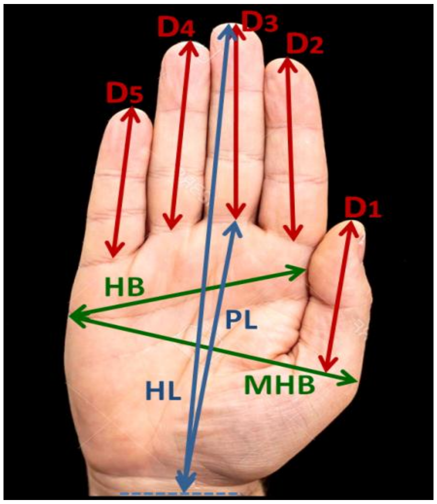


Figure 3 Illustration of hand anthropometric landmarks. D_1, thumb length; D_2, index finger length; D_3, middle finger length; D_4, ring finger length; D_5, little finger length; HL, hand length; PL, palm length; HB, hand breadth; MHB, maximum hand breadth

4.Results

The right and left sides of males (n=64) and females (n=64) hands dimensions were anthropometrically measured and descriptively analyzed using SPSS version 28.0 software. Group mean and standard deviation (SD) were calculated.

To investigate if there were any differences between male and female mean measurements, an independent t-test was used. Significance was defined as a p value of less than 0.05. The correlation between the measured right and left hand dimensions for both males and females was also investigated using Pearson correlation coefficients and linear regression equations. The mean, SD, Standard Error of the Estimate (SEE), and independent t-test of the nine anthropometric measurements in males and females of both right and left hands are demonstrated in *Tables 2* and *3* respectively.

Figures 4 and *5* demonstrate Spider charts of all the measured anthropometric parameters in male and female participants for both right and left hands respectively. It can be observed that two polygons (nonagons) are formed by joining all the measured data in the axes. The blue nonagon depicts the anthropometric measures of the males' hands whereas the red nonagon depicts the females' hands measured anthropometry. The following *Tables 4, 5, 6,* and *7* demonstrate Pearson's correlation of the nine anthropometric hand measures in both right and left hands in males and females respectively. The following *Tables 8* and *9* exhibit the linear regression equations for the right and left hand dimensions in males and females respectively.

Table 2 Descriptive statistics of anthropometric measurements of males and females right hand

Anthropometric measurement	Mean ± SD		± SEE		Independent t-test	
	Male n=64	Female n=64	Male n=64	Female n=64	P value	t
Thumb length D_1	68.96 ± 7.74	62.36 ± 6.81	1.436	1.194	0.05	1.822
Index finger length D_2	74.58 ± 6.82	74.50 ± 5.88	1.378	0.99	0.05	1.750
Middle finger length D_3	80.77± 7.20	77.13 ± 6.22	1.422	1.167	0.05	2.140
Ring finger length D_4	74.45 ± 8.11	71.67 ± 5.40	1.287	1.073	0.02	1.386
Little finger length D_5	65.66 ± 8.32	60.82 ± 5.50	1.463	0.94	0.005	2.880
Hand length HL	184.74 ± 30.60	182.79 ± 16.10	3.66	2.422	0.01	3.713
Palm length PL	110.10 ± 9.37	106.31 ± 8.04	2.97	3.35	0.05	2.122
Hand breadth HB	86.21 ± 7.46	78.37 ± 6.40	2.03	2.38	0.001	4.655
Maximum hand breadth MHB	113.51 ± 11.67	107.10 ± 8.33	2.18	2.661	0.001	4.321

Table 3 Descriptive statistics of anthropometric measurements of males and females left hand

Anthropometric measurement	Mean ± SD		± SEE		Independent t-test	
	Male n=64	Female n=64	Male n=64	Female n=64	P value	t
Thumb length D_1	63.2 ± 5.67	56.66 ± 4.49	1.388	1.02	0.02	2.124
Index finger length D_2	79.06 ± 6.70	71.92 ± 6.30	1.305	0.88	0.05	1.899
Middle finger length D_3	85.91 ± 8.15	76.24 ± 6.13	1.398	1.127	0.04	2.002
Ring finger length D_4	78.91 ± 7.73	70.88 ± 7.73	1.270	1.008	0.01	1.355
Little finger length D_5	65.20 ± 6.44	59.47 ± 5.44	1.416	0.83	0.01	2.578
Hand length HL	187.36 ± 26.51	178.31 ± 13.52	3.360	2.28	0.01	2.649
Palm length PL	110.10 ± 11.88	101.87 ± 9.19	2.50	3.09	0.05	1.831
Hand breadth HB	84.74 ±6.90	77.50 ± 5.48	2.091	2.186	0.001	4.156
Maximum hand breadth MHB	112.43 ± 12.16	104.27 ± 8.66	2.22	2.342	0.001	3.942

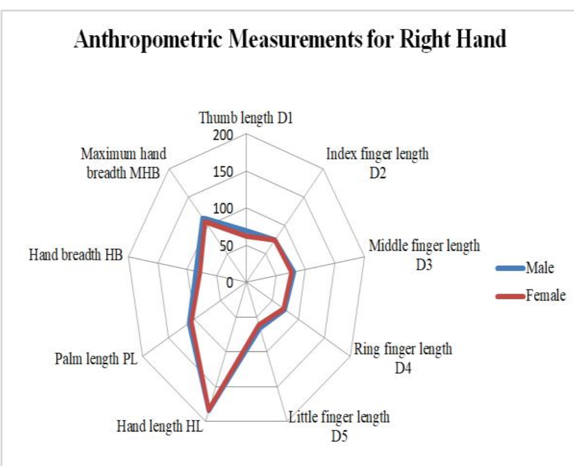


Figure 4 Spider chart of the measured anthropometric parameters in male and female participants of right hand

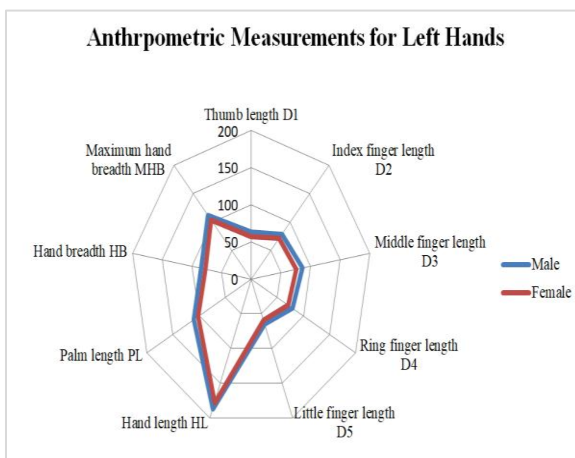


Figure 5 Spider chart of the measured anthropometric parameters in male and female participants of left hand

Table 4 Pearson's correlation for the within anthropometric measurements of males right hand

	D_1	D_2	D_3	D_4	D_5	HL	PL	HB	MHB
D_1	1	-	-	-	-	-	-	-	-
D_2	0.881	1	-	-	-	-	-	-	-
D_3	0.823	0.905	1	-	-	-	-	-	-
D_4	0.862	0.864	0.837	1	-	-	-	-	-
D_5	0.660	0.739	0.710	0.672	1	-	-	-	-
HL	0.805	0.782	0.823	0.807	0.603	1	-	-	-
PL	0.664	0.501	0.836	0.722	0.677	0.640	1	-	-
HB	0.793	0.748	0.841	0.776	0.629	0.799	0.647	1	-
MHB	0.842	0.827	0.865	0.835	0.586	0.902	0.653	0.802	1

Table 5 Pearson's correlation for the within anthropometric measurements of males left hand

	D_1	D_2	D_3	D_4	D_5	HL	PL	HB	MHB
D_1	1	-	-	-	-	-	-	-	-
D_2	0.854	1	-	-	-	-	-	-	-
D_3	0.895	0.900	1	-	-	-	-	-	-
D_4	0.730	0.820	0.865	1	-	-	-	-	-
D_5	0.752	0.765	0.808	0.775	1	-	-	-	-
HL	0.752	0.765	0.839	0.773	0.747	1	-	-	-
PL	0.680	0.687	0.827	0.710	0.724	0.812	1	-	-
HB	0.814	0.811	0.872	0.699	0.688	0.839	0.647	1	-
MHB	0.828	0.804	0.861	0.690	0.652	0.899	0.653	0.830	1

Table 6 Pearson's correlation for the within anthropometric measurements of females right hand

	D_1	D_2	D_3	D_4	D_5	HL	PL	HB	MHB
D_1	1	-	-	-	-	-	-	-	-
D_2	0.843	1	-	-	-	-	-	-	-
D_3	0.777	0.896	1	-	-	-	-	-	-
D_4	0.773	0.886	0.836	1	-	-	-	-	-
D_5	0.835	0.884	0.889	0.893	1	-	-	-	-
HL	0.746	0.789	0.709	0.749	0.775	1	-	-	-
PL	0.812	0.817	0.874	0.888	0.865	0.812	1	-	-
HB	0.595	0.700	0.622	0.591	0.604	0.839	0.668	1	-
MHB	0.582	0.710	0.633	0.619	0.601	0.881	0.652	0.830	1

Table 7 Pearson's correlation for the within anthropometric measurements of females left hand

	D_1	D_2	D_3	D_4	D_5	HL	PL	HB	MHB
D_1	1	-	-	-	-	-	-	-	-
D_2	0.819	1	-	-	-	-	-	-	-
D_3	0.732	0.888	1	-	-	-	-	-	-
D_4	0.774	0.866	0.822	1	-	-	-	-	-
D_5	0.764	0.813	0.754	0.754	1	-	-	-	-
HL	0.628	0.648	0.698	0.698	0.642	1	-	-	-
PL	0.843	0.852	0.852	0.863	0.761	0.843	1	-	-
HB	0.708	0.687	0.608	0.683	0.559	0.528	0.714	1	-
MHB	0.685	0.637	0.533	0.656	0.571	0.873	0.679	0.818	1

Table 8 Linear regression equations between the *right hand* dimensions in males and females

Males			Females		
Regression equation	R^2	± (SEE)	**Regression equation**	R^2	± SEE
D_1=5.98+0.743 D_2	0.376	6.178	D_1=6.67+0.71 D_2	0.312	6.04
D_1=8.12+0.635 D_3	0.351	5.41	D_1=7.302+0.639 D_3	0.399	5.81
D_1=3.198+0.775 D_4	0.343	5.484	D_1=4.915+0.73 D_4	0.397	5.77
D_1=20.454+0.678 D_5	0.436	5.637	D_1=9.22+0.75 D_5	0.398	5.13
D_1=2.407+0.555 PL	0.347	5.25	D_1=5.848+0.41 PL	0.356	5.00
D_1=28.54+0.192 HL	0.132	5.233	D_1=18.28+0.424 HL	0.259	5.39

Males			Females		
Regression equation	**R^2**	**± (SEE)**	**Regression equation**	**R^2**	**± SEE**
D_1=3.806+0.476 HB	0.329	5.388	D_1=11.97+0.479 HB	0.354	5.14
D_1=9.323+0.479 MHB	0.409	5.166	D_1=12.99+0.467 MHB	0.340	5.104
D_2=3.405+0.893 D_3	0.490	5.739	D_2=4.158+0.855 D_3	0.477	6.03
D_2=-0.19+0.977 D_4	0.454	6.155	D_2=9.99+0.831 D_4	0.485	6.04
D_2=26.65+0.709 D_5	0.245	5.57	D_2=18.123+0.785 D_5	0.29	5.36
D_2=17.38+0.595 PL	0.411	5.25	D_2=12.907+0.547 PL	0.623	5.024
D_2=60.853+0.318 HL	0.251	5.154	D_2=20.058+0.278 HL	0.84	5.619
D_2=20.054+0.508 HB	0.260	5.484	D_2=14.54+0.596 HB	0.391	5.679
D_2=19.88+0.531 MHB	0.383	5.15	D_2=14.688+0.539 MHB	0.404	5.615
D_3=14.87+0.947 D_4	0.478	6.043	D_3=10.076+0.928 D_4	0.490	5.271
D_3=34.175+0.72 D_5	0.204	5.145	D_3=23.11+0.923 D_5	0.390	5.146
D_3=15.282+0.662 PL	0.370	4.953	D_3=14.241+0.609 PL	0.502	4.849
D_3=10.829+0.408 HL	0.190	5.852	D_3=5.281+0.418 HL	0.263	5.343
D_3=26.41+0.603 HB	0.407	4.721	D_3=24.755+0.554 HB	0.387	5.381
D_3=20.85+0.587 MHB	0.448	4.382	D_3=15.708+0.604 MHB	0.400	5.32
D_4=34.97+0.71 D_5	0.452	5.787	D_4=18.11+0.923 D_5	0.397	5.145
D_4=16.812+0.58 PL	0.350	5.614	D_4=12.241+0.609 PL	0.360	4.63
D_4=23.19+0.294 HL	0.178	6.086	D_4=17.281+0.418 HL	0.388	5.216
D_4=20.93+0.599 HB	0.302	4.93	D_4=25.755+0.554 HB	0.349	5.636
D_4=19.47+0.507 MHB	0.397	4.302	D_4=22.708+0.504 MHB	0.383	5.49
D_5=12.55+0.478 PL	0.363	5.87	D_5=7.679+0.541 PL	0.400	5.186
D_5=17.857+0.251 HL	0.147	5.97	D_5=8.642+0.298 HL	0.248	5.32
D_5=18.89+0.445 HB	0.396	5.69	D_5=10.7+0.519 HB	0.365	5.276
D_5=20.877+0.39 MHB	0.343	4.976	D_5=11.787+0.461 MHB	0.361	5.29
PL=30.27+0.405 HL	0.615	3.25	PL=10.06+0.524 HL	0.587	3.244
PL=37.89+0.713 HB	0.588	3.52	PL=33.068+0.748 HB	0.590	3.686
PL=36.60+0.676 MHB	0.562	3.487	PL=37.403+0.613 MHB	0.638	3.19
HL=61.723+1.23 HB	0.550	3.88	HL=65.829+1.223 HB	0.612	3.82
HL=57.98+1.14 MHB	0.546	3.825	HL=60.414+1.164 MHB	0.589	3.27
HB=5.081+0.875 MHB	0.456	4.61	HB=10.97+0.804 MHB	0.51	4.357

Table 9 Linear regression equations between the left hand dimensions in males and females

Males			Females		
Regression equation	**R^2**	**± SSE**	**Regression equation**	**R^2**	**± SSE**
D_1=8.645+0.726 D_2	0.43	5.208	D_1=7.811+0.712 D_2	0.471	5.436
D_1=7.732+0.66 D_3	0.400	5.61	D_1=7.836+0.628 D_3	0.335	6.085
D_1=3.35+0.776 D_4	0.333	5.53	D_1=4.716+0.729 D_4	0.399	4.79
D_1=18.94+0.719 D_5	0.366	5.33	D_1=15.57+0.719 D_5	0.383	4.87
D_1=9.84+0.534 PL	0.366	5. 33	D_1=10.23+0.442 PL	0.283	5.416
D_1=22.21+0.234 HL	0.462	4.93	D_1=11.068+0.25 HL	0.410	5.227
D_1=11.89+0.54 HB	0.460	5.7	D_1=6.28+0.522 HB	0.301	5.233
D_1=8.11+0.52 MHB	0.486	5.53	D_1=12.397+0.47 MHB	0.469	5.365
D_2=5.83+0.833 D_3	0.513	5.35	D_2=9.081+0.784 D_3	0.319	5.572
D_2=10.212+0.84 D_4	0.372	5.46	D_2=9.571+0.832 D_4	0.467	4.914
D_2=24.58+0.752 D_5	0.380	6.02	D_2=23.745+0.773 D_5	0.461	5.52
D_2=20.29+0.525 PL	0.385	6.013	D_2=11.679+0.583 PL	0.161	5.856
D_2=18.97+0.323 HL	0.472	5.656	D_2=23.608+0.265 HL	0.361	4.954
D_2=19.74+0.518 HB	0.36	5.55	D_2=22.675+0.511 HB	0.372	5.393
D_2=18.525+0.485 MHB	0.346	5.63	D_2=24.813+0.441 MHB	0.405	4.662
D_3=8.814+0.96 D_4	0.448	5.23	D_3=21.341+0.911 D_4	0.449	5.709
D_3=29.15+0.861 D_5	0.335	4.96	D_3=28.227+0.828 D_5	0.369	5.584
D_3=18.04+0.623 PL	0.404	5.59	D_3=20.137+0.576 PL	0.239	6.843
D_3=14.47+0.297 HL	0.384	4.74	D_3=4.914+0.411 HL	0.452	5.658
D_3=24.587+0.603 HB	0.46	6.13	D_3=29.45+0.522 HB	0.369	5.544
D_3=17.407+0.563 MHB	0.440	5.29	D_3=34.12+0.426 MHB	0.284	5.907

Males			Females		
Regression equation	**R^2**	**± SSE**	**Regression equation**	**R^2**	**± SSE**
D_4=26.86+0.842 D_5	0.300	4.8	D_4=21.921+0.914 D_5	0.362	3.702
D_4=17.83+0.516 PL	0.298	4.81	D_4=15.73+0.557 PL	0.139	6.24
D_4=21.32+0.33 HL	0.204	5.34	D_4=3.524+0.396 HL	0.344	5.218
D_4=29.96+0.535 HB	0.488	5.43	D_4=23.112+0.535 HB	0.366	4.649
D_4=19.05+0.611 MHB	0.477	5.49	D_4=23.608+0.478 MHB	0.330	4.803
D_5=7.101+0.52 PL	0.358	5.26	D_5=11.345+0.485 PL	0.258	6.167
D_5=18.255+0.244 HL	0.325	5.455	D_5=7.977+0.295 HL	0.379	6.124
D_5=16.42+0.447 HB	0.47	5.74	D_5=19.393+0.438 HB	0.313	5.268
D_5=19.473+0.4 MHB	0.424	6.001	D_5=17.314+0.415 MHB	0.325	5.219
PL=38.873+0.39 HL	0.608	3.188	PL=5.73+0.555 HL	0.597	3.211
PL=29.718+0.782 HB	0.569	3.631	PL=35.86+0.707 HB	0.552	3.611
PL=27.94+0.732 MHB	0.540	3.33	PL=37.183+0.631 MHB	0.622	3.122
HL=56.517+0.54 HB	0.547	3.45	HL=60.393+1.27 HB	0.610	3.829
HL=55.56+0.19 MHB	0.526	3.785	HL=62.805+1.123 MHB	0.561	3.615
HB=4.353+0.879 MHB	0.445	4.848	HB=6.63+0.838 MHB	0.512	4.521

5.Discussion

All anthropometric dimensions of the right and left hands were found to be significantly correlated with each other in both genders. For both the right and left hands, the anthropometric dimensions and stature of the recruited people were statistically larger in males than females. The index and middle finger lengths had the strongest correlation in both genders (r = 0.905 for men, r = 0.896 for females). Furthermore, there was a strong correlation between hand length and maximum hand breadth (r = 0.900 for men and r = 0.888 for females). For both the right and left hands, the t-test revealed that the mean values of all anthropometric measures were considerably larger for males than females (P<0.05). In all of the measured hand dimensions, there was no significant bilateral variation. As a result, regression equations were derived from the hand dimensions using the mean of the right and left hands combined.

The measured factors were used to estimate stature using a linear regression analysis. Regression equations have been calculated independently for each measurement and each gender. The regression equations were developed to forecast the difference between the estimated and real stature by reconstructing each hand measurement from every potential single measurement. The obtained SEE and coefficient of determination (R^2) revealed that these equations were accurate, (*Tables 8* and *9*).

In males, the minimum SEE value was obtained for palm length reconstruction using hand length (3.25 mm for the right side and 3.188 mm for the left side), while in females, the minimum SEE value was obtained for palm length reconstruction using maximum hand breadth (3.19 mm for the right side and 3.122 mm for the left side). Furthermore, the predictive value, or coefficient of determination, was highest for reconstructing palm length from hand length in males (0.615 for the right side and 0.608 for the left side), while it was highest for reconstructing palm length from maximum hand breadth in females (0.638 for the right side and 0.615 for the left side). Because the SEE and R^2 results for hand length from palm length and from maximum hand breadth were minimal and maximal respectively in males and females, the hand length, palm length, and maximum breadth can provide the most reliable estimation of stature by linear regression analysis when compared to the other anthropometric measurements. A low SEE value meant more precision.

The findings were consistent with those observed in earlier studies. The variations in anthropometric measures between the right and left hands were shown to be inconsequential. The length and breadth of the hands were symmetrical, with the lengths of the fingers differing slightly. For certain persons who are subjected to severe manual activity, frequent usage of the dominant side results in muscular strengthening and higher muscle and bone growth of the respective side. As a result, in this investigation, bilateral hand anthropometric measures were taken. Hand anthropometric measurements in females were smaller than in males. Large differences were existed in hand length or breadth, while they were small with the hand fingers length. Such gender differences can be logically explained according to the physiological and anatomical configuration of both genders, by the fact that females are genetically shorter than males and the hormones play an important role in differential growth. Therefore, gender-specific correlation coefficients and regression equations need to be developed when estimating stature from measurements of body parts. The sensitivity to measurement errors and lack of repeatability that might result from repeated measurements and inadequate staff training were the study's limitations. However, non-invasive, costly hand anthropometric bilateral analyses were carried out to evaluate statures in the target population study. An enhancement in future research would be to slightly expand the sample size and add more clinical information to the anthropometric measures.

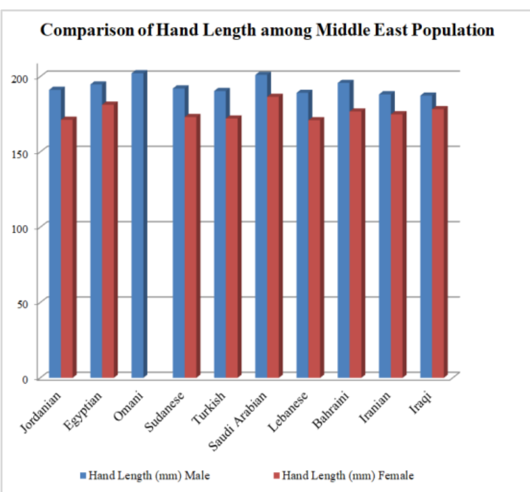
For the purpose of personal identification, finger length considered a valid indicator of height. Stature can be more accurately predicted using the middle finger length. In order to accurately estimate height by finger length for different age groupings in Iraq, further research is needed. Thus, this study found that a low SEE score suggests higher accuracy in the estimated height. Compared to SEE of the other hand metrics in this instance, SEE is lower for both hand length and palm length. It is the opposite for the coefficient of determination (R^2). Hence, the regression model predicts stature from hand length and palm length more correctly than it does from the other hand characteristics in both genders.

5.1Comparative analysis

This study compares the variations in hand anthropometric measurements of selected ten Middle Eastern populations. *Table 10* demonstrates this comparison between dominant hand length and hand breadth in males and females. This comparison shows that Iraqi population’s dominant hand length and breadth measurements were consistent with those of distinctive populations. *Figure* 6 illustrates comparative pictorial representations of the average hand length and breadth among males and females of these selected Middle East countries and our study population respectively.

Table 10 Comparison of dominant hand length and breadth SD between present study and other studies from the middle east

Study authors	Population ethnicity	Hand length (mm)		Hand breadth (mm)	
		Male	Female	Male	Female
Mandahawi et al. 2008 [35]	Jordanian	191.2 ± 10.2	171.3 ± 7.44	87.7 ± 4.82	77.8 ± 3.92
Aboul-hagag et al. 2011 [36]	Egyptian	194.74 ± 9.22	181.32 ± 9.02	81.32 ± 3.93	71.66 ± 3.97
Ahmed 2013 [37]	Sudanese	192.1 ± 11.0	173.1 ± 8.4	79.7 ± 5.4	70.6 ± 3.3
Cakit et al. 2014 [38]	Turkish	190.40 ± 9.69	172.16 ± 8.14	78.44 ± 4.52	76.06 ± 4.66
Ibrahim et al. 2018 [39]	Saudi Arabian	201.1 ± 11.4	186.5 ± 8.8	87.76 ± 5.5	76.6 ± 3.4
Bahmad et al. 2020 [40]	Lebanese	189.20 ± 9.9	171.0 ± 1.02	87.4 ± 0.5	77.4 ± 0.48
Kamel et al. 2020 [41]	Bahraini	195.8 ± 18.3	176.8 ± 9.5	88.9 ± 6.0	77.0 ± 4.4
Pajokh et al. 2022 [42]	Iranian	188.2 ± 8.6	174.9 ± 9.8	85.6 ± 8.3	78.4 ± 3.8
Khadem et al. 2012 [43]	Omani	202.2 ± 22.7	-	77.6 ± 17.8	-
Present Study 2023	Iraqi	187.36 ± 26.51	178.31 ± 13.52	84.74 ± 6.90	77.5 ± 5.48



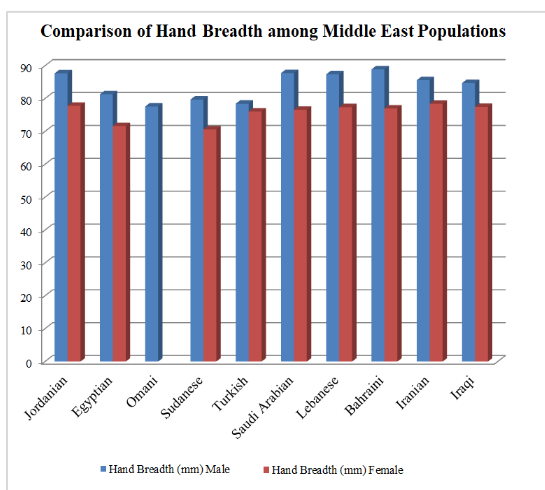


Figure 6 Comparative pictorial representation of the average hand length (left) and hand breadth (right) among selected Middle East populations

Overall, it can be observed that among these ten nations, Omani [43] and Saudi Arabian [39] males had the longest hand with 202.2 mm and 201.1 mm respectively, while Iraqi and Iranian [42] males' appeared to have the shortest hands with 187.36 mm and 188.2 mm respectively. In females, Saudi Arabian [39] and Egyptian [36] hands were the longest with 186.5 mm and 181.32 mm respectively, while Lebanese [40] and Jordanian [35] females' appeared to have the shortest hands with 171.0 mm and 171.3 mm respectively. As can be observed, Egyptians [36] had the largest difference between the male and female mean hand length with more than 23 mm gap, while Iraqis had the smallest hand length difference in both genders with only 9 mm gap. Moreover, Bahraini [41] males outgrew other Middle East populations in the hand breadth with 88.9 mm whereas Omani [43] males appeared to have the smallest hand breadth with 77.6 mm. Iranian [42] females with a value of 78.4 mm and Jordanian [35] females with a value of 77.8 mm had the largest hand breadth average measurements, while Sudanese [37] females appeared to have the smallest hand breadth with 70.6 mm. As can be observed, Turkish [38] had the smallest difference between the male and female mean hand breadth with more than 2 mm gap, while most other Middle East populations had about 10 mm hand breadth difference in both genders. Egyptian [36] and Sudanese [37] males had longer hands than the populations of Jordan, Turkey, Lebanon, Iran and Iraq, whereas they had shorter hands than the populations of Oman, Saudi Arabia and Bahrain. In comparison to Egyptian [36] and Sudanese [37] females, Turkish [38] females had wider hands, but they had narrower hands than the females of Iran, Jordan, Iraq, Lebanon, Bahrain and Saudi Arabia. Hand anthropometric data for Omani female populations were unavailable.

In terms of ethnicity, culture, and history, most Middle Eastern nations are closely related to one another. Based on their geography, the people of Iran, Iraq, Jordan and Lebanon in particular are geographically connected. The same manner is observed with both Egypt and Sudan on one side, and Saudi Arabia, Bahrain and Oman on the other side.

Yet, this information may still be helpful in the overall application. Certain results from comparisons with other nations may have been impacted by variations in measurement procedures, measuring precision, and instruments utilized.

5.2Study limitations and advantages

Among Iraqi population, hand anthropometric data were gathered for this study. To expand representation for the Iraqi people in the future, broader anthropometric data collecting will be required. The limited sample size for both genders in this study may restrict the generalizability of the current findings. It is also generally recognized that a number of additional characteristics, besides gender and nationality, have an impact on body proportions. Age group is among the most crucial. This element may have an impact on our findings. Our study does not have enough participants to accurately test for this factor impact. The current findings need to be confirmed by other research.

Also, we realize that skeleton anthropometric measurements may be more accurate than soft tissue-based measurements, but from a practical and therapeutic standpoint, the latter technique of measurement is preferable. Moreover, utilizing anthropometric measurements based on soft tissues is said to be a quick, straightforward, trustworthy, and efficient way. Because they are simpler to measure than other anthropometric markers like ulna length or knee height, hand anthropometric measurements may be a striking alternative for measuring body height. Using a pocket ruler or an anthropometrical tape makes measuring the hand anthropometric characteristics more accessible and useful; it takes less time for daily practice and needs little movement and cooperation from the subject. Regression studies utilizing hand measures revealed to be one of the simplest and most reliable techniques, even if a number of alternative strategies have been employed to estimate height from body segments and long limb bones. Notwithstanding these limitations, non-invasive, affordable, and appropriate methods for hand anthropometric measurements were used to assess statures in target population research. An enhancement in future research would be to slightly expand the sample size and add clinical information to the anthropometric measures.

A complete list of abbreviations is shown in *Appendix I.*

6.Conclusion and future work

The hand anthropometric dimensions were determined, and regression equations were established between the stature and these dimensions for (128) males and females within the age range of 18 to 69 years old in the Iraqi population in the present study.

Statistically significant differences were found between the male and female groups in all anthropometric hand measures and stature, with male mean values being larger than female mean values. These statistically significant disparities could be attributed to girls' earlier maturity and physical development than boys. These findings were consistently comparable with earlier findings that reported smaller female hand dimensions than male hand dimensions in many human communities, proving once again that anthropometric measures are very distinctive to populations. The hand dimensions, like the bones and many other body parts, were regarded as relevant for gender verification. Furthermore, it was shown that stature was significantly and positively correlated with all hand anthropometric measurements, with hand length, maximum breadth, and palm length showing the highest correlation with stature than the other dimensions. Additionally, it was found that bilateral symmetry in hand measurement was quantified, and no statistically significant differences were determined between the right- and left-hand measures in both genders. As a result, it was concluded that individuals between the ages of 18 and 69 years old could estimate their height using hand anthropometric measurements. Further research could be expanded in the future to include people who are under and/or over that age range.

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Conflicts of interest

The authors have no conflicts of interest to declare.

Author’s contribution statement

The author conceived the topic of this research and designed the study. He performed the data analysis and drafted the manuscript writing with its edited revisions.

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Appendix I

S. No.	Abbreviation	Description
1	BMI	Body Mass Index
2	CMC	Carpometacarpal
3	D_1	Thumb Length (mm)
4	D_2	Index Finger Length (mm)
5	D_3	Middle Finger Length (mm)
6	D_4	Ring Finger Length (mm)
7	D_5	Little Finger Length (mm)
8	DIP	Distal Inter Phalangeal
9	HB	Hand Breadth (mm)
10	HL	Hand Length (mm)
11	IP	Interphalangeal
12	MHB	Maximum Hand Breadth (mm)
13	MCP	Metacarpophalangeal
14	PIP	Proximal Interphalangeal
15	PL	Palm Length (mm)
16	SD	Standard Deviation
17	SPSS	Statistical Package for the Social Sciences
18	SEE	Standard Error of the Estimate