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Research article

Normative data for the anthropometric hand dimensions of the Mexican population

Estándares para las dimensiones antropométricas de la mano de la población mexicana

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Abstract:
Introduction: Work-related musculoskeletal disorders are major occupational health risks that can be positively influenced by appropriate machine, tool, and workstation designs. Despite their importance in ergonomics, normative data for hand anthropometric dimensions have rarely been studied. This study aims to develop normative data for the Mexican population, analyze gender differences, and compare the data with those from other countries. **Methodology:** A survey of hand anthropometry in the Mexican population was conducted (2.275 males and 562 females). Four dominant hand dimensions were measured: hand length and breadth, palm length, and handgrip diameter. **Results:** We have presented descriptive statistics in this study (mean, standard deviation, and 5, 50, 95 percentiles). The results indicated significant differences between the sexes within the Mexican population for all hand dimensions. **Discussion:** significant differences were observed in data from other countries (mainly Asian countries), even with Latin American and Mexican (old surveys) populations. All data developed represent the Mexican population. There is no evidence of the development of similar data including a wide age range, both genders and big data sample. **Conclusions**: The presented data can be used to design hand tools, machinery, products, and workstations.

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Keywords: hand anthropometry; percentiles; gender differences; anthropometric survey; Mexico; Ergonomics; age group anthropometric differences.

Resumen:
Introducción: Los desórdenes musculo-esqueléticos son riesgos de salud ocupacional que pueden disminuirse mediante el uso de máquinas y diseño de herramientas y estaciones de trabajo adecuados. A pesar de su importancia en Ergonomía, los estándares antropométricos de la mano han sido poco estudiados. El objetivo del presente trabajo es desarrollar estándares para la población mexicana, analizar las diferencias de género y comparar los datos con los de otras poblaciones. **Metodología**: Se llevó a cabo un muestreo antropométrico de la población mexicana (2.275 hombres, 562 mujeres). Se recolectaron cuatro dimensiones antropométricas de la mano: longitud y ancho de la mano, longitud de la palma y diámetro de agarre. **Resultados:** Se presentan estadísticas básicas (media, desviación estándar, y percentiles 5, 50, y 95). Los resultados indican diferencias significativas entre ambos sexos de la población mexicana en las cuatro dimensiones estudiadas. **Discusión**: Se observaron diferencias significativas con los datos de otras poblaciones (principalmente países asiáticos), inclusive con países latinoamericanos, incluyendo estudios previos de México. No se encontró evidencia del desarrollo de datos similares considerando un amplio rango de edad, ambos géneros y tamaño de muestra. **Conclusiones**: Los datos presentados pueden utilizarse en el diseño de herramientas de mano, máquinas, productos, y estaciones de trabajo.

Palabras clave: antropometría de la mano; percentiles; diferencia de género; muestreo antropométrico; México; Ergonomía; Diferencias antropométricas por grupo de edad.

1. Introduction

Anthropometry, a part of ergonomics, refers to measurements of the human body, such as size, weight, and proportions. Anthropometry aims to understand human physical variations to achieve fitness (Eksioglu, 2004; Kong & Kim, 2015; Pheasant & Haslegrave, 2015), comfort, and usability of products and workplaces. Therefore, designers should use correct and updated anthropometric measurements for each target group of users to design/redesign traditional tools and machinery to reduce the occurrence of musculoskeletal diseases (Bhattacharjya & Kakoty, 2020; Cakit et al., 2014; García-Cáceres et al., 2012; Hanson et al., 2009). Anthropometric dimensions can be affected by sex, race, and age; therefore, data from different populations should not be used in ergonomic design.

Work-related musculoskeletal disorders (MSDs) are major occupational health hazards in industrial jobs (Macdonald & Oakman, 2015) and can cause occupational health, productivity, and economic losses. These disorders can be caused by repetitive motions, poor posture, or continuous excessive force (Chen et al., 2022). The European Foundation for the Improvement of Living and Working Conditions (European Foundation for the Improvement of Living and Working Conditions, 2011) reports that 46% workers work in correcting or painful positions at least a quarter of the time, and 64% and 63% of male and female workers make repetitive hand and arm movements, respectively, a greater percentage of Europeans than that 10 years ago. In addition, the wrist is associated with the longest duration of absenteeism and a greater loss of productivity (Chen et al., 2022).

Work-related MSDs are commonly caused by awkward postures, repetitive movements, and forceful exertion; severely low temperatures or vibrations can cause these disorders to rapidly deteriorate (Acaröz et al., 2019; Punnett & Wegman, 2004, Anderson et al., 1997). Laal et al. (2022) studied the effect of ergonomic and anthropometric indices, postural risk, and demographic variables on MSDs in nurse aides and concluded that it is necessary to consider anthropometric dimensions and demographic diversity in tool and workstation design to avoid the occurrence of work-related MSDs (Laal et al., 2022).

The important anthropometric dimensions used in hand tools and workstation design include stature, sitting height, and hand dimensions (Massiris et al., 2014). Despite the lack of anthropometric standards, several studies have been conducted worldwide. In 1991, Greiner (Greiner, 1991) presented the hand anthropometry of U.S. Army personnel based on a survey conducted between 1988 and 1989. This study included 84 anthropometric dimensions taken from a sample including 1003 men and 1304 women. The final report presents the summary statistics and percentile tables.

In 2014, Cakit et al. conducted an anthropometric survey of 92 men and 73 women, all of whom were dental students in Turkey; moreover, 67 anthropometric and 26 biomechanical measurements were taken (Cakit et al., 2014).

In 2010, Chuan et al. collected and compared 36 anthropometric measures in Singapore and Indonesia (245 male and 132 female subjects from Indonesia, and 206 male and 109 female subjects from Singapore) (Chuan et al., 2010). Khadem and Anisul reported hand anthropometrics of a Bangladeshi male population in the age range of 16–64 years old, based on a sample of 470 subjects (Khadem & Islam, 2014). Mandahawi et al. (2008) conducted a study in Jordan to develop normative data for hand dimensions and found significant differences between male and female subjects and between Jordanian populations (Mandahawi et al., 2008). Kong and Kim (2015) conducted an anthropometric survey of 20 male and 20 female undergraduate and graduate students, ages 20–35-year-old, to study the relationship between hand dimensions and force (Kong & Kim, 2015). Jee and Yun (2015) conducted a hand anthropometric survey of 321 people (167 males and 154 females) and identified four hand shape types using factor and cluster analyses (Jee & Yun, 2015). Obi (2016) conducted an anthropometric survey of agricultural workers and found significant differences between male and females, with no significant differences when comparing data with other populations (Obi, 2016). In 2020, Bhattacharjya and Kakoty conducted a full body anthropometric survey, in which 265 males and 188 females aged 18–60 years participated, compared the data to other populations, and applied it in designing a pedal-operated chak (Bhattacharjya & Kakoty, 2020).

Few studies have been conducted in Latin America. Massiris et al. (2015) measured 32 hand dimensions in 120 males and 86 females in northern Colombia and found significant differences between the regions in Colombia and across countries (compared with the USA, Chile, Jordan, Korea, and Japan populations) (Massiris et al., 2015). In Mexico, Lavender et al. (2002) reported data for 21 anthropometric measures of 87 females between the ages of 16 and 40 years who participated in a survey conducted in 1998. All were employees of an electric motor manufacturing facility located in northeastern Mexico at that time. The results were compared with the US population anthropometric data, and significant differences were observed (Lavender et al., 2002).

Although some studies have been conducted worldwide to develop anthropometric databases, human physical characteristics are influenced by various factors, such as sex, age, culture, nutrition, social development (Lee et al., 2019), profession, and health. Owing to these differences, it is necessary to build and update different anthropometric databases for each country or population.

Awkward postures are of the main risk factors for the prevalence of work-related MSDs and can be originated by deficiencies in the anthropometric design. Due to the lack of recent anthropometric databases for the Mexican population, anthropometric data obtained from other populations around the world could be used in the hand tools and workstations designs for Mexican people, increasing the risk of work-related MSDs. There have been conducted few anthropometric studies around the world that can be compared with the data developed by this stud, in order to identify the differences or similitudes between the anthropometry of the populations.

There is no scientific evidence for the development of recent hand anthropometric surveys in the Mexican population. Therefore, the main objective of this study was to develop normative data for the Northwest Mexican population, analyze the gender-age differences, and compare them with other country's anthropometric standards for hand dimensions.

2. Methodology

2.1. Subjects

A total of 2.275 male and 562 female participants residing in Northwest Mexico, including graduate students and industrial workers, voluntarily participated in this survey. The participant's ages ranged from 15 to 59 years. All participants were in good health and did not have any normal mobility problems. Basic statistics for male and female age populations (mean, standard deviations (SD), and the total number of subjects in the group (N) are presented by five-year age groups (according to the National Institute of Statistics, Geography, and Informatics) in Table 1. The groups with more subjects were 35–39 and 40–44 as well as 25–29 and 20–24 groups, for the male and female population, respectively.

Table 1.

Age statistics - Male population

Age group	**Male**			**Female**		
	Mean	**SD**	**N**	**Mean**	**SD**	**N**
15-19	18.92	0.27	26	18.94	0.25	16
20-24	22.16	1.39	359	22.02	1.26	125
25-29	27.07	1.42	415	26.84	1.38	141
30-34	31.98	1.45	393	32.07	1.45	120
35-39	36.93	1.43	456	37.15	1.44	103
40-44	41.77	1.38	425	41.42	1.26	43
45-49	46.47	1.32	161	45.90	0.88	10
50-54	51.12	1.11	33	51.33	2.31	3
55-59	55.43	0.53	7			

Source: Developed by authors based on data.

2.2. Body dimensions

Four hand dimensions were used in this study. Only the dominant hand (the hand that the participants identified as the most frequently used to accomplish fundamental daily life tasks) was measured. These measurements are listed in Table 2.

Table 1.

Body dimension description

Body dimension (BD)	Description
Hand Length (HL)	The length of the right hand between the stylion landmark on the wrist and the tip of the middle finger, measure with a sliding caliper.
Palm Length (PL)	The distance between the center of the crease at the base of the middle finger and the ventral stylion landmark, measured with a sliding caliper.
Hand breath (HB)	The breath of the right hand between the landmarks at the metacarpal II and metacarpal V, measured with a sliding caliper.
Hand Grip Diameter (HGD)	The maximum circumference of the circle drawn by the index finger and thumb of the dominant hand.

Source: ISO 7250-1:2017

2.3. Procedure and Equipment

Traditional anthropometric equipment was used in the survey; a Martin type 0–300 mm sliding caliper with 1 mm accuracy was used to measure the HL, PL, and HB, while a calibrated 27.8 cm height and 35–95 mm diameter range grip cone was used to register the grip diameter. HL, PL, and HB were recorded in cm, whereas HGD was measured in mm.

All participants were informed at the beginning of data collection about the objective of the study, equipment, measurements, procedures, and possible applications of the data to be collected. A team of measurers was trained in data collection procedures (both theoretical and practical techniques to measure the dimensions and locate anthropometric landmarks).

3. Results

3.1. Statistics

General and age grouped descriptive and inferential statistics, such as mean, standard deviation (SD), and 5th, 50th, and 95th percentiles are presented in Tables 3 and 4, respectively. These data can be used in product and workplace design. The mean ± SD of the HL, PL, HB, and HGD dimensions are 18.82 ± 0.85 cm, 10.77 ± 0.62 cm, 8.79 ± 0.51 cm, and 48.14 ± 3.86 mm for the general male population, and 17.46 ± 0.80 cm, 9.99 ± 0.56 cm, 7.80 ± 0.52 cm, and 45.51 ± 3.66 mm, for the general female population, respectively.

Table 3.

General Male and Female population anthropometric statistics

AD	Male					Female				
	Mean	SD	P5	P50	P95	Mean	SD	P5	P50	P95
HL	18.82	0.85	17.42	18.80	20.22	17.46	0.80	16.14	17.40	18.77
PL	10.77	0.62	9.75	10.70	11.78	9.99	0.56	9.07	10.00	10.90
HB	8.79	0.51	7.96	8.80	9.62	7.80	0.52	6.94	7.70	8.65
HGD	48.14	3.86	41.80	48.00	54.48	45.51	3.66	39.49	45.00	51.53

Source: Developed by authors based on data.

Table 4.

Hand dimension statistics per age group

AD	Male					Female				
	Mean	SD	P5	P50	P95	Mean	SD	P5	P50	P95
					15–19 Group					
HL	18.66	0.77	17.39	18.66	19.93	17.46	0.74	16.24	17.46	18.69
PL	10.55	0.52	9.69	10.55	11.41	10.18	0.52	9.32	10.18	11.03
HB	8.43	0.55	7.53	8.43	9.34	7.74	0.47	6.97	7.74	8.50
HGD	47.38	3.19	42.14	47.38	52.63	47.19	3.69	41.12	47.19	53.26
					20–24 Group					
HL	18.80	0.79	17.49	18.80	20.11	17.49	0.77	16.22	17.49	18.76
PL	10.79	0.58	9.83	10.79	11.76	9.95	0.53	9.08	9.95	10.82
HB	8.75	0.52	7.89	8.75	9.61	7.90	0.50	7.07	7.90	8.73
HGD	49.16	3.66	43.14	49.16	55.19	46.26	3.51	40.49	46.26	52.03
					25–29 Group					
HL	18.80	0.84	17.41	18.80	20.19	17.45	0.76	16.21	17.45	18.70
PL	10.80	0.72	9.62	10.80	11.99	10.00	0.56	9.08	10.00	10.93
HB	8.77	0.51	7.93	8.77	9.60	7.74	0.54	6.86	7.74	8.63
HGD	48.62	3.73	42.48	48.62	54.76	45.80	3.60	39.88	45.80	51.72
					30 – 34 Group					
HL	18.87	0.82	17.51	18.87	20.22	17.37	0.84	15.99	17.37	18.76
PL	10.79	0.58	9.84	10.79	11.75	9.93	0.64	8.89	9.93	10.98
HB	8.88	0.52	8.02	8.88	9.74	7.75	0.46	6.98	7.75	8.51
HGD	48.59	3.85	42.26	48.59	54.92	45.32	3.73	39.18	45.32	51.45
					35–39 Group					
HL	18.85	0.88	17.40	18.85	20.31	17.43	0.74	16.21	17.43	18.64
PL	10.76	0.61	9.76	10.76	11.76	10.03	0.46	9.27	10.03	10.79
HB	8.86	0.51	8.03	8.86	9.69	7.76	0.54	6.87	7.76	8.64
HGD	47.89	3.91	41.46	47.89	54.32	45.00	3.74	38.85	45.00	51.15
					40–44 Group					
HL	18.85	0.86	17.43	18.85	20.27	17.51	0.93	15.99	17.51	19.04
PL	10.74	0.60	9.76	10.74	11.72	9.92	0.53	9.05	9.92	10.80
HB	8.75	0.48	7.97	8.75	9.53	7.84	0.60	6.86	7.84	8.83
HGD	47.34	3.85	41.01	47.34	53.67	43.53	3.28	38.13	43.53	48.94
					45–49 Group					
HL	18.66	0.96	17.09	18.66	20.24	17.94	1.08	16.17	17.94	19.71
PL	10.65	0.60	9.67	10.65	11.63	10.30	0.61	9.29	10.30	11.31

HB	8.69	0.44	7.97	8.69	9.42	8.07	0.52	7.22	8.07	8.92
HGD	46.71	3.71	40.61	46.71	52.82	46.00	2.87	41.28	46.00	50.72
					50–54 Group					
HL	18.85	0.78	17.57	18.85	20.12	17.97	1.53	15.45	17.97	20.48
PL	10.70	0.41	10.02	10.70	11.38	10.33	0.76	9.09	10.33	11.58
HB	8.63	0.45	7.89	8.63	9.37	7.73	0.25	7.32	7.73	8.15
HGD	46.85	3.32	41.39	46.85	52.31	44.00	2.65	39.65	44.00	48.35

Source: Developed by authors based on data.

3.2. Mean comparisons

Table 5 presents the p-value of the mean comparison and the 95% confidence intervals for the general male and female populations. It can be observed that male dimensions are greater than female dimensions in all cases. Tables 6 and 7 show the test p-values for the mean comparison of each pair of groups for male and female populations, respectively.

Table 5.

Female vs Male mean comparison

AD	Confidence Interval	p-value
HL	(-1.4401, -1.2902)	0.000*
PL	(-0.8319, -0.7269)	0.000*
HB	(-1.0409, -0.9451)	0.000*
HGD	(-2.968, -2.283)	0.000*

**Statistically significant values p<0.05 (two-tailed).* H_o: $\mu_{female} = \mu_{male}$

Source: Developed by authors based on data.

In the case of the male population, there were no significant differences between the group mean dimensions for the palm and hand lengths, while the 30–34 HB group differed from the rest of the group's dimensions. In the case of HGD, the younger and older groups were similar, while the middle-aged groups (20–24, 30–34) differed from the middle-aged groups (mainly 35–39, 40–44, 45–49).

In the case of the female population, the mean of the four anthropometric dimensions was statistically similar, but in the 40–44 group HB, compared with the 15–19, 20–24, and 25–29 groups.

The 95% confidence intervals and p-values for the mean comparison by sex and age group are presented in Table 8. In the case of the HL dimension, only dimensions 45–49 and 50–54 was statistically similar. In the case of PL, HB, and HGD, the younger and older groups were statistically similar in the age–sex comparison.

Table 6.

Male mean comparison

Age Group	15–19	20–24	25–29	30–34	35–39	40–44	45–49	50–54	55–59
				Hand Length (HL)					
15–19									
20–24	0.993								
25–29	0.992	1.000							
30–34	0.923	0.969	0.969						
35–39	0.946	0.993	0.993	1.000					
40–44	0.951	0.995	0.996	1.000	1.000				
45–49	1.000	0.821	0.816	0.312	0.41	0.438			
50–54	0.992	1.000	1.000	1.000	1.000	1.000	0.958		
55–59	0.996	1.000	1.000	1.000	1.000	1.000	0.995	1.000	
				Palm Length (PL)					
15–19									
20–24	0.386								
25–29	0.352	1.000							
30–34	0.392	1.000	1.000						
35–39	0.560	0.998	0.992	0.998					
40–44	0.683	0.947	0.913	0.951	1.000				
45–49	0.991	0.218	0.195	0.217	0.538	0.792			
50–54	0.959	0.942	0.916	0.946	0.995	1.000	1.000		
55–59	0.798	0.993	0.995	0.992	0.984	0.975	0.905	0.954	
				Hand Breath (HB)					
15–19									
20–24	**0.143**								
25–29	**0.108**	1.000							
30–34	**0.010***	0.020*	0.039*						
35–39	**0.015***	0.075	0.139	1.000					
40–44	**0.142**	1.000	1.000	0.005*	0.025*				
45–49	**0.382**	0.923	0.743	0.001*	0.002*	0.912			
50–54	**0.863**	0.868	0.775	0.090	0.150	0.868	0.998		
55–59	**0.825**	1.000	1.000	0.980	0.992	1.000	1.000	1.000	
				Hand Grip Diameter (HGD)					
15–19									
20– 24	**0.185**								
25–29	**0.625**	0.512							
30–34	**0.656**	0.483	1.000						
35–39	**0.997**	0.000 *	0.114	0.177					
40–44	**1.000**	0.000 *	0.000 *	0 .000*	0.467				
45–49	**0.986**	0.000 *	0.000 *	0 .000*	0.019 *	0.683			
50–54	**0.999**	0.013 *	0.116	0.131	0.731	0.996	1.000		
55–59	**1.000**	1.000	1.000	1.000	1.000	0.999	0.982	0.992	

*Statistically significant values p<0.05 (two-tailed). H_o: $\mu_{group1} = \mu_{group2}$

Source: Developed by authors based on data.

Table 7.

Female mean comparison.

Age Group	15–19	20–24	25–29	30–34	35–39	40–44	45–49	50–54
Hand Length (HL)								
15–19								
20– 24	1.000							
25–29	1.000	1.000						
30–34	1.000	0.951	0.991					
35–39	1.000	0.999	1.000	0.999				
40–44	1.000	1.000	1.000	0.988	0.999			
45–49	0.910	0.879	0.838	0.727	0.806	0.929		
50–54	0.996	0.997	0.995	0.989	0.994	0.998	1.000	
Palm Length (PL)								
15–19								
20–24	0.719							
25–29	0.913	0.989						
30–34	0.692	1.000	0.982					
35–39	0.961	0.902	1.000	0.888				
40–44	0.715	1.000	0.986	1.000	0.934			
45–49	0.999	0.649	0.801	0.626	0.860	0.629		
50–54	1.000	0.962	0.982	0.958	0.988	0.954	1.000	
Hand Breath (HB)								
15 –19								
20 – 24	0.977							
25 –29	0.834	0.965						
30 – 34	0.565	0.450	0.964					
35 – 39	0.391	0.158	0.701	0.998				
40 – 44	0.034*	0.000*	0.005*	0.077	0.276			
45 – 49	0.981	1.000	1.000	0.995	0.962	0.316		
50 – 54	0.659	0.798	0.897	0.970	0.992	1.000	0.917	
Hand Grip Diameter (HGD)								
15–19								
20–24	0.881							
25–29	1.000	0.206						
30–34	1.000	0.182	1.000					
35–39	1.000	0.421	1.000	1.000				
40–44	0.996	0.999	0.978	0.979	0.992			
45–49	0.712	0.966	0.565	0.566	0.618	0.914		
50–54	1.000	0.912	1.000	1.000	1.000	0.995	0.770	

*Statistically significant values $p<0.05$ (two-tailed). H_o: $\mu_{group1} = \mu_{group2}$

Source: Developed by authors based on data.

Table 8.

Mean comparison for the group age, Female vs Male.

Age Group	Hand Length (HL)		Palm Length (PL)		Hand Breath (HB)		Hand Grip Diameter (HGD)	
	Confidence Interval	p-value	Confidence Interval	p-value	Confidence Interval	p-value	Confidence Interval	p-value
15–19	(-2.096, -0.302)	0.002*	(-0.998, 0.248)	0.681	(-1.286, -0.108)	0.009*	(-2.096, -0.302)	0.002*
20–24	(-1.593, -1.028)	0.000*	(-1.045, -0.650)	0.000*	(-1.034, -0.664)	0.000*	(-1.593, -1.028)	0.000*
25–29	(-1.607, -1.082)	0.000*	(-1.004, -0.595)	0.000*	(-1.202, -0.840)	0.000*	(-1.607, -1.082)	0.000*
30–34	(-1.800, -1.187)	0.000*	(-1.087, -0.631)	0.000*	(-1.309, -0.960)	0.000*	(-1.800, -1.187)	0.000*
35–39	(-1.717, -1.129)	0.000*	(-0.919, -0.543)	0.000*	(-1.307, -0.898)	0.000*	(-1.717, -1.129)	0.000*
40–44	(-1.874, -0.800)	0.000*	(-1.133, -0.508)	0.000*	(-1.251, -0.563)	0.000*	(-1.874, -0.800)	0.000*
45–49	(-2.271, 0.825)	0.768	(-1.235, 0.531)	0.897	(-1.366, 0.121)	0.131	(-2.271, 0.825)	0.768
50–54	(-10.545, 8.788)	0.991	(-5.113, 4.386)	0.998	(-2.071, 0.277)	0.109	(-10.54, 8.788)	0.991

*Statistically significant values $p<0.05$ (two-tailed). Ho: $\mu_{FemaleGroup1} = \mu_{MaleGroup1}$.

Source: Developed by authors based on data.

3.3. Comparison with other studies

Table 9 presents the results of the comparison of Mexican male hand length, indicating that Mexican male dimensions are statistically similar to the Southern Thai and Malaysian, Asian, and the Colombian male populations. In the case of the Mexican female population, hand length is different from that of the Asian countries, the Colombian population, and even the Mexican population reported in 2000.

In the case of hand breadth, Mexican male and female populations are statistically different from the Singapore, Colombia, and Nigerian populations, showed in Table 10; in the case of palm length, Mexican population dimensions are different from Colombian population dimensions (Table 11).

Table 9.

Other studies hand length mean comparison.

Country	Statistics	Male	Female
Mexico	Mean (SD)	18.82(0.85)	17.46(0.80)
	n	2,275	562
vs. Bangladesh (Khadem & Islam, 2014)	Mean (SD)	19.60(1.17)	-
	n	470	-
	p-value	**0.000***	-
vs. India (Dewangan et al., 2008, 2010)	Mean (SD)	17.5(1.0)	16.53(0.73)
	n	801	400

	p-value	**0.000***	**0.000***
vs. Southern Thai (Klamklay et al., 2008)	Mean (SD)	19.11(7.16)	-
	n	100	-
	p-value	0.686	-
vs. Malaysia (Mohamad et al., 2010)	Mean (SD)	19.2(5.47)	17.3(1.52)
	n	516	491
	p-value	0.116	**0.037***
vs. Assam, India (Bhattacharjya & Kakoty, 2020)	Mean (SD)	17.3(0.9)	16.10(0.8)
	n	265	188
	p-value	**0.000***	**0.000***
Singapore (Lee et al., 2019)	Mean (SD)	18.4(0.9)	17.1(0.9)
	n	50	50
	p-value	**0.002***	**0.008***
Nigeria (Obi, 2016)	Mean (SD)	19.142 (1.958)	15.886 (4.95)
	n	200	100
	p-value	**0.022***	**0.002***
Colombia (Oviedo-Trespalacios et al., 2017)	Mean (SD)	19.034 (1.36)	16.822(1.063)
	N	129	86
	p-value	0.079	**0.000***
Mexico (Lavender et al., 2002)	Mean (SD)	**-**	16.8 (0.8)
	N	**-**	87
	p-value	**-**	**0.000***

*Statistically significant values $p<0.05$ (two-tailed). H_o: $\mu_{group1} = \mu_{group2}$

Source: Developed by authors based on data.

Table 10.

Hand breadth mean comparison with other studies.

Country	Statistics	Male	Female
Mexico	Mean (SD)	8.79(0.51)	7.80(0.52)
	n	2,275	562
Singapore (Khadem & Islam, 2014)	Mean (SD)	8.1(0.5)	7.1(0.4)
	n	50	50
	p-value	**0.000***	**0.000***
Colombia (Oviedo-Trespalacios *et al.*, 2017)	Mean (SD)	9.825 (1.089)	8.674 (1.143)
	n	129	86
	p-value	**0.000***	**0.000***
Nigeria (Obi, 2016)	Mean (SD)	8.082 (0.836)	7.215 (0.627)
	n	200	100
	p-value	**0.000***	**0.000***

*Statistically significant values $p<0.05$ (two-tailed). H_o: $\mu_{group1} = \mu_{group2}$

Source: Developed by authors based on data.

Table 11. *Other studies palm length mean comparison.*

Mexico	Mean (SD)	10.77 (0.62)	9.99 (0.56)
	n	2,275	562
Colombia (Oviedo-Trespalacios *et al.*, 2017)	Mean (SD)	10.455 (0.857)	9.394(0.65)
	n	129	86
	p-value	**0.000***	**0.000***

*Statistically significant values p<0.05 (two-tailed). H_o: $\mu_{group1} = \mu_{group2}$

Source: Developed by authors based on data.

4. Discussion

The main factors that can influence the difference/equality of the hand dimensions are sample size, sample subjects, and hand measurement (left–right; dominant/non-dominant). The Singapore survey included 50 men and 50 women, which affected the representativeness of the sample. In the case of the Malaysian and Southern Thai populations (similar to the hand-length male Mexican population), the sample included undergraduate students and workers at universities, while the rest of the population included agricultural/farmer workers (Indian, Assam, Nigeria) and workers from different activities (Bangladesh industrial, bankers, employees, doctors, students, Singapore, students and employees at universities, and Colombia). The studies considered for comparison measured the right hand, whereas this study considered the dominant hand.

The main limitation of the present study is that the sample included students and workers from the industry; therefore, this can be extended to other types of work activities relevant to the design of hand tools, such as agricultural work.

5. Conclusions

A total of 2.837 subjects were recruited to develop hand anthropometric standards for the Northwest Mexican population. The means, standard deviation, and percentiles 5, 90, and 50 were presented, and can be used in hand tool and workstation design. Differences from other country's anthropometric data were found, even in Latin American and Mexican (old surveys for the hand length) populations. The developed data can be useful in Mexican hand tool design to improve worker's abilities and productivity. Further studies can include more hand dimensions that can be useful in the design of hand tools and protective equipment, such as finger and thumb dimensions, and the use of new technologies in measurement techniques, such as motion capture systems based on vision sensors.

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