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Anthropometrics of University Students in Northern Mexico

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Abstract

The main objective of this research was to build a database on anthropometric features from a sample of students enrolled in the Industrial Design program at the Universidad Autonoma de Ciudad Juarez (UACJ), to contrast anthropometric data with other Mexican regions, and to generate predictive models of the participants' body dimensions. A set of 36 body dimensions were measured based on international standards. Two anthropometric kits Rosscraft model Centurion were used for measurements. 140 students, 70 male and 70 female, enrolled in the Industrial Design program at the UACJ were measured. The values of mean, standard deviation, and percentiles were calculated. Besides, 26 predictive models of body segments were developed using simple linear regression. Body weight and stature of students in Northern Mexico are significant larger than people from other Mexican regions. We now hold anthropometric data of 36 body dimensions and 26 predictive models of body segments.

Keywords

Anthropometry, Product Design, Statistics and Data Analysis, Industrial Design

1. Introduction

Physical features of human beings are in constant evolution. In countries like Mexico, recent improvements in feeding patterns and health care have had an important impact on the bodily dimensions of their populations. This leads to the need for anthropometric data to be constantly updated. Anthropometric data is applied mainly in the design of objects, products and spaces to be used and/or inhabited by the subjects who were measured. Some examples are school/academic, home and urban furniture, housewares, tools, cars, workstations, among others. Some studies have shown that school furniture used in primary schools do not match the body size of students, thus favoring musculoskeletal discomfort in children [1]. Updated anthropometric data is very important for any population/civilization since the determination of the correct dimensions of objects depends largely on upgrading existing anthropometric data.

In Mexico, there are few studies focused on generating anthropometric data of the population. Probably, one of the first research study related to anthropometry in Mexico was published in 1933, and it included a historical collection of physical anthropology and anthropometry [2]. Another study reported anthropometric data of students and workers of the Universidad Nacional Autónoma de México (UNAM) and other Mexican cities [3]. The book "The anthropometric technique applied to industrial design", in which the main anthropometric procedures and their applications of the product design are mentioned [4]. Ergonomists' Society of Mexico [5] published on its website (www.semac.org) the results from what is called a national anthropometric study.

A comprehensive search starting on the year 2000, yielded the following studies related to anthropometry research in Mexico: 1) The book "Anthropometric dimensions of Latin American Populations: Mexico, Cuba, Colombia, Chile" which includes anthropometric data gathered from samples in four Mexican locations (Guadalajara, Leon, Mexico-USA border, and Mexico City) as well as samples from the other mentioned countries [6]; 2) Anthropometric study of primary school students in the western region of Mexico [7]; 3) Anthropometric data of people suffering from crucial paraplegia in the Mexican states of Sonora and Sinaloa [8]; 4) Anthropometric dimensions of workers (male and female) of Ciudad Juarez [9]. Anthropometric data of automotive industry workers in northwestern Mexico [10]; 5) Anthropometric measurements for hand-tools design [11].

Also, in Mexico anthropometric studies focused on specific populations have been developed for seniors [6] [12], athletes [13], and people with dwarfism [14].

One of the applications given to the anthropometric data is the generation of predictive models of body segments [15]. These models help when anthropometric data to determine the dimensions of an object/product are not enough. In this context, www.ergonautas.com website contains an application that allows estimating the length of seven body segments in relation to stature. This application was developed using a anthropometric data developed in 1966 [15]. In the same way, predictive models of 11 body segments of Mexican children from 6 to 12 years old were developed [7].

This article addresses the case of the Universidad Autonoma de Ciudad Juárez (UACJ). Here, students enrolled in the Industrial Design program develop prototypes, models, and designs used by them in different tests, such as functionality, usability, and product validation. Due to the lack of anthropometric data on the population in northern Mexico, the designs are developed using information coming from other populations, the most common being from the United States of America [16] or from the western region of Mexico [6]. This leads to unsuitable designs for the anthropometric characteristics of the students who would be the primary users of those developments. As an undesirable and unfair result, the design students get failed in the mentioned procedures.

This research had three objectives. The first objective was to build a database on anthropometric features from a sample of students enrolled in the Industrial Design program at the UACJ. The second objective was to compare the body weight and stature with data from other Mexican regions. The final objective was to generate predictive models of the participants' body dimensions, based on their stature.

2. Materials and Methods

2.1. Participants

The sample was composed of students enrolled in the Industrial Design program at the UACJ. The inclusion criteria were:

- Being a student at any level of the industrial design program
- Being free of physical injuries at the time of measurements
- Not having sustained a single bone fracture throughout their entire life

Ethics committee of the Universidad Autonoma de Ciudad Juarez, Mexico reviewed and approved the study. Participants signed a consent form accepting their participation in the study. Also, participants were informed of the wearing requirements, objectives, benefits of the study, as well as the absence of health risks by participating on it. They were informed that the data gathered would be treated in full confidentially and used for academic purposes only.

2.2. Materials

Two anthropometric kits Rosscraft model Centurion with an accuracy of 0.5 mm were used for measurements. The anthropometric kit has a precision and calibration certificate issued by the manufacturer. The perimeter of the head, arms and legs were measured using a flat steel tape included in the anthropometric kit. The weight was recorded using a Torino scale that was constantly adjusted during the course of the study. In addition to the measurements, participants were asked to fill out a survey enquiring on demographic data.

2.3. Variables

Thirty-six body dimensions were measured. The site and definition of each anthropometric parameter were based on the standard procedure [17]. **Table 1** shows the names of the dimensions.

2.4. Study Organization

A team of two students and two researchers (called anthropometrist) were trained to perform anthropometric measurements and their procedures were analyzed to corroborate consistency in measurements. All measurements were performed in the Ergonomic Product Design Lab at the UACJ. All measurements were taken in the afternoon,

Table 1. Anthropometric dimensions measured in the study.

N°	Body dimension	N°	Body dimension
1	Body weight	19	Shoulder-elbow length, sitting
2	Stature, standing	20	Elbow-finger tips length, sitting
3	Eye height, standing	21	Thorax depth, sitting
4	Shoulder height, standing	22	Abdominal depth, sitting
5	Elbow height, standing	23	Head breadth, sitting
6	Hip height, standing	24	Biacromial shoulder breadth, sitting
7	Knuckle height, standing	25	Bideltoid shoulder breadth, sitting
8	Finger tips height, standing	26	Hip breadth, sitting
9	Height, sitting	27	Arm reach to wall, lateral, standing
10	Eye height, sitting	28	Shoulder-fist length, standing
11	Shoulder height, sitting	29	Maximum horizontal reach, standing
12	Thigh height, sitting	30	Maximum vertical reach, standing
13	Knee height, sitting	31	Maximum Arms Span, standing
14	Popliteal height, sitting	32	Elbow-to-elbow breadth, standing
15	Thigh thickness, sitting	33	Hand length
16	Buttock-knee length, sitting	34	Hand breadth
17	Buttock-popliteal cavity length, sitting	35	Foot length, standing
18	Head length, sitting	36	Foot breadth, standing

and the subjects were barefooted and wore T-shirt and thin shorts. In addition to the measurements, participants completed a form with demographic information (age, gender, date of measurement, and place of birth) and signed a consent form. The measurements were performed in four posts.

The four post were organized according with the body dimensions and the measurement instrument. The first post included the standing heights; the second post included the diameters, deeps, and reaches; the third post included the sitting measurements; and the fourth post included the face, head, feet, and hands measurements. In every post, an anthropometrist performed the measurements, and a second anthropometrist wrote the measurements in a data sheet previously designed. Additionally, the second anthropometrist guided the participants inside the measurement room, gave the instructions about the proper clothing, and placed de participants in the correct positions. In order to avoid fatigue effects, a rotation schedule was designed every 30 minutes.

The distribution of the body dimensions were organized as follows (see Table 1 to identify the body dimensions):

Post 1: Body weight, body dimensions 2 - 8

Post 2: body dimensions 9 - 26

Post 3: body dimensions 27 - 34

Post 4: body dimensions 35 - 36

Participants were cited one week in advance and notified about the proper clothing needed in the study. If women brought hairpins, they were removed so they would not interfere with the measurement. All subjects were also asked to empty their pockets and other personal items such as watches, bracelets, etc.

The procedure was performed in approximately 15 minutes. The coordinator of the research team supervised the whole procedure, and with the help of a research assistant checked every data sheet at the end of the measurement of each subject. Finally, when the measurement process was finished, the anthropometer and other measurement devices were cleaned and cheeked to verify their accuracy.

2.5. Statistics

Because the population was known and finite (450 students of the Industrial Design program), the sample size was determined using the Equation (1).

$$n = \frac{N * Z^2 * p * q}{d^2 * (N - 1) + Z * p * q} \quad (1)$$

where:

n: simple size

N: population size

p: proportion waiting (in this case 5% = 0.05)

q: 1-p

Z: standard value

d = precision

Data were captured in Excel® software and later migrated for statistical analysis in SPSSv17 software. Prior to any statistical analysis, search and treatment of outliers considering the acceptable ranges for each dimension was performed. Arithmetic mean, standard deviation, minimum, and maximum were calculated. The differences between anthropometric data collected in this study and those from other populations were calculated using one side T-test. For the development of predictive models of body segments, the simple linear regression analysis was applied. A value of $\alpha = 0.05$ was used in all calculations.

3. Results

A convenience sample of 140 students was drawn from the population and chosen randomly. The participation was on a voluntary basis. We selected 70 men and 70 women with average age of 21.5 (±1.5) and 21.2 (±2.3), respectively. The study was completed in six months starting on July 2014 and ending on December 2014.

3.1. Anthropometric Data

The results obtained after performing anthropometric measurements (mean, standard deviation, minimum, maximum for male and female students are shown in Table 2 and Table 3, respectively.

Table 2. Anthropometric data of male students.

N˚	Body dimension	Male (N = 70)			
		Mean	S.D.	Min	Max
1	Body weight	80	19	51	163
2	Stature, standing	1726	72	1560	1859
3	Eye height, standing	1617	63	1472	1726
4	Shoulder height, standing	1426	66	1270	1552
5	Elbow height, standing	1099	64	975	1404
6	Hip height, standing	995	62	835	1223
7	Knuckle height, standing	759	42	654	876
8	Finger tips height, standing	662	39	555	757
9	Height, sitting	1308	50	1166	1446
10	Eye height, sitting	1211	45	1090	1328
11	Shoulder height, sitting	1008	41	898	1120
12	Thigh height, sitting	577	31	501	646
13	Knee height, sitting	522	33	445	600
14	Popliteal height, sitting	423	28	342	501
15	Thigh thickness, sitting	142	20	107	209
16	Buttock-knee length, sitting	602	34	507	678
17	Buttock-popliteal length, sitting	479	36	390	552
18	Head length, sitting	199	7	183	214
19	Shoulder-elbow length, sitting	349	26	295	392
20	Elbow-finger tips length, sitting	478	24	417	519
21	Thorax depth, sitting	212	26	148	302
22	Abdominal depth, sitting	245	50	171	505
23	Head breadth, sitting	159	6	145	172
24	Biacromial shoulder breadth, sitting	436	29	383	567
25	Bideltoid shoulder breadth, sitting	494	47	366	690
26	Hip breadth, sitting	384	39	316	531
27	Arm reach to wall, lateral, standing	872	57	739	977
28	Shoulder-fist length, standing	744	54	585	859
29	Maximum horizontal reach, standing	1375	119	899	1923
30	Maximum vertical reach, standing	1875	158	1417	2146
31	Maximum Arms Span, standing	1759	84	1525	1940
32	Elbow-to-elbow breadth, standing	902	47	794	1015
33	Hand length	187	9	168	208
34	Hand breadth	93	89	69	830
35	Foot length, standing	263	14	231	295
36	Foot breadth, standing	96	6	74	109

S.D.: standard deviation; Min: minimum; Max: maximum; P: percentile. All dimensions in mm; body weight in kg.

Table 3. Anthropometric data of female students.

N°	Body dimension	Female (N = 70)			
		Mean	S.D.	Min	Max
1	Body weight	59	13	39	110
2	Stature, standing	1599	60	1478	1746
3	Eye height, standing	1503	63	1380	1769
4	Shoulder height, standing	1314	54	1190	1447
5	Elbow height, standing	1015	45	931	1140
6	Hip height, standing	929	49	810	1044
7	Knuckle height, standing	712	34	654	812
8	Finger tips height, standing	622	36	560	709
9	Height, sitting	1251	44	1153	1392
10	Eye height, sitting	1158	59	1058	1445
11	Shoulder height, sitting	967	43	865	1075
12	Thigh height, sitting	563	45	491	713
13	Knee height, sitting	479	28	418	537
14	Popliteal height, sitting	424	28	354	486
15	Thigh thickness, sitting	131	20	100	202
16	Buttock-knee length, sitting	562	31	501	647
17	Buttock-popliteal length, sitting	466	29	408	537
18	Head length, sitting	190	7	176	210
19	Shoulder-elbow length, sitting	326	20	270	362
20	Elbow-finger tips length, sitting	424	24	376	498
21	Thorax depth, sitting	203	20	162	260
22	Abdominal depth, sitting	204	33	154	303
23	Head breadth, sitting	151	6	139	164
24	Biacromial shoulder breadth, sitting	368	22	330	477
25	Bideltoid shoulder breadth, sitting	417	37	305	495
26	Hip breadth, sitting	382	43	195	481
27	Arm reach to wall, lateral, standing	777	52	659	883
28	Shoulder-fist length, standing	666	40	575	747
29	Maximum horizontal reach, standing	1331	124	1160	1766
30	Maximum vertical reach, standing	1730	187	1228	2015
31	Maximum Arms Span, standing	1590	80	1342	1763
32	Elbow-to-elbow breadth, standing	809	58	528	930
33	Hand length	169	9	155	190
34	Hand breadth	74	3	65	84
35	Foot length, standing	235	12	212	258
36	Foot breadth, standing	87	6	77	105

S.D.: standard deviation; Min: minimum; Max: maximum; P: percentile. All dimensions in mm; body weight in kg.

3.2. Data Comparison with Other Samples from Mexico

Body weight and stature dimensions obtained in this study were compared to data gathered from Ciudad Juarez [9] and three regions of Mexico [6] (Guadalajara, León, and Mexico City). Information includes anthropometric data of students, workers, and drivers. Figure 1 shows the results of the body weight comparisons of male and female subjects.

Body weight of male students from Ciudad Juarez was significantly higher than the other five Mexican regions ($t = 3.070$, $p = 0.003$). Body weight of female students was significantly lower than workers of Guadalajara [6] ($t = -2.088$, $p = 0.042$), had no significant differences with female workers of Ciudad Juarez [9] ($t = -0.973$, $p = 0.335$), and Mx-USA border [6] ($t = 0.700$, $p = 0.487$), and was significantly higher than students of Guadalajara ($t = 2.930$, $p = 0.005$). The stature of male students from Ciudad Juarez had no significant differences with male workers of Ciudad Juarez [9] ($t = -0.277$, $p = 0.782$) and was significantly higher than the other four Mexican regions ($t = 2.802$, $p = 0.006$). The stature of female students had no significant differences with female workers of Ciudad Juarez [9] ($t = -0.806$, $p = 0.424$) and was significantly higher than the other four Mexican regions ($t = 3.447$, $p = 0.001$).

3.3. Predictive Models for the Dimensions of Body Segments

Considering the large amounts of work, time, and resources invested in the conduction

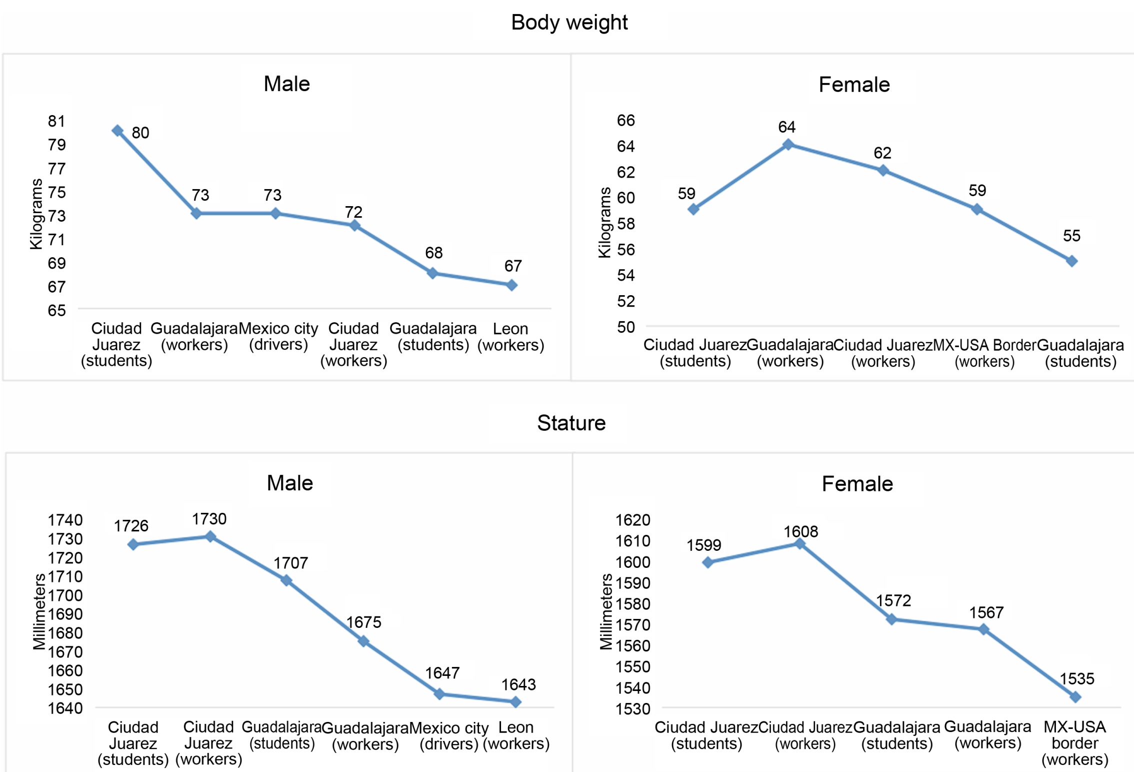

Figure 1. Body weight and Stature comparison between students of Ciudad Juarez and people of other Mexican regions.

of an anthropometric study, it is desirable to develop linear regression models with which to predict the dimensions of some body segments, based on the value of another salient anthropometric feature. Stature is the logic candidate for this role, mainly due to two factors: 1) it is by far the easiest dimension to be measured and 2) a large number of body dimensions show high levels of correlation with it.

Predictive models are useful when a design for a specific user is required, or when a rapid prototype to be used by individuals with similar anthropometric characteristics is needed. Foot-breadth and foot-length dimensions obtained a significant predictive model; however, they were not included in the list. Table 4 shows the 26 significant predictive models (including male and female results) generated through linear regression analysis.

In order to exemplify the use of the predictive models, an example related with the design of a chair for a single male user with a stature of 1700 mm (X). In this case, it was necessary to determine the Seat Height (SH) and the Seat Deep (SD) of the chair. Using the model 12 (see Table 4), the prediction of SH was 418.64 mm (see Equation (2)). Using the model 14 (see Table 4), the prediction of the SD was 471.73 mm (see Equation (3)).

$$\mathrm{SH} = 0.272(\mathrm{X}) - 10.851 = 0.272 * 1700\ \mathrm{mm} - 10.85 = 418.64\ \mathrm{mm} \quad (2)$$

$$\mathrm{SD} = 0.32(\mathrm{X}) - 72.268 = 0.32 * 1700\ \mathrm{mm} - 72.268 = 471.73\ \mathrm{mm} \quad (3)$$

4. Discussion

Data of thirty-six body dimensions of 140 students (70 men and 70 women) from the north of Mexico were collected and analyzed. Due to the average body weight of male students was at least 7 kg more than the body weight of the other male subjects included in this study, it was significantly higher than the body weight of the people of the five regions of Mexico considered in this study, even more than 13 kg than workers of the Leon city. Contrary to the body weight of male students, the body weight of female students had no significant differences with female workers of Ciudad Juarez and Mx-USA Border. The stature of male and female students and male and female workers of Ciudad Juarez had no significant differences. These results indicate that geographic origin, despite the same country, does have a significant effect on variation of anthropometric dimensions [18], mainly in body weight and stature.

An important issue that affects the stature and weight of every population is the age [19]; however, this variable was not considered in the comparisons developed in this study. In this context, students of Ciudad Juarez and Guadalajara had similar age. In contrast, the workers of Ciudad Juarez, Guadalajara, and Leon and drivers of Mexico City were older than the students of Ciudad Juarez.

Anthropometric data gathered in this study is useful in the design of products for the Industrial Design students. Using the mean and standard deviation, calculation of percentiles only needs an easy step. Although the participants' sample was limited, anthropometric data could be useful to design processes, products, furniture, tools, among

Table 4. Predictive models of body segments.

Body dimension	Gender	R-value	Predictive model
Y_1. Eye height, standing	M	0.987	$Y = 0.867(X) + 121.28$
	F	0.885	$Y = 0.937(X) + 5.095$
Y_2. Shoulder height, standing	M	0.950	$Y = 0.870(X) - 75.450$
	F	0.983	$Y = 0.852(X) - 48.861$
Y_3. Elbow height, standing	M	0.618	$Y = 0.553(X) + 145.45$
	F	0.887	$Y = 0.661(X) - 42.431$
Y_4. Hip height, standing	M	0.787	$Y = 0.683(X) - 184.23$
	F	0.886	$Y = 0.719(X) - 220.49$
Y_5. Knuckles height, standing	M	0.824	$Y = 0.483(X) - 74.490$
	F	0.743	$Y = 0.424(X) + 34.197$
Y_6. Fingertips height, standing	M	0.800	$Y = 0.439(X) - 95.132$
	F	0.663	$Y = 0.388(X) - 15.284$
Y_7. Height, sitting	M	0.832	$Y = 0.583(X) + 302.98$
	F	0.769	$Y = 0.564(X) + 384.921$
Y_8. Eye height, sitting	M	0.764	$Y = 0.484(X) + 374.82$
	F	0.535	$Y = 0.523(X) + 320.962$
Y_9. Shoulder height, sitting	M	0.694	$Y = 0.400(X) + 317.25$
	F	0.714	$Y = 0.507(X) + 156.25$
Y_{10}. Thighs height, sitting	M	0.664	$Y = 0.371(X) - 117.49$
	F	0.535	$Y = 0.406(X) - 86.56$
Y_{11}. Knee height, sitting	M	0.797	$Y = 0.183(X) - 117.497$
	F	0.723	$Y = 0.332(X) - 52.076$
Y_{12}. Popliteal height, sitting	M	0.462	$Y = 0.183(X) + 107.54$
	F	0.579	$Y = 0.272(X) - 10.851$
Y_{13}. Buttock-knee length, sitting	M	0.776	$Y = 0.374(X) - 43.011$
	F	0.798	$Y = 0.409(X) - 92.82$
Y_{14}. Buttock-popliteal cavity length, sitting	M	0.639	$Y = 0.320(X) - 72.268$
	F	0.582	$Y = 0.277(X) + 22.88$
Y_{15}. Shoulder to elbow length, sitting	M	0.499	$Y = 0.182(X) + 35.841$
	F	0.779	$Y = 0.260(X) - 89.97$
Y_{16}. Elbow to fingertip length	M	0.832	$Y = 0.280(X) - 4.750$
	F	0.842	$Y = 0.338(X) - 117.29$
Y_{17}. Thigh Thickness, sitting	M	0.341	$Y = 0.94(X) - 20.526$
	F	0.328	$Y = 111(X) - 46.619$
Y_{18}. Briacromial shoulder breadth, sitting	M	0.457	$Y = 186(X) + 115.026$
	F	0.492	$Y = 178(X) + 83.68$
Y_{19}. Bideltoid shoulder breadth, sitting	M	0.279	$Y = 184(X) + 176.71$
	F		NS
Y_{20}. Arm Reach to wall lateral, sitting	M	0.678	$Y = 538(X) - 56.43$
	F	0.568	$Y = 0.494(X) - 11.937$
Y_{21}. Shoulder fist length, standing	M	0.614	$Y = 0.461(X) - 51.38$
	F	0.611	$Y = 0.412(X) + 7.504$
Y_{22}. Maximum horizontal reach, standing	M	0.404	$Y = 0.673(X) + 213.58$
	F	0.400	$Y = 0.828(X) + 7.336$
Y_{23}. Maximum vertical reach standing	M	0.449	$Y = 1.103(X) - 28.15$
	F	0.370	$Y = 1.151(X) - 111.47$
Y_{24}. Maximum arms span, standing	M	0.840	$Y = 0.988(X) + 53.94$
	F	0.766	$Y = 1.028(X) - 54.78$
Y_{25}. Elbow to elbow breadth, standing	M	0.774	$Y = 0.512(X) + 17.40$
	F	0.655	$Y = 0.629(X) - 197.30$
Y_{26}. Hand length	M	0.681	$Y = 0.087(X) + 36.253$
	F	0.758	$Y = 0.111(X) - 9.086$

others for the working population of the Ciudad Juarez and nearby cities. Additionally, data could be useful for research purposes.

The linear regression analysis showed that dimensions of 26 body segments positively correlated with the stature. Nonetheless, although all the predictive models were statistically significant, only three dimensions (eye height standing, shoulder height standing, and elbow to fingertip length sitting) yielded regression coefficients higher than 0.8, which means that the level of correlation is very good [20] and the prediction based on those three linear regression models will be reasonably reliable. However, for popliteal height sitting, thickness sitting, biacromial shoulder breadth sitting, bideltoid shoulder breadth sitting, maximum horizontal reach standing, and maximum vertical reach standing yielded correlation coefficients between 0.2 and 0.5 considered as low/bad [20]. Thus, the length estimation of these body segments will produce a gross error, being highly unreliable.

5. Conclusions

The data presented in this article comes from a small sample of university students in northern Mexico and does not represent the country's entire population. The average values of the dimensions stature and weight (of students of Ciudad Juarez) for our subjects were higher than those measured on people from other three regions in Mexico.

Using linear regression procedures, 26 predictive models of body segments based on the stature were generated and could be used to develop rapid prototypes and product design for specific users. However, these models are reasonably reliable only for the dimensions eye height standing, shoulder height standing, and elbow to finger-tip length sitting.

With this study, we now hold anthropometric data of 36 body dimensions that could be used in the design of models, prototypes, and products by Industrial Design students. The most important limitations of this study were the low number of participants and their origins (university students). Therefore, these two factors should be considered when using the data to design objects/products for different populations.

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