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The Development of Sizing System for Clothes of Benghazian Adults Based on Anthropometric Data

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***Abstract*— The development of clothing sizing system is the best way to provide the best suitable size in clothing design. A sizing system classifies a specific population into homogeneous subgroups based on some key body dimensions. The current project objective is to develop a clothing sizing system for Libyan adults based on anthropometric body measurements of Libyan adults between 18 and 25 years old. The aim of the current project is to examine anthropometric measurements for people, to collect body measurements of adults in Benghazi and analyze those using simple statistical methods to understand the body ranges and variations present for each gender and age group to develop sizing system of them. nineteen body dimensions were measured for each person to develop clothing sizing system. The measurements were gathered from a total of 60 adults (30 males and 30 females between 18 and 25 years old) from Benghazi. The anthropometric data were analyzed using Minitab program. ANOVA tests were used to identify differences between age groups, and t-test were used to identify differences between genders. The results of ANOVA showed that there are no differences between all the body measurements, and the results of t-test showed that there are differences between most of the body measurements. These differences were considered when developing sizing system. Pearson correlation coefficients analysis was carried out to determine the interrelationships between the various body measurements. From these findings it may be concluded that the weight is very strongly correlated with some other dimensions. The mean values and the standard deviation were used for creating size steps for the size chart. Three kinds of sizes were identified: L (large), M (medium) and S (small)..**

***Index Terms*— Anthropometric data; sizing system; children clothing; Apparel sizing; Libyan Adult**

1. INTRODUCTION

A table of numbers representing the values of important measurements used to divide the target population's various bodies into homogeneous groupings is known as a size system (Gupta, and Zakaria , 2014). People belonging to the same subgroup have identical body characteristics and clothing sizes.

One of the major problems associated with unfitting garments is the absence of updated anthropometric data. Until recently, traditional manual anthropometry was used for anthropometric studies and human body measurements (Bilhassan et al, 2018; Bilhassan et al, 2018; Bilhassan, 2019; Bilhassan et al, 2022). A number of factors, including age and gender, have an impact on the size schedule. A number of studies have discovered that age and gender differ significantly in almost all body measuremntes (Ariadurai et al., 2009; Bari et al., 2015; Beazley, 1999; Chung et al., 2007; Gupta and Gangadhar, 2004; Gupta and Zakaria, 2014; Kang et al., 2001; Lee, 2013; Muslim et al., 2014; Zakaria, 2011, Bilhassan et al, 2018 (a); Bilhassan, 2018 (b); Bilhassan et al, 2019; Bilhassan et al, 2022).

There aren't any size charts available in Libya right now for all ages groups. The development of the size charts for adults Libyan is a result of this work. developing a size chart based on Libyan adult anthropometric body measurements is the main goal. The results of the adult people are covered in this article.;

2. METHODOLOGY

The purpose of this project is to collect data based on anthropometric measurements for university students in Benghazi, Libya. Body measurements were taken. These anthropometric data will be used to obtain anthropometric measurement for developing clothing sizing system.

2.1 Participants

Sample size includes a total of 100 Libyan university students (50 males and 50 females). The students aged between 18 to 25 years. The sample was randomly selected from the departments of the Faculty of Engineering in the city of Benghazi during spring 2022. All students voluntarily participated in the study.

2.2 The Body Measurements

Based on the objective of this project, only nineteen anthropometric dimensions are selected and used to establish the clothing sizing systems for students. These dimensions are selected based on previous (Alarody, 2016; Elmabrouk, 2016; Albarki, 2017; Boushagour, 2018; Elurfi et al, 2018; Elaneizi, 2022; Bilhassan et al, 2018; Bilhassan et al, 2018; Bilhassan, 2019; Bilhassan et al, 2022). Tables 1 shows the body dimensions. These measurements are used to make different types of clothing. The measurements were taken from the left or right sides of the body for participants are left-handed or right-handed respectively. However, most of the measurements were taken from the right side of the body. While their anthropometric measurements were taken, respondents wore light cloths to get accurate readings. Respondents were also told not to wear shoes

when their height and weight measurements were taken During anthropometric data measurements equipment were used measuring is anthropometric kit (Rosscraft Centurion Kit). Readings were also taken two times and the average of the readings was recorded as the actual anthropometric measurements of the respondents.

2.3 Anthropometric Data Analysis

After conducting the anthropometric survey, the anthropometric data obtained from this study served as the basis of information for the analysis. Statistical Package (Minitab) Version 17.1 was employed for data inputting and analysis. Descriptive statistics including mean, min., max., and standard deviation, were used to describe and summarize the data collected. The normality test was used to determine if a data collected followed a normal distribution. As expected, data for all measurements followed a normal distribution.

Subsequently, t-test, ANOVA test and Pearson correlation coefficients analysis were conducted to develop the sizing system. The objective of using each test is as follows. The aim of ANOVA analysis is to identify differences between age groups. T-tests were carried out to identify differences between genders. Moreover, Pearson correlation coefficients analysis was carried out to determine the interrelationships between the various body measurements. Size chart is to be developed based on the results of the analysis. Standard deviation and operations of addition or subtraction are used to determine the S (small) size and L (large) size (Adu-Boakye et al., 2012).

Table 1. The Anthropometric Dimension

No.	Measurement	Unit
1	Weight	Kg
2	Height	Cm
3	Cervical height	Cm
4	Highest shoulder to chest	Cm
5	Head circumference	Cm
6	Mid-neck girth	Cm
7	Chest girth	Cm
8	Waist Height	Cm
9	Centre back waist	Cm
10	Arm hole depth	Cm
11	Across back shoulder	Cm
12	Across back width	Cm
13	Back waist	Cm
14	Waist girth	Cm
15	Crotch height	Cm
16	Hip girth	Cm
17	Thigh girth	Cm
18	Knee girth	Cm
19	Ankle girth	Cm

3. RESULTS AND DISCUSSION

3.1 Descriptive Analysis

The mean and standard deviation for all measurements are shown in Table 2,3.

3.2 Differences of Anthropometric Measurements by Age(ANOVA)

The results of ANOVA test show that almost all of the anthropometric measurements have no significant differences (P-value < 0.05) between the ages of respondents. These differences would not be considered to design clothing sizing systems for different age groups (as shown in Table 4). Therefore, these results mean that age is not one element that influences the development of the human body for theses ages group [Elaneizi et al, 2022].

Table 2. The Mean and Standard Deviation (female) By Age

Body dimensions	18-20	20-22	22-25
Weight	64.1	53	61.4
Height	158.1	157.5	161.5
Cervical height	140.25	136.77	142.43
Highest shoulder to chest	21.23	18.97	20.06
Head circumference	52.65	53.02	54.29
Mid-neck girth	33.06	29.8	31.43
Chest girth	92.06	81.78	85.55
Waist Height	80.66	70.29	81.42
Centre back waist	49.33	49.07	52.07
Arm hole depth	38.74	36.11	36.5
Across back shoulder	38.6	35.83	36.33
Across back width	27.44	24.48	26.06
Back waist	27.41	28.15	29.01
Waist girth	95.64	95.2	95.2
Crotch height	71.12	71.21	69.61
Hip girth	100.89	92.19	101.32
Thigh girth	51.84	48.56	50.1
Knee girth	36.41	32.81	34.9
Ankle girth	22.49	20.4	21.57

Table 3. The Mean and Standard Deviation (male) By Age

Body dimensions	18-20	20-22	22-25
Weight	78.7	70.1	79.5
Height	174.6	173.15	178.95
Cervical height	78.7	152.85	156.5
Highest shoulder to chest	15.9	15.12	15.77
Head circumference	56.32	55.71	56.35
Mid-neck girth	37.25	35.98	36.61
Chest girth	90.1	88.27	90.02
Waist Height	88.68	80.83	83.84
Centre back waist	60.8	60.72	63.6
Arm hole depth	36.68	36.84	37.91
Across back shoulder	42.17	43.35	43.96
Across back width	30.38	29.54	30.56
Back waist	30.82	28.12	28.75
Waist girth	94.71	96.55	98.17
Crotch height	74.87	76.42	79.35
Hip girth	101.87	99.57	104.7
Thigh girth	47.3	46.67	47.7
Knee girth	38.76	37.16	37.99
Ankle girth	25.13	24.87	24.43

Table 4. Differences of Anthropometric Measurements Between Age Groups (ANOVA).

No.	Measurement	P-Value	Sig.
1	Weight	0.141	Not sig.
2	Height	0.323	Not sig.
3	Cervical height	0.183	Not sig.
4	Highest shoulder to chest	0.612	Not sig.
5	Head circumference	0.669	Not sig.
6	Mid-neck girth	0.161	Not sig.
7	Chest girth	0.157	Not sig.
8	Waist Height	0.694	Not sig.
9	Centre back waist	0.472	Not sig.
10	Arm hole depth	0.704	Not sig.
11	Across back shoulder	0.863	Not sig.
12	Across back width	0.225	Not sig.
13	Back waist	0.822	Not sig.

14	Waist girth	0.131	Not sig.
15	Crotch height	0.826	Not sig.
16	Hip girth	0.130	Not sig.
17	Thigh girth	0.641	Not sig.
18	Knee girth	0.238	Not sig.
19	Ankle girth	0.551	Not sig.

3.3 Differences of Anthropometric Measurements by Gender (t-test)

T-test show that most of the anthropometric measurements have significant differences between the gender of respondents. These differences would be considered to design clothing sizing systems for different genders. There are no differences in the Chest girth, Arm hole depth, Back waist, Hip girth, Thigh girth, Knee girth between genders as shown in Table 5. These differences would not be considered in design the clothing sizing systems that are appropriate for adults of different genders.

Table 5. Differences Of Anthropometric Measurements Between Gender (T-Test).

No.	Measurement	P-Value	Sig.
1	Weight	0.001	Sig
2	Height	0.000	Sig
3	Cervical height	0.000	Sig
4	Highest shoulder to chest	0.000	Sig
5	Head circumference	0.003	Sig
6	Mid-neck girth	0.000	Sig
7	Chest girth	0.162	Not Sig.
8	Waist Height	0.003	Sig
9	Centre back waist	0.000	Sig
10	Arm hole depth	0.984	Not Sig.
11	Across back shoulder	0.000	Sig
12	Across back width	0.000	Sig
13	Back waist	0.434	Not Sig.
14	Waist girth	0.003	Sig
15	Crotch height	0.002	Sig
16	Hip girth	0.482	Not Sig.
17	Thigh girth	0.122	Not Sig.
18	Knee girth	0.122	Not Sig.
19	Ankle girth	0.000	Sig

3.4 Correlation Analysis

A key measurement should also be a body measurement with strong relationships with most other body dimensions. Consequently, based on this selection, it was possible to develop sizing system. They can be good predictors of the size of other parts of the body. The criteria for key measurements vary and there are various methods to be established in this regard. By using correlation coefficients, it could be possible to identify key measurements. Correlation coefficient values indicate the strength of linear relationships between variables and were, as such, implemented in this study. Pearson correlation coefficients analysis was carried out to determine the interrelationships between the various body measurements. The Pearson correlation coefficient (r) is a measure of the strength of the linear relationship between two random variables. Correlation coefficients range from -1.00 to +1.00. The value of –1.00 represents a perfect negative correlation (indicating a perfect negative linear relationship between variables) and a value of +1.00 represents a perfect positive correlation (indicating a perfect positive linear relationship between variables). A value of 0.00 reflects no correlation (no linear relationship) between the respective variables. The following arbitrary scale for correlations was implemented to indicate the strength of the relationship between measurements: • If correlation coefficient is ,0.5 or less then no relationship • If correlation coefficient is between 0.5 and 0.75 then there is a mild relationship • If correlation coefficient is 0.76 or more it indicates a strong relationship Tables 5 and 6 illustrate the relationships between measurements and shows the correlation coefficients between each measurement for male and the others for female. It is noted that there are no differences between males and females in the key measurement

Table 6. Strong Relationship Between Measurements For Male

Dimensions	Strong relationship
Weight	Knee girth, Chest girth, Waist girth, Arm hole depth, Across back width, Back waist, Hip girth
Height	Cervical height
Mid-neck girth	chest girth, Waist girth, Across back width, Hip girth
Chest girth	Knee girth, Waist girth, Arm hole depth, Across back width, Back waist, Hip girth, Thigh girth
Waist grith	Knee girth, Arm hole depth, Across back width, Back waist, Hip girth, Thigh girth
Arm hole depth	Knee girth, Across back width, Hip girth, Across back shoulder
Across back shoulder	Across back width
Across back width	Knee girth, Back waist, Hip girth, Thigh girth
Back waist	Knee girth, Hip girth, Thigh girth
Waist Height	Crotch height
Hip girth	Knee girth, Thigh girth
Thigh girth	Knee girth

Table 7. Strong relationship between measurements for female

Dimensions	Strong relationship
Weight	Chest grith, Hip girth, Across back width
Waist grith	Hip grith
Arm hole depth	Across back width
Hip girth	Knee girth, Thigh girth

Table 6 shows that the weight measurement appears to have strong relationships with the knee grith, chest grith, waist grith, hip grith, across back width, and back waist. The chest girth measurements appear to have strong relationships with the girths of thigh, hip, knee, waist, arm hole depth and arm back width. The waist girth has strong relationships with the girths of thigh, hip, knee, arm hole depth, and back waist. While, the height has a strong relationship with cervical height (for male).

For females, the results show that the weight measurement appears to have strong relationships with the girths of thigh, hip, and across back width. The hip girth has strong relationships with knee girth and thigh grith (as shown in Table 7).

From the above findings it may be concluded that weight may be critical measurement for male and female. The results are in concordance with the earlier studies of Majumder and Sharma, 2015; Bilhassan et al, 2018a; Bilhassan et al, 2018; Bilhassan, 2019; Saaludin et al, 2020; Tiwari, M., Anand, N., 2020; Tiwari and Anand, 2021; Bilhassan et al, 2022).

3.5 Development of Size Charts

The development of the size chart was carried out using values obtained from the statistical information based on the (t-test) of body dimensions. The mean values and the *standard deviations were used for creating size steps for the size chart. Therefore, different sizes of clothing for male and female must be developed due to the differences in some measurements between genders. Three sizes were developed: S(small), M(medium) and

L(large). These sizes were developed because of there were multiple body shape in each gender group.

There is a difference between genders in the chest girth, arm hole depth, back waist, hip girth, thigh girth, knee girth based on (t-test) analysis. One of the values can be calculated if there is no difference between genders each dimension. However, two values can be calculated if there is difference between genders for that dimensions according to t-test. Table 8 shows the clothing size charts for all body dimensions.

Table 8. Clothing Size Chart Of Respondents (CM)

MEASUREMET	S		M		L	
	M	F	M	F	M	F
Weight	41.86	34.11	76.1	59.5	110.34	84.89
Height	163.72	143.90	175.57	159.03	187.42	174.16
Cervical height	141.54	124.04	153	140	164.47	155.96
Highest shoulder to chest	12.49	8.638	16	20	19.51	31.36
Head circumference	52.57	44.32	56	53	59.43	61.68
Mid-neck girth	32.27	25.16	37	31	41.73	36.84
Chest girth	64		87		110	
Waist girth	52.50	50.93	84	77	115.50	103.08
Centre back waist	48.14	40.01	62	50	75.86	59.99
Arm hole depth	28		37		46	
Across back shoulder	36.94	29.40	43	37	49.06	44.61
Across back width	24.31	20.38	30	26	35.69	31.63
Back waist	19		29		39	
Waist length	85		96		107	
Crotch height	65.51	55.82	77	71	88.49	86.18
Hip girth	77		99		122	
Thigh girth	27		36		46	
Knee girth	36		49		62	
Ankle girth	17.731	16.739	25	21	32.269	25.261

4. CONCLUSION

The study was carried out to develop size chart using anthropometric measurements of university students aged 18 to 25 years in Benghazi, Libya. Several anthropometric measurement data obtained were used to develop clothing size. Weight, waist grith and chest grith measurements are key measurements for male that determine which size the respondents belong to. Moreover, Weight is key measurements for female that determine which size the respondents belong to. Because of the differences in some anthropometric measurements used to make clothing sizes, this study has been able to prove that there are significant differences between genders for some measurements. Therefore, clothing manufacturers have to take into account gender when make the cloths. Thus, the development of sizes should be according to their procedure in order to produce an accurate size that fits the consumer's body, especially children. The next phase in the ongoing study is to finish gathering anthropometric data and evaluation for the remaining age groups. After that database for sizing system in the Libya are going to be established.

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