Development of a Clothing Sizing System for Benghazian Children Based on Anthropometric Measurements

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Abstract— the current study is the second step towards the overall objective of development of a clothing sizing system for Libyan children based on anthropometric body measurements of Libyan school children. The aim of this paper is to examine anthropometric measurements for students in grades four, five and six in the basic education stage, to collect body measurements of school children in Benghazi and analyze them using simple statistical methods that would help determining the body ranges and variations present for students in the three grades and use them, in turn, to develop sizing system of these grades. The anthropometric data were analyzed using Minitab program. ANOVA and kruskal-Wallis tests were used to identify differences between age groups. The results showed that there are differences between the most body measurements except the arm length and waist to hip length. These differences were taken into account when developing the sizing system. Pearson correlation coefficients analysis was carried out to determine the interrelationships between the various body measurements. From these findings it can be concluded that the weight is very strongly correlated with some dimensions. Height and weight measurements were used as a guide to determine the size of clothes. 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; school children; children anthropometry**.

I. INTRODUCTION

Clothing sizing system is essential for effective clothing design and production [7]. The goal of the sizing system is to satisfy consumers' needs for apparel that fits [10]. Size labels in apparel provide guidance for consumers to locate garments that fit their body.

However, each apparel manufacturer has its own sizing systems based on its target market. Consumers' body builds and sizes are different depend on gender, age, and body type. Garment sizing systems vary from country to country because the physical body of consumers varies. Each government has developed their unique sizing standard for their own people. Apparel manufacturers and retailers, who have their national consumer group as a target, have difficulties targeting consumers in other countries. With these difficulties, apparel manufacturers and retailers have desired to have an international sizing system. A solution that overcomes those challenges is one using garment size labeling, expressed in terms of body measurements. Many standard garment sizing systems are used in the world such as US, British, European, Japanese, Korean and Chinese sizing systems, and so on. These systems identify the sizes and body types in the majority of their targeted population.

Populations were divided into several groups that had similar body measurements. Allowing all individuals in a specific size group to use a garment with dimensions specific to that size group in this way was the objective of body sizing for the clothing industry. Apparel sizes for children are designated by height or age.

Clothing standardization has become necessary and an important issue of ready-to-wear clothing leading to the development of many different sets of body dimensions having the same size designation.

The childhood is important stage of growth the human body, so clothing plays an important role in childhood. Careful selection of clothes for a young child can satisfy some of his/her important needs, help to get more attention from peer group and identification of sex. Proper fit is particularly important in childhood because it is the period of greatest potential growth and body development. Children require the most flexible and comfortable attire possible. When a garment is properly styled and sized, it is reflecting the children's growth and also does not disturb body movements [2, 5]. Children who wear clothing that fits their body will contribute to their growth and the development of a healthy body [2].

This study is motivated by the need to examine anthropometric measurements among school children in Libya; to develop garment sizing systems for Libyan school students. The aim of the current study is to examine anthropometric measurements for students in grades four, five and six in the basic education stage, to collect body measurements of school children and analyze those using simple statistical methods to understand the body ranges and variations present for students to develop size chart of these grades.

II.   RESEARCH METHODOLOGY

This section explains the material and method used in this research.

A.   Participants

Sample size includes a total of 180 Libyan primary school students (90 males and 90 females), with thirty students from each grade. The students aged between 9 to 11 years. The sample was randomly selected from one public school and one private school in the city of Benghazi during the school year (2015/2016). Measurements were taken after getting permission from the officials and principals in each school and all students voluntarily participated in the study.

B.   The Body Measurements

Based on the objective of the research and previous studies [3, 6], only 26 anthropometric dimensions are commonly used in clothing design were selected to establish the sizing systems. These measurements are used to make different types of clothing such as school uniforms. The measurements were taken on the right side of the body which is actually bigger than the left side. While their anthropometric measurements were taken, respondents wore light cloths to get accurate readings. Also, Respondents were also told not to wear shoes when their height and weight measurements were taken. Those 26 body dimensions are listed in Table 1 as follows:

Table 1. Body Measurements

No.	Body Dimensions	No.	Body Dimensions
1	Weight	14	Shoulder to waist length
2	Height	15	Front body length
3	Head circumference	16	Back body length
4	Neck circumference	17	Waist to hips length
5	Waist circumference	18	Shoulder length
6	Chest circumference	19	Front body width
7	Hip circumference	20	Back body width
8	Arm circumference	21	Knee circumference
9	Elbow circumference	22	Calf circumference
10	Wrist circumference	23	Waist to Ankle length
11	Thigh circumference	24	Trousers length
12	Shoulder to shoulder length	25	Inside leg length
13	Shoulder to wrist length	26	Outside leg length

During anthropometric data measurements, two kinds of equipment were used (flexible and rigid tapes). Readings were also taken three times and the average of the readings was recorded as the actual anthropometric measurements of the respondents.

C.   Anthropometric Data Analysis

The data obtained from this study was analyzed using Minitab 16 Statistical Package Program for Windows. Descriptive statistics, such as mean, min., max. and standard deviation, were used to describe and summarize the data collected. To develop children's clothing sizes, the mean values were used. T-tests were carried out to identify differences between genders. ANOVA analysis and Kruskal-Wallis test were carried out to identify differences between age groups. ANOVA was carried out for all dimensions except arm length and waist to hip length. While Kruskal-Wallis test was conducted to find the difference for arm length and waist to hip length dimensions because these dimensions do not follow normal distribution. 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 is used to determine the S (small) size and L (large) size [1].

III.   RESULT AND DISCUSSION

A.   Descriptive Analysis

Values obtained from the anthropometric survey show that the data are normally distributed. This study found that the mean height for male is (137.40, 143.33 and 147.15) cm for grade 4, 5 and 6 respectively, while mean height for female respondents is (139.7, 143.00 and 152.60) cm for grade 4, 5 and 6 respectively. The standard deviation (SD) for almost all dimensions is quite large, showing great variation in the measurements.

B.   Differences of Anthropometric Measurements by gender

Table 2 shows significant differences in the anthropometric measurements between genders using t test. This study found that thirteen of the measurements for gender are different. Therefore, these differences mean that gender is element that influences the development of the human body, and will eventually affect the sizes of clothing [3]. In conclusion, this difference would have to be considered to produce clothing that is appropriate for children of different gender.

Table 2. Differences of Anthropometric Measurements by Gender

Measure	t	P
Neck circumference	3.86	0.000
Hip circumference	-3.64	0.000
Waist circumference	-6.84	0.000
Wrist circumference	3.99	0.000
Shoulder to shoulder length	-4.97	0.000
Shoulder to waist length	-3.50	0.001
Front body length	3.93	0.000
Waist to hip length	6.52	0.000
Front body width	2.22	0.028
Thigh circumference	-2.32	0.021
Ankle circumference	3.31	0.001
Inside leg length	4.39	0.000
Outside leg length	4.47	0.000

C. Differences of Anthropometric Measurements by Age

Table 3 shows significant differences in the anthropometric measurements between the age groups using one way ANOVA test. This study found that most of the measurements for the ages of 9, 10 and 11 (grade 4, 5 and 6) are different. Therefore, these differences mean that age is one element that influences the development of the human body, and will eventually affect the sizes of clothing [3]. Table 4 showed that there are no differences in the anthropometric measurements: Arm length and Waist to hip length using Kruskal-Wallis test. In conclusion, this difference would have to be considered to produce clothing that is appropriate for children of different ages.

Table 3. Differences of Anthropometric Measurements by Age

Measure	F	P
Weight	24.02	0.000
Height	33.20	0.000
Head circumference	3.73	0.026
Neck circumference	8.00	0.000
Chest circumference	17.44	0.000
Hip circumference	7.71	0.001
Waist circumference	6.49	0.002
Elbow circumference	11.58	0.000
Wrist circumference	3.88	0.022
Back body width	8.94	0.000
Shoulder to shoulder length	16.77	0.000
Shoulder to wrist length	12.43	0.000
Shoulder to waist length	14.82	0.002
Front body length	9.85	0.000
Back body length	6.49	0.002
Shoulder length	13.10	0.000
Front body width	4.16	0.017
Thigh circumference	10.16	0.000
Knee circumference	18.05	0.000
Calf circumference	22.68	0.000
Ankle circumference	13.10	0.000
Trousers length	17.18	0.000
Inside leg length	10.67	0.000
Outside leg length	17.38	0.000

Table 4. Differences of Anthropometric Measurements by Age (Kruskal-Wallis)

Measure	F	P
Arm length	2.68	0.071
Waist to hip length	2.07	0.129

D. Correlation Analysis

Pearson correlation coefficients analysis was carried out to determine the interrelationships between the various body measurements.

Correlation coefficients for strong relationship were showed in Table 5. A correlation coefficients of 0.76 or more indicates a strong relationship. It is noted that the height measurement appears to have good correlation with shoulder to shoulder length, trousers length and inside leg length. Weight has strong correlation with chest circumference, hip circumference, elbow circumference, thigh circumference, knee circumference and calf circumference. Moreover, chest circumference has strong correlation with hip circumference, waist circumference, elbow circumference, thigh circumference, knee circumference and calf circumference. Additionally, elbow circumference has strong correlation with knee circumference and calf circumference. Finally, tight circumference has strong correlation with calf circumference. Finally, thigh circumference has strong correlation with calf circumference.

From these findings it may be concluded that weight measurement is the most critical measurement. Chest circumference is common to body garments. In general, it can be inferred that theses dimensions are the important landmarks on the body and hence should be related closely to the garment measurements.

Table 5. Correlation Coefficients

measurements	6	7	8	10	21	22	23
2	0.87	0.77	0.72	0.78	0.767	0.80	0.85
6	1	0.87	0.76	0.81	0.78	0.82	0.83
7		1	0.83	0.73	0.71	0.75	0.72
10				1	0.69	0.80	0.80
21					1	0.72	0.80
22						1	0.86

E. Development of Size Chart

The development of the size chart was carried out by using values obtained from the statistical information based on the t-test and ANOVA test of body dimensions. Therefore, clothing must be developed with different sizes for age and gender because of the differences in some measurements between gender and age. Therefore, different sizes of clothing for boys and girls aged 9, 10 and 11 years must be developed due to the differences in some measurements between age groups. Three sizes were developed: S (small), M (medium) and L (large). These sizes were developed because there were multiple body shapes in each group of 9, 10 and 11 years old.

There is a difference between ages in height measurement and most of the measurements based on ANOVA analysis. One of the values can be taken if there is no difference between each parameter. However, three values can be taken if there is difference between each parameter according to t-test and ANOVA analysis respectively.

The population was classified on basis of the height. It was divided into three height categories. According to research [6], the population was divided into three height categories, namely:

$$\text{Short} = (\text{Mean} - 2SD) \qquad (1)$$
$$\text{Medium} = (\text{Mean}) \qquad (2)$$
$$\text{Tall} = (\text{Mean} + 2 SD) \qquad (3)$$

Besides height measurement, weight measurements can also be used as a guide in choosing clothing sizes. The size codes were determined after generating the three size steps values from the body dimensions. The size codes were based on the S, M and L coding methods. Table VI shows the size codes together with the body dimensions. They were calculated into three categories depend on the height and weight.

IV. CONCLUSION

The study was carried out to develop size chart using anthropometric measurements of school children aged 9, 10 and 11 years in Benghazi, Libya. Several anthropometric measurement data obtained were used to develop clothing size. Weight and chest circumference measurements are key measurements 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 children from different groups of age for almost all anthropometric measurements and also between genders for some measurements.

Table 6. Clothing Size Chart of Respondents (CM)

Measurement		S	M	L
	9 Years	21.15	34.35	47.55
1	10 years	19.08	39.20	59.32
	11 years	19.57	43.85	68.13
	9 Years	123.75	140.00	156.25
2	10 years	130.54	142.50	154.43
	11 years	132.71	150.00	167.29
	9 Years	48.47	53.00	57.53
3	10 years	50.44	54.00	57.56
	11 years	50.58	54.00	57.42
	9 years			
	Female	23.06	29.8	36.54
	Male	24.5	28.2	31.9
	10 years			
4	Female	24.1	31.1	38.1
	Male	24.63	30.23	35.83
	11 years			
	Female	28.68	35.2	41.72
	Male	25.72	30.9	36.08
	9 Years	53.65	66.50	79.35
5	10 years	52.41	69.00	85.59
	11 years	53.60	74.50	95.40
	9 years			
	Female	50.66	61	71.34
	Male	46.32	64	81.68
	10 years			
6	Female	48.28	69.8	91.32
	Male	53.27	75.43	97.59
	11 years			
	Female	47.36	65.3	83.24
	Male	47.71	74.03	100.35
	9 years			
	Female	51.4	64.8	78.2
	Male	56.9	73.3	89.7
	10 years			
7	Female	53.22	68.4	83.58
	Male	53.83	71.43	89.03
	11 years			
	Female	48.86	67.8	86.74
	Male	63.05	85.17	107.29
	9 Years	6.27	21.00	35.73
8	10 years	15.23	22.25	29.27
	11 years	16.45	24.00	31.55
	9 Years	15.93	20.00	24.07
9	10 years	16.58	21.75	26.92
	11 years	15.92	22.00	28.08
	9 years			
	Female	13.04	15.9	18.76
	Male	10.87	14.23	17.59
	10 years			
10	Female	13.22	15.8	18.38
	Male	10.94	15.48	20.02
	11 years			
	Female	12.5	16.7	20.9
	Male	11.71	15.33	18.95
	9 Years	22.29	29.00	35.71
11	10 years	22.26	31.50	40.74
	11 years	24.84	31.00	37.16
	9 years			
	Female	31.02	34.9	38.78
	Male	31.89	37.67	43.45
	10 years			
12	Female	32.44	37	41.56
	Male	30.71	38.97	47.23
	11 years			
	Female	32.14	38.4	44.66
	Male	32.79	41.57	50.35
	9 Years	38.82	46.00	53.18
13	10 years	37.32	48.50	59.68
	11 years	40.55	49.50	58.45

Table 7. CONT.

Measurement		S	M	L
	9 years			
	Female	25.84	34.2	42.56
	Male	33.89	39.83	45.77
	10 years			
14	Female	29.36	38.5	47.64
	Male	23.31	41.77	60.23
	11 years			
	Female	32.78	42.5	52.22
	Male	33.75	42.93	52.11
	9 years			
	Female	30.28	39.1	47.92
	Male	32.07	37.13	42.19
	10 years			
15	Female	37.14	42.8	48.46
	Male	33.11	39.85	46.59
	11 years			
	Female	34.58	40.7	46.82
	Male	27.19	38.57	49.95
	9 Years	32.67	39.00	45.33
16	10 years	34.43	42.00	49.57
	11 years	32.95	40.00	47.05
	9 years			
	Female	15.14	17.8	20.46
	Male	11.34	15.4	19.46
	10 years			
17	Female	9.8	16.9	24
	Male	11.01	14.87	18.73
	11 years			
	Female	12.36	17.1	21.84
	Male	7.92	14.1	20.28
	9 Years	9.19	12.00	14.81
18	10 years	5.85	14.00	22.15
	11 years	9.78	13.00	16.22
	9 years			
	Female	22.66	29.6	36.54
	Male	20.41	28.27	36.13
	10 years			
19	Female	27.78	32.2	36.62
	Male	19.67	29.43	39.19
	11 years			
	Female	24.74	30.2	35.66
	Male	22.37	30.57	38.77
	9 years			
	Female	22.42	37.7	52.98
	Male	27.89	37.07	46.25
	10 years			
20	Female	22.08	31.9	41.72
	Male	22.81	31.57	40.33
	11 years			
	Female	29.3	39.9	50.5
	Male	21.65	37.07	52.49
	9 Years	23.55	30.00	36.45
21	10 years	24.91	32.00	39.09
	11 years	26.41	34.00	41.59
	9 Years	20.61	27.00	33.39
22	10 years	20.32	29.00	37.68
	11 years	22.34	31.00	39.66
	9 years			
	Female	17.58	22.8	28.02
	Male	16.24	20.6	24.96
	10 years			
23	Female	16.88	23.3	29.72
	Male	16.2	23	29.8
	11 years			
	Female	19.28	25.5	31.72
	Male	18.53	23.47	28.41
	9 Years	63.93	75.50	87.07
24	10 years	68.24	77.50	86.76
	11 years	72.37	81.50	90.63
	9 years			
	Female	46.18	55.9	65.62
	Male	42.07	53.37	64.67
	10 years			
25	Female	45.08	57.5	69.92
	Male	40.81	54.43	68.05
	11 years			
	Female	52.72	62.4	72.08
	Male	47.78	56.5	65.22
	9 years			
	Female	51.68	62.7	73.72
	Male	44.22	59.2	74.18
	10 years			
26	Female	50.78	63.3	75.82
	Male	50.45	60.07	69.69
	11 years			
	Female	57.38	70.5	83.62
	Male	54.04	64	73.96

Therefore, clothing manufacturers have to take into account the age and 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 grades in the basic education stage. After that database for sizing system in the Libya are going to be established.

ACKNOWLEDGMENT

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