A STATISTICAL ANALYSIS OF BODY MEASUREMENTS OF FILIPINO WOMEN[1]

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Introduction and Purpose

Man's quest to learn and understand his own body make-up has led to the development of a scientific method of measuring the human body we now know as anthropometry. As far back as ancient Egypt, the length of the middle finger was taken as one third the height of the head, neck and one-nineteenth of the whole body.

In early Roman times, architects, engineers and painters made use of the rule that the distance between the crown of the head and the chin is one-eighth of the body height, and to this day, this factor is utilized by designers as a guideline in the production of garments (Winks, 1978).

It was only in the 17^{th} century that anthropometry was established. Adolphe Quetelet, a Belgian statistician and considered founder of anthropometry, showed, in 1835, that in representative samples of the population, most human metric traits are normally distributed. Statisticians, like Karl Pearson, R. A. Fisher and C. R. Rao, have made use of anthropometric data in developing statistical techniques for classifying individuals, for analyzing variation, and for reducing a larger set of measured traits in terms of a few reference axes.

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Anthropometric studies have found application in studies of evolution, race, genetics, growth and aging, physiology, disease, behavior, equipment design and sizing of clothes.

In the areas of equipment design and garment manufacturing, anthropometric studies have been conducted in different countries of the world. Many of these, however, were concerned with the development of military equipment and protective garments. Comparatively very little work has been done on civilian populations. It was only in 1941 when a scientific study of body measurements for the construction of women's apparel was first reported by O'Brien and Shelton; and among the first to develop a standard system of sizing clothes were the United Kingdom, Denmark, France, Germany, the USSR, and Japan. Surprising as it may seem, Italy, the world's center of fashion design, has no official sizing system for clothing (Winks, 1978).

The problem of establishing a standard system of sizing clothes stems from the fact that body dimensions vary in both size and shape not only among nationalities but also among peoples of the same nationality. For instance, the ratio of sitting height to total height for male German military personnel is 0.514 while that for the Japanese is 0.544 (Winks, 1978). This indicates that for the same height, Japanese have shorter legs than do Germans.

In the Philippines, the market for ready-made garments has grown considerably in the past few years, yet no standard sizing system for clothing exists. Different manufacturers have their own sizing scheme. Thus, garments labelled the same size but made by different manufacturers vary greatly; and even garments labelled the same size made by the same manufacturer are observed to vary. This variation is one of the main causes of dissatisfaction among customers and loss of good will to both manufacturers and retaillers.

It is therefore the purpose of this lecture to present a statistical analysis of body measurements of Filipino women in order to provide a basis for establishing a standard system of sizing for women's apparel.

Materials

The data used in this study were collected in a 1975 nationwide survey conducted by the Philippine Bureau of Standards (PBS) and the UP College of Home Economics in Diliman under a joint project sponsored by the NSDB.[1] The analysis of the data was conducted in UPLB under a project sponsored by the PBS.[2] The data consists of 51 body measurements taken on a sample of 12,024 Filipino women aged 18 to 65 years. The body measurements, all recorded in centimeters to the nearest millimeter, except for weight in kilograms and shoulder slope in degrees, were:

A. Weight
B. Vertical Measurements:

1. Stature
2. Cervicale height
3. Bust height
4. Waist height
5. Abdominal-extension height
6. Hip height
7. Sitting-spread height
8. Crotch height
9. Tibiale height
10. Total posterior arm length
11. Upper posterior arm length
12. Anterior arm length
13. Cervicale to waist anterior
14. Anterior waist length
15. Shoulder to waist length
16. Neck to bust length
17. Posterior waist length
18. Scye depth
19. Trunk line
20. Arm length, shoulder to scye
21. Waist to hip length
22. Total crotch length
23. Anterior crotch length
24. Vertical trunk girth

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[1]Rañoa, V. F. Final Report. "A Study of Body Measurements of Filipino Men, Women, and Children for Sizing Apparel and Patterns". Project No. NSDB-PBS 7502 In. 1976.

[2]Gironella, A. I. N., et. al. Final Report, Part I. "A Statistical Analysis of Body Measurements of Filipino Men, Women, and Children for Sizing Apparel and Patterns". 1980.

C. Horizontal Measurements:

1. Chest girth
2. Bust girth
3. Waist girth
4. Abdominal-extension girth
5. Hip girth
6. Sitting-spread girth
7. Maximum thigh girth
8. Midway thigh girth
9. Bent-knee girth
10. Knee girth
11. Maximum calf-girth
12. Ankle girth
13. Neckbase girth
14. Armscye girth
15. Upper-arm girth
16. Elbow girth
17. Forearm girth
18. Wrist girth
19. Shoulder length
20. Anterior chest width
21. Posterior chest width
22. Anterior bust arc
23. Anterior waist arc
24. Abdominal extension arc
25. Posterior hip arc

D. Shoulder Slope

Methodology

In the development of the sizing system, basic statistics like the mean, standard deviation and coefficient of variation of each body measurement were first calculated and then correlation analysis was performed to determine relationships and inter-relationships among body parts. Body dimensions were then grouped into two: (a) control dimensions; and (b) dependent dimensions.

Control dimensions[3] are dimensions of the body where fit is critical and they are used to divide the population into size groups. They are therefore the dimensions on which the sizing system is built. These are the dimensions that must be measured on the individual to assign her to the proper group size. To these dimensions were assigned tolerance limits beyond which fit was considered inadequate.

[3]Canada Standard System for Sizing Women's Apparel. National Standard of Canada. Can. 2-49. 201-M78. 1978.

After having identified the control dimensions, regression analysis was performed from which size ranges were developed.

The dependent dimensions are dimensions of the body that are not controls. These dimensions were estimated by regressing them on the control dimensions.

Results and Discussion

The basic statistics are given in Table 1 and these provide an overall picture of the body dimensions of the average Filipino woman. The mean height is 150 cm (4 ′11″), with a standard deviation of 5 cm., while the mean weight is 45 kg (99 lbs) with a standard deviation of 7 kg. This means that about 68% of the Filipino women have heights between 145-155 cm (4 ′9″– 5 ′1 ″) and about the same proportion have weights between 38-52 kg (84-114 lbs).

The dimensions of the average woman, however, are of little interest to the garment manufacturers inasmuch as women vary much in size and shape to be properly fitted the garment of an average woman. A measure of the relative variability of the body measurements is given by the coefficient of variation (CV). It can be seen in the table that shoulder slope and weight are most variable and girth measurements appear to be more variable than vertical measurements.

To determine the extent of the relationship among body measurements, correlation analysis was done. The results show that the vertical measurements are, in general, independent of the horizontal measurements; that horizontal or girth measurements are highly correlated; and that vertical measurements are also highly correlated. While weight is not highly correlated with vertical measurements, it is observed to be very highly correlated with the girth measurements.

Table 1. MEAN, STANDARD DEVIATION, COEFFICIENT OF VARIATION OF 51 BODY MEASUREMENTS OF 12,024 FEMALE ADULTS

	Mean	*Standard Deviation*	*CV (%)*
1. Weight	44.97	7.24	16.10
Vertical Measurements:			
2. Stature	149.85	5.18	3.46
3. Cervicale height	127.62	4.86	3.81
4. Bust height	106.79	4.70	4.40
5. Waist height	94.72	4.12	4.35
6. Abdominal-extension height	85.21	4.00	4.69
7. Hip height	75.11	3.66	4.88
8. Sitting spread height	66.01	3.98	6.02
9. Crotch height	66.20	3.44	5.20
10. Tibiale height	40.36	2.27	5.63
11. Total posterior arm length	56.15	2.55	4.54
12. Upper posterior arm length	31.62	1.66	5.26
13. Anterior arm length	41.40	2.32	5.61
14. Vertical trunk girth	138.23	6.65	4.81
15. Cervical to waist anterior	43.80	2.39	5.46
16. Anterior waist length	28.90	2.22	7.69
17. Shoulder to waist length	35.43	2.41	6.80
18. Neck to bust length	24.87	2.62	10.52
19. Posterior waist length	34.80	2.29	6.57
20. Scye depth	15.95	1.77	11.10
21. Trunk line	17.44	1.86	10.64
22. Arm length, shoulder to scye	11.69	1.23	10.56
23. Waist to hip length	20.50	2.08	10.14
24. Total crotch length	67.64	5.08	7.50
25. Anterior crotch length	34.64	3.16	9.13
Horizontal Measurements:			
26. Chest girth at armscye	80.58	5.46	6.78
27. Bust girth	82.15	6.73	8.19

Table 1 (continued)

	Mean	*Standard Deviation*	*CV(%)*
28. Waist girth	68.16	6.98	10.24
29. Abdominal-extension girth	80.82	7.85	9.72
30. Hip girth	85.22	5.83	6.84
31. Sitting-spread girth	82.04	6.59	8.04
32. Maximum thigh girth	49.21	4.56	9.27
33. Midway thigh girth	43.62	4.29	9.84
34. Bent knee girth	33.29	2.71	8.15
35. Knee girth at tibiale	32.42	2.61	8.04
36. Maximum calf girth	31.50	2.56	8.13
37. Ankle girth	22.91	1.54	6.70
38. Neckbase girth	36.68	2.28	6.21
39. Armscye girth	35.64	3.04	8.53
40. Upper arm girth	26.26	2.82	1[illegible]73
41. Elbow girth	25.07	1.90	7.57
42. Forearm girth	22.96	1.73	7.54
43. Wrist girth	14.68	0.78	5.32
44. Shoulder length	11.01	1.06	9.59
45. Anterior chest girth	29.13	1.92	6.58
46. Posterior chest width	34.15	2.38	6.98
47. Anterior bust arc	44.25	4.67	10.56
48. Anterior waist arc	36.98	4.79	12.96
49. Abdominal-extension arc	43.97	5.11	11.63
50. Posterior hip arc	42.30	3.87	9.15
Angle:			
51. Shoulder slope	21.72	3.62	16.67

This means that a tall woman may have the same weight as a short woman; and that heavier women tend to have larger girth measurements. Shoulder slope is not highly correlated with any other measurement. Among girth measurements, adjacent body dimensions tend to be more highly correlated. For instance, the correlation between chest girth and bust girth is 0.880, between bust girth and waist girth is 0.848, but between chest and waist girths, the correlation is 0.837.

These results indicate that both horizontal and vertical controls need to be defined in the sizing system to be developed.

A. Horizontal Measurements

In the selection of the horizontal control dimension, weight which seems to be a very good indicator of girth measurements is not a body dimension requiring fit. To determine how girth measurements are related for constant weight, the partial correlation matrix was computed for girth measurements with weight held constant. A portion of the partial correlation matrix[4] for selected girth measurements is given in Table 2.

Table 2. PARTIAL CORRELATION OF SELECTED GIRTH MEASUREMENT WITH WEIGHT CONSTANT

		(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
(1)	Chest	0.60	0.46	0.35	0.08	0.01	0.03	−0.06	0.19	0.28	0.39	0.19
(2)	Bust		0.53	0.40	0.07	0.01	0.04	−0.08	0.11	0.22	0.32	0.12
(3)	Waist			0.63	0.10	−0.03	−0.03	−0.03	0.11	0.26	0.34	0.11
(4)	Abdominal extension				0.22	0.08	−0.01	−0.07	0.08	0.24	0.30	0.11
(5)	Hip					0.52	0.50	0.22	0.02	0.10	0.20	0.08
(6)	Sitting-spread						0.50	0.25	−0.04	0.07	0.18	0.11
(7)	Thigh							0.31	−0.02	0.08	0.29	0.09
(8)	Knee								0.07	0.01	0.05	0.09
(9)	Neckbase									0.13	0.06	0.05
(10)	Armscye										0.38	0.23
(11)	Upper arm											0.29
(12)	Elbow											1.00

The analysis shows that girths in the upper portion of the body and arms are positively correlated and so are girths in the lower portion and legs. It is also observed that leg girths are generally negatively correlated with girths in the upper portion of the body but these correlations are quite small. Leg girths are generally positively correlated with arm girths but the correlations are quite low. Further-

[4] Tirol, M. B. C. "Principal Component Analysis of Body Measurements Filipino Women", M. S. Thesis, UPLB, Nov. 1981.

more, girths in the upper portion are independent of girths in the lower portion of the body.

The results of the partial correlation analysis then suggest that two horizontal control dimensions are needed, one for the upper portion and another for the lower portion of the body, and based on the variability of dimensions where fit is considered critical, bust girth and hip girth were taken as horizontal control dimensions.

Considering now the bivariate distribution of bust girth and hip girth in order to set up a system of grouping women by bust-hip girth, regression analysis was done. The model $Y = \alpha + \beta X + \epsilon$ was assumed where Y = bust girth and X = hip girth. The sample regression equation obtained was $\hat{Y} = 8.50 + 0.86X$ indicating that, on the average, bust girth increases by 0.86 cm. for every centimeter increase in hip girth. Women may then be classified by bust-hip measurements after specifying tolerance limits for these control dimensions.

With values of the control dimensions as independent variables, dependent dimensions may be estimated by regressing each one of them on bust and hip girths, using the model, $Y = \alpha + \beta_1 X_1 + \beta_2 X_2 + \epsilon$, where X_1 = bust girth and X_2 = hip girth. Regression techniques gave the estimates of the parameters of the model as shown in Table 3.

B. Vertical Measurements

In the selection of the vertical control dimension, the correlation analysis showed a very strong positive relationship among height measurements, and among lengths of the upper portion of the body, but comparatively low correlations among lengths of the lower portion and the upper portion of the body. This suggests that two vertical control dimensions are needed. To determine how the vertical measurements are related for constant stature, the partial correlation matrix was computed. The analysis showed that, again, height measurements are positively correlated.

Table 3. ESTIMATES OF THE INTERCEPT, PARTIAL REGRESSION COEFFICIENTS AND COEFFICIENT OF MULTIPLE DETERMINATION FOR GIRTH OR HORIZONTAL MEASUREMENTS

Dependent Dimension	*Intercept*	*Coefficient of*		R^2
		Bust Girth	*Hip Girth*	
Neckbase	19.16	0.10	0.10	0.29
Chest	14.23	0.56	0.24	0.80
Waist	–14.54	0.67	0.33	0.75
Abdominal Extension	–12.87	0.58	0.54	0.71
Sitting spread	–2.85	0.08	0.92	0.77
Maximum Thigh	–9.42	0.08	0.61	0.76
Midway Thigh	–5.36	0.08	0.49	0.60
Bent knee	4.15	0.03	0.31	0.53
Knee	4.52	0.03	0.30	0.53
Maximum Calf	3.45	0.06	0.27	0.55
Ankle	12.70	0.03	0.09	0.20
Armscye	3.46	0.18	0.20	0.55
Upper arm	–7.83	0.19	0.22	0.71
Elbow	5.69	0.09	0.14	0.50
Forearm	4.13	0.08	0.14	0.56
Wrist	7.71	0.03	0.05	0.38
Vertical trunk	63.44	0.21	0.68	0.58
Shoulder length	7.92	0.01	0.03	0.04
Anterior chest width	14.98	0.07	0.09	0.26
Anterior bust arc	–4.85	0.53	0.06	0.68
Anterior waist arc	–13.54	0.41	0.20	0.60
Abdominal extension arc	–10.63	0.37	0.28	0.58
Posterior chest width	16.39	0.15	0.06	0.81
Posterior hip arc	-0.42^{ns}	–0.02	0.52	0.58
Shoulder slope	18.76	0.01^{ns}	0.03	0.003

^{ns}Not significant at $\alpha = 1\%$.

However, lengths of the lower portion are negatively correlated with those of the upper portion. In other words, for women of the same height, the longer the legs, the shorter the trunk.

Based on the correlation analysis and on the variability of the vertical dimensions, the control dimensions selected were crotch height (or leg length) and posterior waist length.

A plot of the distribution of women by posterior waist length and crotch height showed that the two dimensions are independent for all practical purposes (correlation being 0.21). From the plot, women were divided into four classes: short trunk-short leg, short trunk-long leg, long trunk-short leg, and long trunk-long leg. These classes with sufficient tolerance limits cover the entire population quite well.

With the values of the control dimensions as independent variables, the dependent dimensions may be estimated by regressing each one of the height measurements on the controls. Further considerations of the other vertical measurements necessitated the inclusion of the bust and hip girths as control since these vertical dimensions were measured with the tape following the contour of the body. Regression analysis gave the estimates of the parameters of the linear regression model as shown in Table 4.

A complete sizing system, therefore, can be developed by pairing off the bust-hip girth combination with the posterior waist length-crotch height combination. That is, a woman can be assigned to her proper group size by measuring her bust girth, hip girth, posterior waist lenght, and leg length.

Table 4. ESTIMATES OF THE INTERCEPT, PARTIAL REGRESSION COEFFICIENTS AND COEFFICIENT OF MULTIPLE DETERMINATION FOR VERTICAL MEASUREMENTS

Dependent Dimension	*Intercept*	*Coefficient of*				R^2
		Crotch Height	*Posterior Waist Length*	*Bust Girth*	*Hip Girth*	
Stature	59.10	1.06	0.59	–	–	0.64
Cervicale height	40.33	0.97	0.67	–	–	0.66
Bust height	36.73	0.92	0.26	–	–	0.51
Waist height	29.45	0.94	0.90	–	–	0.63
Abdominal exention height	20.96	0.86	0.20	–	–	0.60
Hip height	16.62	0.81	0.14	–	–	0.61
Sitting-spread height	10.53	0.77	0.13	–	–	0.47
Tibiale height	7.76	0.44	0.11	–	–	0.48
Upper posterior arm	7.96	0.24	0.09	0.01	0.04	0.36
Anterior arm length	10.94	0.38	0.13	–0.01	0.01	0.38
Total posterior arm	14.84	0.42	0.13	0.03	0.07	0.48
Trunk line	9.27	-0.01^{ns}	0.36	–0.05	–	0.19
Waist to hip	8.24	0.10	–0.09	–0.01	0.11	0.11
Cervicale to waist anterior	15.44	0.05	0.32	0.08	0.09	0.36
Neck to bust	9.87	–0.04	0.16	0.12	0.02	0.17
Shoulder to waist	10.05	0.05	0.31	0.09	0.04	0.28

Table 4 (Continued)

Dependent Dimension	*Intercept*	*Coefficient of*				R^2
		Crotch Height	*Posterior Waist Length*	*Bust Girth*	*Hip Girth*	
Anterior waist	9.56	0.02	0.31	0.04	0.04	0.20
Scye depth	–0.98	0.04	0.24	0.04	0.04	0.22
Arm to scye	2.41	0.02	0.04	0.05	0.03	0.17
Total crotch length	18.67	0.08	–0.28	0.10	0.53	0.48
Anterior crotch length	8.81	0.02	–	0.09	0.21	0.29

[ns]Not significant at $\alpha = 1\%$

Summary and Conclusions

Fifty-one body measurements taken on a sample of 12,024 Filipino women aged 18-65 years were analyzed in order to develop a basis for sizing garments. Correlation analysis showed that vertical and horizontal body measurements are, generally, independent indicating that vertical and horizontal control dimensions need to be identified. Bust girth and hip girth were selected as horizontal controls, and posterior waist length and crotch height were selected as vertical controls. These control dimensions serve to identify the size group to which a woman should belong to be properly fitted a garment. Regression analysis was used to determine the dependent dimensions with the control dimensions as independent variables. The complete sizing system was obtained by pairing off bust-hip girth combination with posterior waist-leg length combination. The system developed provides a basis for sizing garments of women.

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