PRINCIPAL COMPONENT ANALYSIS OF BODY MEASUREMENTS OF FILIPINO WOMEN

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Introduction

In designing clothes, furniture, sports equipment, and other equipment for which body measurements are needed, a sizing system that is basically fitted for the Filipinio is of utmost concern. The main problem in setting up a sizing system is the selection of a combination of body measurements that is most closely related to the other measurements. These measurements are the basis of classifying the population into size groups. They are the control measurements upon which the whole sizing system is built. Because of this, importance is given on the selection of the control measurements.

The theoretical aspects in sizing garments and patterns were first discussed by O'Brien and Shelton [3] in developing a sizing system for garment and pattern construction for American women. Gironella, *et al.* [2] developed a system of sizing apparel for Filipinos which was patterned after the Canadian Standard System [1]. This system requires that the control dimensions be body measurements where garment fit is considered critical.

This paper considers the problem of selecting control dimensions for body measurements of Filipino women using principal components and presents the sizing system in the selected controls using regression.

Materials and Methods

The data used in this study were collected in a 1975 nationwide survey by the Philippine Bureau of Standards under NSDB

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Project No. NSDB-PBS 7502 In. The data consist of 51 body measurements taken on a sample of 12,024 Filipino women aged 18 to 65 years. The 51 body dimensions, all recorded in centimeters to the nearest millimeter, except for weight in kilograms and shoulder slope in degrees, are given in Appendix A.

Horizontal or girth measurement were shown [2] to be generally independent of vertical measurements, girth measurements including weight were highly correlated while the vertical measurements were similarly correlated. This two-way variation required a coplanar system to represent it, thus, the need to use two control measurements. The controls representing horizontal and vertical measurements were the basis for sizing, with the values of the other measurements computed from two-way regression on the controls. The control measurement desired should be representative of an entire set of body measurements; that is, it should account for most of the variations in and should be highly correlated with the other measurements.

Principal component analysis was applied on the vertical and horizontal measurements to select a control measurement for each group. A high correlation coefficient (close to unity) between the first principal component and a measurement would show that the measurement would be as perfect an indicator of the set of measurements as the first principal component. This measurement would then be used as the control.

The partial correlations, holding control constant, and residual standard deviations after eliminating variation due to the control were then computed.

The control selected would be a good indicator of the set of measurements under consideration if it satisfied the following conditions: (1) the partial correlations (holding control constant) among the remaining measurements were close to zero. This would imply that the measurements were not correlated with each other but were actually correlated with the control measurements used ;(2) the residual standard deviations after eliminating the variation due to the control measurement were less than those after eliminating the variation due to any other measurement. This would mean that the control measurement accounted for most of the variation in the other measurements.

Based on these two conditions, it could therefore be said that the control measurement selected accounted for most of the variation in and was highly correlated with the other measurements.

From among the selected control dimensions for the horizontal and vertical measurements, several alternative sizing systems were developed. The accuracy on how these combinations of control measurements predicted the remaining measurements were compared by examining the multiple correlation of the body measurements with these controls.

Results and Discussion

A. Horizontal Measurements

The correlation coefficients of the first and second principal components extracted from the correlation matrix of weight and the 25 horizontal body measurements are presented in Table 1. The first component appeared to be a measure of general average of all horizontal dimensions and weight. Almost all body dimensions have high positive correlations with this component. Weight, with a value of 0.9526, showed the highest correlation with the first component. The second highest correlation was 0.9116 for the hip girth, followed by chest girth, 0.8969. Shoulder length showed the least correlation with this component with a value of 0.2195. About 60% of the total variance in the 25 body dimensions and weight is accounted for by component 1.

Component 2 explained a much smaller percentage (6.1%) of the total variance. This component appeared to be a comparison of the upper and lower body girths since this component was generally negatively correlated with girths of the upper part of the body and was positively correlated with girths of the lower part. Weight, neck-base girth, anterior chest width, and shoulder length showed small correlations with this component. These results indicated that among women of the same size (with the first principal component as index) there were positive correlations among the upper body girths, among the lower body girths and among the leg girths, but with negative correlations between the upper body and leg girths.

TABLE 1. COMPONENT CORRELATION OF WEIGHT AND 25 HORIZONTAL BODY DIMENSIONS OF 12,024 WOMEN

Body Dimension	*Component*	
	1	*2*
Weight	.9526	.0319
Chest girth at armscye	.8969	−.1934
Bust girth	.8753	−.2701
Waist girth	.8721	−.3542
Abdominal extension girth	.8527	−.3252
Hip girth	.9116	.1158
Sitting spread girth	.8660	.2017
Maximum thigh girth	.8736	.2366
Midway thigh girth	.8099	.2860
Bent knee girth	.7666	.3452
Knee girth at tibiale	.7745	.3504
Maximum calf girth	.8036	.3340
Ankle girth	.5199	.3167
Neckbase girth	5924	−.0217
Armscye girth	.7958	−.1123
Upperarm girth	.8883	−.0864
Elbow girth	.7840	.0515
Forearm girth	.8334	.1147
Wrist girth	.7033	.1076
Anterior chest width	.5576	.0104
Anterior bust arc	.7670	−.2978
Anterior waist arc	7924	−.4352
Abdominal extension arc	.7831	−.4558
Posterior chest width	.5641	−.0602
Posterior hip arc	.7038	.2552
Shoulder length	.2195	.0388
Proportion of variation accounted for by each component	.602	.061

The partial correlations holding weight constant, were also computed. These are shown in Table 2. The values obtained confirmed the result of the principal component analysis. There were positive correlations among the upper body girths, among the lower body girths and among the leg girths. The upper body girths and leg girths were negatively correlated. The negative correlations between the upper body and leg girths, however, were very small, the largest value being -0.1532 which was between the calf and abdominal extension girths. The highest positive correlation for the girths was 0.6616 which was between the maximum thigh and midway thigh girths.

For comparison, five sets of partial correlations were computed with each of the trunk girths: chest, bust, waist, abdominal extension and hip, being held constant. The highest correlation with any one of the trunk girths held constant ranged from 0.7170, between chest and bust girths with hip girth held constant, to 0.8042, between midway thigh girth and maximum thigh girth with abdominal extension girth held constant. There were a few negative correlations among the horizontal measurements, which were basically correlations with the width and arc measurements and shoulder length. The girth measurements were all positively correlated except for the case when hip girth was the constant variable where there were a few negative correlations. However, the negative correlations were small, the largest was -0.2402, between abdominal extension arc and posterior hip arc, with hip girth held constant.

The partial correlations were lowest for almost all the horizontal measurements when weight was held constant, as compared with the partial correlations when either one of the trunk girths was the fixed variable. These results showed the superiority of weight to the other girth measurements for use as control.

Before weight was finally selected from among the other horizontal dimensions, the residual standard deviations, after eliminating variation due to weight, of each of the five trunk girth measurements were computed and compared. These are shown in Table 3. It was evident that the residual standard deviations for almost all the horizontal measurements were smaller when variation due to weight was removed. Having satisfied the two criteria that were set in the selec-

Table 2. Partial correlations among 25 horisontal measurements of 12,024 women with weight constant.

MEASUREMENTS	BUST GIRTH	WAIST GIRTH	ABDOMINAL EXTN GIRTH	HIP GIRTH	SITTING SPREAD GIRTH	THIGH GIRTH (MAX)	MIDWAY THIGH GIRTH	BENT KNEE GIRTH	KNEE GIRTH AT TIBIALE	MAX CALF GIRTH	ANKLE GIRTH	NECK BASE GIRTH	ARM SCYE GIRTH
Chest girth at armscye	.6038	.4636	.3513	.0806	.0081	.0315	.0214	-.0520	-.0562	-.0032	-.0368	.1889	.2851
Bust girth		.5296	.4039	.0670	.0070	.0411	-.0083	-.0633	-.0816	-.0513	-.0605	.1134	.2207
Waist girth			.6287	.0969	-.0319	-.0328	-.0750	-.0932	-.0944	-.1239	-.0944	.1086	.2602
Abdominal ext'n girth				.2237	.0787	-.0091	-.0868	-.0903	-.0731	-.1532	-.0673	.0841	.2449
Hip girth					.5224	.5019	.2886	.2501	.2200	.1629	-.0104	.0170	.1017
Sitting spread girth						.5870	.4397	.2766	.2467	.2402	-.0009	-.0353	.0704
Thigh girth (max)							.6616	.5292	.3085	.3283	-.0401	-.0225	.0795
Midway thigh girth								.2547	.3248	.3878	.0077	.0512	.0420
Bent knee girth									.4519	.3436	.1424	-.0083	.0268
Knee girth at tibiale										.3588	.1999	.0737	.0124
Maximum calf girth											.1986	.0175	.0122
Ankle girth												.0580	-.0249
Neckbase girth													.1347
Armscye girth													
Upper arm girth													
Elbow girth													
Forearm girth													
Wrist girth													
Anterior chest width													
Anterior bust arc													
Anterior waist arc													
Abdominal extension arc													
Posterior chest arc													
Posterior hip arc													

MEASUREMENTS	UPPER ARM GIRTH	ELBOW GIRTH	FORE ARM GIRTH	WRIST GIRTH	ANTERIOR CHEST WIDTH	ANTERIOR BUST ARC	ANTERIOR WAIST ARC	ABDOMINAL EXT. ARC	POSTERIOR CHEST ARC	POSTERIOR HIP ARC	SHOULDER LENGTH
Chest girth at armscye	.3867	.1862	.2149	.1200	.1557	.3199	.3292	.2982	.3236	.0261	.0200
Bust girth	.3239	.1180	.1110	.0321	.0806	.5952	.3903	.3351	.2259	-.0007	-.0240
Waist girth	.3434	.1146	.0553	.0215	.0009	.3348	.7284	.5568	.1155	.0005	-.0558
Abdominal ext'n girth	.2961	.1109	-.0132	.0588	.0310	.2252	.4834	.7103	.0829	.0737	-.0259
Hip girth	.2052	.0843	.0812	-.0151	.0315	.0542	.0599	.1381	.0075	.4761	-.0064
Sitting spread girth	.1834	.1114	.1130	-.0437	.0274	.0446	-.0256	.0247	-.0478	.2921	.0007
Thigh girth (max)	.2883	.0863	.1789	-.0982	-.0025	.0505	-.0266	-.0504	-.0332	.2908	-.0456
Midway thigh girth	.2032	.0638	.2018	-.0611	.0056	-.0070	-.0482	-.0756	-.0240	.1664	-.1041
Bent knee girth	.0462	.1328	.1442	.0889	.0117	-.0328	-.0686	-.0924	-.0163	.1688	.0355
Knee girth at tibiale	.0486	.0940	.1189	.1075	.0203	-.0469	-.0840	-.0863	.0039	.1635	-.0635
Maximum calf girth	.1113	.1396	.2845	.1148	.0015	-.0817	-.1025	-.1329	.0167	.1187	-.0142
Ankle girth	-.0909	.0751	.0799	.2616	.0605	-.0638	-.1154	-.0876	.0457	.0263	.0255
Neckbase girth	.0609	.0522	.0375	.0983	.1280	-.0015	.0391	.0382	.1385	.0639	-.1456
Armscye girth	.3772	.2313	.2313	.1674	.0411	.1376	.1933	.1906	.0269	.0710	-.0959
Upper arm girth		.2899	.3943	.0784	.0018	.2308	.2818	.2598	.0644	.1084	-.0867
Elbow girth			.5524	.3050	.0111	.0726	.0836	.0883	.0403	.0205	.0296
Forearm girth				.3538	.0200	.0729	.0478	.0132	.0637	.0382	.0011
Wrist girth					.0674	-.0290	-.0205	.0300	.0848	.0203	.0503
Anterior chest width						.1250	.0130	.0049	.0195	.0122	.2640
Anterior bust arc							.4142	.3295	-.0156	-.0622	.0011
Anterior waist arc								.6636	.0058	-.1339	-.0516
Abdominal extension arc									.0169	-.1557	-.0337
Posterior chest arc										.0326	.2048
Posterior hip arc											-.0690

TABLE 3. SIMPLE STANDARD DEVIATIONS OF WEIGHT AND 25 HORIZONTAL MEASUREMENTS OF 12,024 WOMEN AND RESIDUAL STANDARD DEVIATIONS AFTER ELIMINATING VARIATION DUE TO EACH OF SIX MEASUREMENTS.

Measurement	*Simple Standard Deviation*	*Residual Standard Deviation*					
		Weight	*Hip Girth*	*Chest Girth at Armscye*	*Bust Girth*	*Waist Girth*	*Abdominal Extension Girth*
Weight	7.2387	–	3.3422	3.8423	4.0990	4.1217	4.3274
Chest girth at armscye	5.4638	2.9001	3.4762	–	2.5950	2.9914	3.3439
Bust girth	6.7313	3.8117	4.4627	3.1970	–	3.5640	4.0616
Waist girth	6.9826	3.9759	4.5813	3.8230	3.6921	–	3.4056
Abdominal ext. girth	7.8577	4.6974	4.9867	4.8091	4.7413	3.8324	–
Hip girth	5.8311	2.6923	–	3.7099	3.8259	3.8258	3.7006
Sitting spread girth	6.5947	3.6267	3.2106	4.6426	4.7697	4.8561	4.7391
Thigh girth (max.)	4.5610	2.4943	2.2540	3.1714	3.2448	3.3525	3.3934
Midway thigh girth	4.2915	2.7264	2.7398	3.2176	3.3204	3.4081	3.4772
Bent knee girth	2.7133	1.8479	1.8597	2.1670	2.2120	2.2372	2.2657
Knee girth at tibiale	2.6060	1.7505	1.7939	2.0694	2.1237	2.1360	2.1511
Maximum calf girth	2.5616	1.6171	1.7358	1.9329	2.0081	2.0626	2.1155
Ankle girth	1.5356	1.3251	1.3759	1.3996	1.4160	1.4272	1.4264
Neckbase girth	2.2775	1.8935	1.9731	1.8956	1.9572	1.9615	1.9889
Armscye girth	3.0416	2.0431	2.2054	2.0804	2.1883	2.1465	2.1951
Upperarm girth	2.8213	1.5785	1.7363	1.6257	1.7451	1.7271	1.8221
Elbow girth	1.8970	1.3041	1.4066	1.3848	1.4504	1.4546	1.4766
Forearm girth	1.7299	1.0811	1.2078	1.1769	1.2640	1.2975	1.3561
Wrist girth	0.7803	0.5811	0.6318	0.6165	0.6445	0.6476	0.6459
Anterior chest width	1.9168	1.6251	1.6787	1.6379	1.6860	1.7247	1.7205
Anterior bust arc	4.6724	3.2605	3.5395	3.2155	2.6366	3.2336	3.4764
Anterior waist arc	4.7934	3.2466	3.5527	3.2142	3.1373	2.2255	2.9665
Abdominal ext. arc	5.1135	3.5119	3.7084	3.5235	3.4979	2.9611	2.4820
Posterior chest width	2.3829	2.0220	2.1004	1.9166	1.9984	2.0762	2.1081
Posterior hip arc	3.8701	2.8697	2.5237	3.1558	3.2253	3.2277	3.1785
Shoulder length	1.0558	1.0290	1.0354	1.0345	1.0402	1.0434	1.0415

tion of a control measurement, weight showed that it was the best indicator of the set of horizontal measurements.

B. Vertical Measurements

The correlation coefficients of the first, second and third principal components extracted from the correlation matrix of the 24 vertical body dimensions are shown in Table 4. The proportion of variation of 40.8 per cent accounted for by the first principal component was relatively small compared to 60 per cent for the horizontal measurements. The height and arm measurements have high correlation with the first principal component, vertical trunk girth and the upper trunk measurements were highly correlated with the second principal component while the crotch measurements with the third principal component. Stature and cervicale height were the two measurements most correlated with the first principal component with correlations of 0.9367 and 0.9380; respectively. Waist height was second with a correlation of 0.8934 followed by abdominal extension height, 0.8563.

The second principal component showed that there is a positive correlation among the height measurements and arm length and also among the trunk measurements, while a negative correlation exists between the two groups. This implies that among women of the same height (as represented by the first principal component), those with long legs had long arms and short trunks.

This relationship was more evident by looking at the partial correlations of the vertical measurements, holding stature constant (see Table 5). The height measurements, except for cervicale height, were negatively correlated with vertical trunk girth, the upper trunk girth, the upper trunk lengths and crotch length.

The measurements that were to be compared with stature were cervicale and waist height, the two other measurements most correlated with the first principal component. Since the first principal component accounted for only 40 per cent of the variation, a combination of two measurements was also used, one that had high correlations with the first component and another with the second component. These two measurements each represented the lower part

TABLE 4. COMPONENT CORRELATION OF 24 HORIZONTAL BODY DIMENSIONS OF 12,024 WOMEN

Body Dimension	*Component*		
	1	*2*	*3*
Stature	.9367	−.0771	−.0422
Cervicale height	.9380	−.0528	−.0227
Bust height	.8201	−.2125	−.0994
Waist height	.8934	−.2566	.2060
Abdominal extension height	.8563	−.2830	−.0094
Hip height	.8331	−3108	−.0532
Sitting spread height	.7153	−.3097	−.1022
Crotch height	.7980	−.3671	−.0520
Tibiale height	.7407	−.2299	−.0196
Total posterior arm length	.8078	−.-0888	.0479
Upper arm length	.7234	−.0529	.0519
Anterior arm length	.6878	−.2689	−.1308
Vertical trunk girth	.5900	.6119	.2721
Cervicale to waist anterior	.4629	.6006	−.4020
Anterior waist length	.3612	.5208	−.5340
Shoulder to waist	.4192	.5846	−.3927
Neck to bust	.1866	.4992	.2135
Posterior waist length	.4576	.4158	−.2998
Scye depth	.4576	.3388	.0946
Trunk line	.2163	.2690	−.6203
Arm to scye	.3089	.4194	.2330
Waist to hip	.3182	.0778	.4902
Total crotch length	.4366	.4128	.6635
Anterior crotch length	.3613	.4113	.6090
Proportion of variation accounted for by each component.	.408	.131	.100

Table 5. Partial correlations of 23 vertical measurements with stature constant.

MEASUREMENTS	BUST HEIGHT	WAIST HEIGHT	ABDOMINAL EXTN HEIGHT	HIP HEIGHT	SITTING SPREAD HEIGHT	CROTCH HEIGHT	TIBIALE HEIGHT	TOTAL POSTERIOR ARM LENGTH	UPPER ARM LENGTH	ANTERIOR ARM LENGTH	VERTICAL TRUNK GIRTH
Cervicale height	.1578	.2738	.2163	.1987	.1320	.1697	.1623	.2076	.1598	.1394	.1586
Bust height		.2341	.1989	.1799	.1469	.1985	.1356	.0362	.0107	.0910	-.0994
Waist height			.4663	.4407	.2623	.4121	.2818	.2344	.1739	.1518	-.0100
Abdominal ext'n height				.4459	.3058	.3790	.2432	.2213	.1769	.2444	-.1839
Hip height					.4030	.4432	.3107	.2556	.1943	.2281	-.1701
Sitting spread height						.3670	.2438	.1429	.1096	.1742	-.1728
Crotch height							.3531	.2157	.1625	.2518	-.2941
Tibiale height								.1698	.1257	.1472	-.0592
Total posterior arm length									.6454	.4564	.0781
Upper arm length										.3438	.0820
Anterior arm length											-.2016
Vertical trunk girth											
Cervicale to waist anterior											
Anterior waist length											
Shoulder to waist											
Neck to bust											
Posterior waist length											
Scye depth											
Trunk line											
Arm to scye											
Waist to hip											
Total crotch length											

MEASUREMENTS	CERVICALE TO WAIST ANTERIOR	ANTERIOR WAIST LENGTH	SHOULDER TO WAIST	NECK TO BUST	POSTERIOR WAIST LENGTH	SCYE DEPTH	TRUNK LINE	ARM TO SCYE	WAIST TO HIP	TOTAL CROTCH LENGTH	ANTERIOR CROTCH LENGTH
Cervicale height	.0058	.0181	.0319	.1134	.2453	.2288	.0282	.1050	.0352	.1024	.0925
Bust height	-.0328	.0088	-.0005	-.4929	-.1265	-.1105	.0067	-.0758	.0034	-.0499	-.1023
Waist height	-.4040	-.4265	-.3289	-.0240	-.3217	-.0133	-.3971	.0418	.2466	.2532	.1720
Abdominal ext'n height	-.2207	-.1740	-.1657	-.0730	-.1259	-.0578	-.1354	-.0460	-.0380	-.0978	-.0796
Hip height	-.2020	-.1919	-.1570	-.0746	-.1328	.0005	-.1455	-.0448	-.4280	-.1075	-.0679
Sitting spread height	-.0934	-.1061	-.1024	-.1233	-.0815	.0241	-.0833	.0067	-.1524	-.1713	-.1673
Crotch height	-.2076	-.1965	-.1638	-.1268	-.1661	-.0046	-.1748	-.0358	-.0800	-.2333	-.1829
Tibiale height	-.0797	-.1043	-.0777	-.0403	-.0443	.0259	-.0709	-.0034	-.0615	-.0443	-.0300
Total posterior arm length	.0026	-.0460	.0160	.1665	.0417	.0882	-.1112	.2156	-.0142	.0611	.0729
Upper arm length	.0110	-.0230	.0303	.1524	.0615	.0911	-.0681	.2125	.0056	.0565	.0813
Anterior arm length	-.0629	-.0330	-.0842	-.0846	.0062	.0532	-.0253	-.0477	-.0598	-.2038	-.1412
Vertical trunk girth	.4080	.2357	.3695	.3669	.2931	.2768	.0588	.3861	.1967	.3087	.5605
Cervicale to waist anterior		.6911	.6403	.1979	.3327	.1716	.3227	.2121	-.0985	.0692	.0562
Anterior waist length			.5809	.1344	.2977	.1194	.3641	.0977	-.1346	-.0745	-.0709
Shoulder to waist				.2456	.3085	.1119	.3431	.2128	-.0994	.0542	.0551
Neck to bust					.1927	.1854	-.0205	.2623	.0658	.2766	.1746
Posterior waist length						.3409	.3399	.1286	-.1211	-.0429	.0659
Scye depth							-.0484	.2723	-.0005	.1864	.1850
Trunk line								-.0365	-.2247	-.2492	-.1701
Arm to scye									.1036	.6896	.2418
Waist to hip										.3586	.2447
Total crotch length											.7290

and upper part of the body, and thus could correspond to stature and cervicale height. These measurements were waist height and cervicale to waist anterior. The partial correlations, holding these measurements constant, and the residual standard deviations after eliminating variation due to each of these measurements were computed and compared with those of stature. The residual standard deviations are presented in Table 6.

As expected, the partial correlations, holding cervicale height constant, showed very little differences. Partial correlations, holding stature constant were slightly lower in value. This was mainly because cervicale height was about 85 per cent of stature. The residual standard deviations after eliminating variation due to stature and cervicale height were almost identical for most measurements.

The partial correlations, holding waist height constant showed smaller correlations with the lower body measurements as compared to the partial correlations, holding stature constant. Waist height controlled the variation of the lower body measurements more than stature did as shown by the smaller residual standard deviations of the lower body measurements when variation due to waist height was eliminated.

Aside from just holding waist height constant, second order partial correlations with cervicale to waist anterior held constant were computed to see if further improvements on the correlations values could be made such that the combination of these two measurements could be comparable to stature. The correlation with the lower body measurements were further reduced, however, the other correlation coefficients were almost identical and some greater than the partial correlations, holding stature constant. The residual standard deviations for these two sets showed very little differences.

From among these measurements, stature was considered as the most practical choice to be the control for the vertical measurements. Although the other three measurements also showed the same degrees of relationship with the other vertical measurements as stature, the advantage that stature had over them was that women generally know their stature than their waist or cervicale heights. Also, stature is more easily measured on a fully clothed woman than either of the two heights.

TABLE 6. SIMPLE STANDARD DEVIATIONS OF 24 VERTICAL MEASUREMENTS OF 12,024 WOMEN, AND RESIDUAL STANDARD DEVIATIONS AFTER ELIMINATING VARIATIONS DUE TO EACH OF FOUR MEASUREMENTS.

Measurement	*Simple Standard Deviation*	*Residual Standard Deviations*			
		Stature	*Cervicale Height*	*Waist Height*	*Waist Height and Length of Cervicale to Waist Anterior*
Stature	5.1839	–	1.7954	2.4972	2.1210
Cervicale height	4.8632	1.6843	–	2.4169	2.1371
Bust height	4.6993	2.6544	2.7880	2.9003	2.7782
Waist height	4.1166	1.9831	2.0458	–	–
Abdominal ext. height	3.9996	2.2419	2.2956	2.0964	2.0762
Hip height	3.6622	2.2297	2.2636	2.0727	2.0594
Sitting spread height	3.9750	2.9752	2.9990	2.9302	2.9101
Crotch height	3.4398	2.2368	2.2717	2.0873	2.0818
Tibiale height	2.2717	1.6705	1.6718	1.6362	1.6205
Total posterior arm length	2.5481	1.8217	1.8012	1.8359	1.7873
Upper arm length	1.6622	1.3197	1.3116	1.3306	1.3069
Anterior arm length	2.3215	1.8244	1.8250	1.8582	1.8435
Vertical trunk girth	6.6499	5.7627	5.6973	5.9937	5.1704
Cervicale to waist anterior	2.3942	2.1871	2.2112	2.3557	–
Anterior waist length	2.2235	2.1000	2.1109	2.2137	1.5175
Shoulder to waist	2.4075	2.2516	2.2619	2.3757	1.7376
Neck to bust	2.6161	2.5979	2.5867	2.6051	2.5441
Posterior waist length	2.2877	2.0896	2.0319	2.2342	2.0263
Scye depth	1.7710	1.7269	1.6973	1.7394	1.6981
Trunk line	1.8564	1.8030	1.8054	1.8560	1.7126
Arm to scye	1.2344	1.2118	1.2057	1.2127	1.1766
Waist to hip	2.0784	1.9656	1.9716	1.9074	1.9069
Total crotch length	5.0762	4.7302	4.7089	4.5790	4.5302
Anterior crotch length	3.1623	3.0345	3.0218	2.9895	2.9703

C. Stature-Weight Systems

As shown in the discussions on horizontal and vertical measurements, weight and stature were selected as indices for these two sets of measurements, respectively. Table 7 gives the figures required to set up a system based on stature and weight. From the three columns of figures, the body measurements corresponding to any given height and weight could be calculated.

The figures in column 1 give the average dimensions of a woman 150 centimeters tall and weighing 45 kilograms. The values, 150 centimeters and 45 kilograms, have been used because they represent the stature and weight, respectively, of the average woman. Column 2 shows how much, on the average, each measurement must be increased to give the dimensions of a woman 10 centimeters taller but with the same weight. This woman is slimmer than the woman represented by the dimensions in column 1. Her vertical measurements are generally smaller, with a few showing increases of less than one centimeter. The algebraic sum of columns 1 and 2 is the average measurements of this woman, 160 centimeters tall and weighing 45 kilograms.

Column 3 shows how much, on the average, each measurement must be increased to give the dimensions of a woman 4 kilograms heavier but with the same stature as in column 1. This woman is stouter, with increases of 3.37 centimeters in the bust girth and 2.88 centimeters in the hip girth. The algebraic sum of columns 1 and 3, represents the average measurements of this woman, 150 centimeters tall and weighing 49 kilograms.

Measurements of any given height and weight could be derived by combining all the three columns. For example, the measurement of a woman 170 centimeters tall and weighing 35 kilograms is desired. Since 170 centimeters is greater than the base figure of 150 centimeters, twice the value in column 2 is added to column 1. The weight of 55 kilograms is greater by 10 kilograms from the base figure of 45 kilogrms, thus, the figure in column 3 multiplied by 2.5 is the increase (or decrease) in the measurements due to the 10 kilogram increase in weight. These values are then added to the result of summing columns 1 and 2.

TABLE 7. SYSTEM OF WOMEN'S BODY MEASUREMENTS BASED ON STATURE AND WEIGHT.

Measurement	*Value Corresponding to Stature 150 cm. and Weight 45 Kgs.*	*Increase (or Decrease) in Value for Each*	
		10-Centimeter Increase (or Decrease) in Stature	*4-Kilogram Increase (or Decrease) in Weight*
	Kilograms	Kilograms	Kilograms
Weight	45.00	0.00	4.00
Vertical measurements:	Centimeters	Centimenters	Centimeters
Stature	150.00	10.00	0.00
Cervicale height	127.75	8.59	0.14
Bust height	106.90	7.66	−0.12
Waist height	94.82	6.87	0.06
Abdominal extension height	85.31	6.62	−0.16
Hip height	75.19	5.70	−0.07
Sitting spread height	66.09	5.30	−0.14
Crotch height	66.28	5.36	−0.22
Tibiale height	40.41	2.97	0.00
Total posterior arm length	56.20	3.14	0.20
Upper posterior arm length	31.64	1.78	0.12
Anterior arm length	41.45	2.93	−0.11
Vertical trunk girth	138.29	2.56	2.59
Cervicale to waist anterior	43.82	0.99	0.60
Anterior waist length	28.92	0.93	0.33
Shoulder to waist length	35.45	0.93	0.48
Neck to bust	24.87	−0.28	0.59
Posterior waist length	34.82	1.39	0.27
Scye depth	15.96	0.27	0.33
Trunk line	17.46	1.01	−0.10

TABLE 7 (Cont'd.)

Measurement	*Value Corresponding to Stature 150 cm. and Weight 45 Kgs.*	*Increase (or Decrease) in Value for Each*	
		10-Centimeter Increase (or Decrease) in Stature	*4-Kilogram Increase (or Decrease) in Weight*
Arm to scye length	11.69	0.03	0.28
Waist to hip length	20.52	1.06	0.16
Total crotch length	67.67	0.89	1.79
Anterior crotch length	34.95	0.35	0.92
Horizontal measurements:	Centimeters	Centimenters	Centimeters
Chest girth at armscye	80.58	−1.54	2.75
Bust girth	82.14	−2.51	3.37
Waist girth	68.13	−3.51	3.60
Abdominal extension girth	80.80	−3.17	3.87
Hip girth	85.24	−0.19	2.88
Sitting spread girth	82.05	−0.63	3.12
Maximum thigh girth	49.21	−0.98	2.23
Midway thigh girth	43.62	−1.13	1.97
Bent knee girth	33.30	0.27	1.06
Knee girth at tibiale	32.43	0.11	1.05
Maximum calf girth	31.50	−0.21	1.12
Ankle girth	22.92	0.54	0.36
Neckbase girth	36.69	−0.03	0.70
Armscye girth	35.64	−0.48	1.30
Upperarm girth	26.25	−1.28	1.45
Elbow girth	25.08	−0.18	0.78
Forearm girth	22.96	−0.33	0.79
Wrist girth	14.68	0.08	0.28
Shoulder length	11.02	0.45	0.08
Anterior chest width	29.14	0.46	0.51
Posterior chest width	34.16	−0.14	0.68
Anterior bust arc	44.25	−1.28	2.01
Anterior waist arc	36.96	−2.47	2.25
Abdominal extension arc	43.96	−2.20	2.32
Posterior hip arc	42.31	0.01	1.43
Angle:	Degrees	Degrees	Degrees
Shoulder slope	21.73	0.19	0.08

D. Stature-Girth Systems

If practical considerations make it impossible to use weight as control measurement, alternative sizing schemes may be considered. These alternative controls to weight were selected from the trunk girth measurements, which were also highly correlated with the other horizontal measurements. Chest and bust girths were highly correlated with each other and showed similar relations with the other measurements. The same was true for the hip and sitting spread girths, and waist and abdominal extension girths. So, based on what was known about the trunk girths, three measurements were selected as alternative to weight. These were bust, waist and hip girths which were measurements in common use and could be easily and accurately measured on a fully clothed woman.

Table 8 shows how accurately each of these three measurements together with stature predicts the remaining 49 measurements and how they compare with the stature-weight combination. No difference was seen in the heights and arm lengths for the combinations, since these measurements largely depended on stature. For the six trunk girths, stature and weight were the only combination where the correlations were all greater than 0.80. Each of the other combinations had at least two lower values than this figure. The stature and weight combination also had a higher correlation with the arm girths than the other three alternative schemes. For the lower body girths and leg girths, the hip-stature combination was just as good as the weight-stature combination in predicting these measurements.

Among the alternatives to stature and weight, no single combination was as good a predictor for all horizontal measurements. Stature-bust and stature-waist were good indicators of the upper trunk and arm girths but poor indicators of the lower trunk and leg girths. Stature-hip was best for the lower body girths and leg girths but a poor indicator of the upper trunk and arm girths.

A disadvantage that can be seen with the use of these alternative schemes is that measurements on which sizing is based tend to increase faster in relation to the other measurements. With bust girth as control, a 6-centimeter increase in bust girth calls for the increase of 5.31 centimeters in waist and 3.66 centimeters in hip. In sizing

TABLE 8. MULTIPLE CORRELATIONS OF 50 MEASUREMENTS WITH STATURE AND EACH OF FOUR OTHER MEASUREMENTS FOR 12,024 WOMEN.

Measurement	*Multiple Correlations*			
	Stature and weight	*Stature and bust girth*	*Stature and waist girth*	*Stature and hip girth*
Weight	–	.8679	.8809	.8939
Stature	–	–	–	– –
Cervicale height	.9363	.9391	.9395	.9390
Bust height	.8263	.8262	.8293	.8258
Waist height	.8766	.8766	.8765	.8766
Abdominal extension height	.8307	.8305	.8308	.8306
Hip height	.7939	.7940	.7934	.7947
Sitting spread height	.6657	.6659	.6643	.6656
Crotch height	.7667	.7632	.7636	7701
Tibiale height	.6777	.6780	.6782	.6778
Total posterior arm length	.7107	.7135	.7148	.7068
Upper posterior arm length	.6187	.6195	.6232	.6151
Anterior arm length	.6229	.6199	.6207	6240
Vertical trunk girth	.8090	.7579	.7848	.7895
Cervicale to waist anterior	.5789	.5663	.6004	.5462
Anterior waist length	.4070	.4041	.3919	.3904
Shoulder to waist length	.4822	.5024	.4574	.4593
Neck to bust	.3859	.3926	.4515	.3267
Posterior waist length	.5299	.4435	.4589	.4447
Scye depth	.3781	.3590	.3891	.3541
Trunk line	.2555	.2647	.2536	.2541
Arm to scye length	.4205	.4061	.4239	.3684
Waist to hip length	.3500	.3485	.3348	.3666
Total crotch length	.6826	.6175	.6322	.6881
Anterior crotch length	.5548	.5104	.5297	.5331
Chest girth at armscye	.8578	.8830	.8466	.7727
Bust girth	.8453	–	.8519	.7535
Waist girth	.8553	.8488	–	.7691
Abdominal extension girth	.8236	.7976	.8745	.7819
Hip girth	.8872	.7813	.7992	–
Sitting spread girth	.8364	.7151	.7130	.8735
Maximum thigh girth	.8433	.7151	.7000	.8711
Midway thigh girth	.7820	.6410	.6227	.7726
Bent knee girth	.7338	.6299	.6314	.7346

TABLE 8. MULTIPLE CORRELATIONS OF 50 MEASUREMENTS WITH STATURE AND EACH OF FOUR OTHER MEASUREMENTS FOR 12,024 WOMEN.

Measurement	*Multiple Correlations*			
	Stature and weight	*Stature and bust girth*	*Stature and waist girth*	*Stature and hip girth*
Knee girth at tibiale	.7411	.6220	.6281	.7292
Maximum calf girth	.7765	.6464	.6315	.7361
Ankle girth	.5316	.4869	.4866	.4947
Neckbase girth	.5558	.5288	.5336	.5022
Armscye girth	.7445	.7043	.7249	.6887
Upperarm girth	.8558	.7858	.7925	.7998
Elbow girth	.7277	.6610	.6673	.6715
Forearm girth	.7858	.6935	.6811	.7160
Wrist girth	.6692	.6064	.6130	.5996
Shoulder length	.2994	.3004	.2989	.2937
Anterior chest width	.5421	.5331	.5135	.5096
Posterior chest width	.5299	.5645	.5246	.4798
Anterior bust arc	.7278	.8261	.7276	.6549
Anterior waist arc	.7744	.7579	.8861	.6903
Abdominal extension arc	.7545	.7296	.8154	.7013
Posterior hip arc	.6710	.5824	.5916	.7583
Shoulder slope	.0562	.0589	.0462	.0604

with waist girth as control, increases of 4.85 centimeters in bust and 3.60 centimeters in hip are called for by a 6.0 centimeter increase in waist girth. With hip girth as control, 6.0 centimeters increase in hip girth would increase the bust by 5.42 centimeters and waist by 5.84 centimeters. These increases are not in proportion to each other. Bust girth increases faster in relation to the other measurements in the first case, waist girth has larger increases than the other measurements in the second case, and hip girth increases faster than the other measurements in the third alternative. For the stature-weight system, the over-emphasis is on weight. But since weight is not used in any garment measure, this system provides well-balanced increases in the body measurements.

Summary and Conclusion

Data consisting of 51 measurements of 12,024 Filipino women with ages 18 to 65 years were used as basis for designing a sizing system. Correlation and principal component analyses were applied on the horizontal and vertical measurements to select controls representing each group of measurements. The measurement representative of the horizontal measurements was weight. Stature was selected as index for the vertical measurements. Stature and weight were used as basis for designing a sizing system for women. Measurements of women for any stature and weight combination could be obtained (Table 7).

Three other sizing schemes were considered with bust, waist and hip girths as alternatives for weight. These alternatives showed some disadvantages. None of the three in combination with stature was as good a predictor of the entire set of horizontal measurements composed of the weight-stature combination. Waist-stature and bust-stature were good predictors of the upper trunk and arm girths but poor predictors of the lower trunk and leg girths. The opposite was for hip stature. A comparison of these sizing schemes showed that increases in the measurements were not in proportion to each other. The measurement that was used as control tend to increase more rapidly in relation to the other measurements.

The weight-stature combination was a better predictor compared to the other alternative schemes. It did not possess the disadvantages presented by the other sizing systems. Since weight was not used in any garment measure, the over-emphasis given on weight as a control did not pose any problem. The system provided well-balanced increases in the measurement. Hence, among the alternative schemes presented, the weight-stature combination was considered the best.

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Appendix A

Body measurements taken on a sample of 12,024 Filipino Women.

1. Weight

Vertical measurements:

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

Horizontal Measurements:

26. Chest girth at armscye
27. Bust girth
28. Waist girth
29. Abdominal-extension girth
30. Hip girth
31. Sitting-spread girth
32. Maximum thigh girth
33. Midway thigh girth
34. Bent-knee girth
35. Knee girth at tibiale
36. Maximum calf girth
37. Ankle girth
38. Neckbase girth
39. Armscye girth
40. Upperarm girth
41. Elbow girth
42. Forearm girth
43. Wrist girth
44. Shoulder length
45. Anterior chest width
46. Posterior chest width
47. Anterior bust arc
48. Anterior waist arc
49. Abdominal extension arc
50. Posterior hip arc
51. Shoulder girth