A Note on the Classification of Human Physique

by Principal Component Analysis*

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INTRODUCTION

Human physique has so far been evaluated under various hypothetic systems (SHELDON et al., '40, '54; DAMON et al., '62; LINDEGARD, '53; BURT, '47; HAMMOND '53; EYSENCK, '45, '59; SELTZER, '46; BEHNKE et al., '59, BEHNKE, '59, '61; HEATH, '63; HEATH et al., '66). These approaches, it seems, dealt mostly with "morpho-genotype" and tried to represent a permanent characteristic of an individual (TANNER, '51), though it is quite difficult to sort off genotypes from phenotypes. Be that as it may be, we felt the necessity of more comprehensive and statistically efficient evaluation of human physique in such cases as to assure the correct sizing of ready-made garments. We want more encompassing method of analysis of anthropometric data.

An answer to the problem may be given by a method of principal component analysis. Principal component analysis is a branch of multivariate analysis dealing with the internal structure of covariance and correlation matrices. It has not only objectivity and high efficiency in estimation, but also, according to LAWLEY and MAXWELL ('63), the property that the roots are extracted in descending order of magnitude, which is important to summarize the data into a few components possible. Such a method, therefore, seems to be most favourable for the present purpose intended to find the best and the fewest indicators of human physique. This method has been widely used in the field of psychology or biology. Little attention of anthropologists, however, has so far been invited to the utility of the method.

Recently, MASUDA ('65) applied principal component analysis to the anthropometric data and suggested the efficiency of the method from the mathematical point of view. He used the data from 256 soldiers of National Defence Force in Japan. It seemed to be valuable as well as interesting to re-examine the analysis on the female data. An object of this report is to describe human physiques in quantitative terms of the principal components obtained from 200 Japanese

* A part of this work was presented at the 21st Joint Meeting of the Anthropological Society of Nippon and the Japanese Society of Ethnology held at Nagasaki in October, '66.

female students. Further object of the report is to compare the present results obtained with the results of MASUDA.

MATERIAL AND METHOD

The investigation was carried out from June to July in 1964. The items measured were determined after due consideration for leading garment manufactures and their patterns. The measuring technique was principally based on the instruction proposed by U. S. Department of Agriculture, Bureau of Home Economics ('41). Body length, width and depth were measured by a MARTIN anthropometer, and girth by a steel tape. Only shoulder slope was estimated from photographs.

Table 1. Body dimensions of 200 Japanese female university students.

Measurement	Mean	Standard deviation
Cervical height	130.38cm	4.31cm
Bust height	109.23	4.05
Hip height	75.98	3.35
Posterior sleeve length	48.87	2.09
Side length	97.19	3.65
Sitting cervical height	60.84	2.13
Posterior waist length	37.92	1.67
Anterior waist length	37.21	1.54
Cervical to bust point	32.57	1.63
Arm scye depth	17.96	1.31
Biacromial breadth	35.84	1.21
Shoulder width	39.23	1.57
Posterior chest width	34.92	1.86
Anterior chest width	31.57	1.52
Bust breadth	26.44	1.38
Waist breadth	21.77	1.25
Hip breadth	31.59	1.38
Bust depth	20.27	1.44
Waist depth	15.19	1.16
Hip depth	22.01	1.63
Neck base girth	36.43	1.04
Arm scye girth	34.84	1.67
Bust girth	81.78	4.15
Waist girth	60.69	3.32
Abdominal extension girth	82.11	4.22
Hip girth	89.15	3.74
Crotch length	67.27	2.78
Vertical trunk girth	143.54	4.21
Weight	49.38kg	4.87kg
Shoulder slope	26.35°	3.65°

Each subject was allowed to wear a swimming suit and a cap knitted of wooly nylon which fit the body snugly but not tightly.

Photographs in the three—front, back and side—standardized poses were also taken on each subject. The subject, stood on a turn table with a gray sheet as a backdrop, was photographed with a 35mm camera fitted with a 55mm lens from a 10m distance.

The subjects comprised 200 healthy university women in Tokyo. The age ranged in 99% from 18 to 25 years. The means and standard deviations of 30 measurements were given in table 1. The present series were not essentially different in height from the average Japanese women but somewhat lighter in body weight (significant at less than 1% level).

A brief outline and practical procedure of principal compo-

Table 2. Correlations among 30 measurements of 200 Japanese female students.

Measurement	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30		
Cervical height	1	1.000																													1	
Bust height ₁	2	.935	1.000																												2	
Hip height	3	.848	.832	1.000																											3	
Posterior sleeve length	4	.808	.749	.801	1.000																										4	
Side length	5	.932	.900	.869	.802	1.000																									5	
Sitting cervical height	6	.715	.622	.447	.438	.571	1.000																								6	
Posterior waist length	7	.587	.468	.304	.363	.326	.689	1.000																							7	
Anterior waist length	8	.455	.398	.408	.403	.345	.375	.331	1.000																						8	
Cervical to bust point	9	.272	.012	.206	.333	.250	.236	.203	.381	1.000																					9	
Arm scye depth	10	.260	.057	.107	.243	.203	.218	.387	-.026	.327	1.000																				10	
Biacromial breadth	11	.501	.410	.422	.538	.451	.368	.341	.293	.434	.309	1.000																			11	
Shoulder width	12	.396	.294	.264	.340	.359	.323	.294	.098	.444	.334	.821	1.000																		12	
Posterior chest width	13	.186	.084	.137	.295	.154	.185	.194	.102	.403	.196	.547	.646	1.000																	13	
Anterior chest width	14	.239	.177	.234	.287	.267	.110	.029	.353	.310	.232	.473	.338	.180	1.000																14	
Bust breadth	15	.052	-.019	.053	.207	.055	-.004	.039	.186	.330	.139	.430	.353	.628	.265	1.000															15	
Waist breadth	16	.188	.056	.190	.331	.168	.101	.187	.193	.472	.245	.451	.357	.515	.318	.706	1.000														16	
Hip breadth	17	.381	.275	.275	.439	.388	.275	.272	.303	.468	.318	.487	.406	.407	.391	.486	.585	1.000													17	
Bust depth	18	.057	-.080	.105	.197	.100	.017	.010	.393	.602	.247	.293	.203	.402	.394	.512	.595	.481	1.000												18	
Waist depth	19	.149	.036	.119	.239	.165	.079	.072	.214	.448	.162	.291	.270	.381	.359	.509	.649	.425	.585	1.000											19	
Hip depth	20	.105	.031	.108	.240	.122	.039	.055	.239	.310	.153	.214	.097	.327	.243	.497	.597	.478	.572	.599	1.000										20	
Neck base girth	21	.363	.256	.308	.427	.332	.227	.234	.293	.547	.187	.581	.536	.444	.351	.469	.530	.513	.382	.476	.387	1.000									21	
Arm scye girth	22	.209	.123	.186	.336	.206	.133	.143	.350	.461	.209	.336	.232	.504	.298	.610	.584	.540	.588	.506	.565	.480	1.000								22	
Bust girth	23	.109	-.017	.142	.271	.130	.040	.080	.380	.584	.245	.430	.343	.595	.409	.764	.732	.579	.867	.661	.607	.496	.700	1.000							23	
Waist girth	24	.175	.034	.167	.317	.172	.092	.127	.246	.532	.240	.388	.341	.536	.389	.674	.882	.587	.668	.851	.635	.567	.665	.786	1.000						24	
Abdominal extension girth	25	.231	.087	.188	.387	.239	.051	.180	.307	.518	.328	.425	.319	.439	.373	.662	.768	.733	.670	.651	.646	.532	.622	.761	.787	1.000					25	
Hip girth	26	.295	.164	.186	.383	.291	.237	.255	.311	.506	.352	.437	.355	.500	.386	.602	.694	.882	.620	.578	.668	.540	.645	.722	.721	.849	1.000				26	
Crotch length	27	.296	.182	.057	.177	.291	.447	.248	.084	.389	.311	.245	.226	.260	.242	.248	.346	.484	.347	.356	.455	.307	.424	.347	.403	.413	.607	1.000			27	
Vertical trunk girth	28	.554	.451	.290	.385	.416	.659	.584	.538	.440	.191	.383	.276	.308	.244	.331	.390	.530	.355	.376	.437	.429	.483	.423	.422	.460	.620	.744	1.000		28	
Weight	29	.447	.306	.354	.495	.423	.319	.330	.459	.593	.334	.522	.401	.558	.450	.653	.726	.770	.685	.653	.690	.620	.762	.798	.789	.830	.901	.578	.687	1.000	29	
Shoulder slope	30	.079	-.013	-.003	.047	.057	.092	.147	-.194	.189	.355	.123	.224	-.110	-.009	-.235	-.115	-.051	-.126	-.112	-.207	.103	-.188	-.185	-.124	-.151	-.106	-.018	-.125	-.115	1.000	30

nent analysis* are given below.

A covariance or correlation matrix among the p observed variates, $x_1, x_2, \dots, x_p$, can be translated into a new set of orthogonal, uncorrelated, standardized components, $y_1, y_2, \dots, y_p$. The translation is made so that y_1 has maximum variance, y_2 has maximum variance subject to being uncorrelated with y_1 , y_3 has maximum variance subject to being uncorrelated with y_1 and y_2 , and so on. The basic equations in this method are

$$x_i = \sum_{j=1}^p w_{ij} y_j \quad (i=1, 2, \dots, p) \dots\dots\dots (1)$$

where y_j is the j th component and w_{ij} the weight of the j th component in the i th variate. And y_j corresponds to the j th latent root taken in order of magnitude, and w_{ij} corresponds to the accompanying latent vector of the correlation matrix.

The practical procedures of analysis in this study are as follows:**

1. The correlation matrix among 30 measurements is calculated.
2. The latent roots and the accompanying standardized latent vectors of the correlation matrix are calculated.
3. The proportion of the variance of the first q principal components to the total variance is expressed as $\frac{\sum_{i=1}^q \lambda_i}{\sum_{i=1}^{30} \lambda_i} \times 100\%$, where λ_i equals to the i th latent root.
4. The j th principal component score of an individual is given by the following equation,

$$y_j = \sum_{i=1}^{30} w_{ij} x_i, \quad (j=1, 2, \dots, 30) \dots\dots\dots (2)$$

where y_j is the j th principal component, w_{ij} i th coefficient of the j th latent vector, x_i the i th measurement nomalized.

5. The contribution ratio of the j th principal component to the i th measurement is expressed by

$$\lambda_i w_{ij}^2 \times 100\% \quad (i, j=1, 2, \dots, 30) \dots\dots\dots (3)$$

6. The i th measurement can be estimated by the first q principal components from the equation

$$x_i = \sum_{j=1}^q w_{ij} y_j \quad (i=1, 2, \dots, 30) \dots\dots\dots (4)$$

RESULT

The correlation matrix among 30 measurements is given in table 2. It was factorized by using principal component analysis. Table 3 shows the largest three latent roots and the corresponding nomalized latent vectors, which correspond to the coefficients of 30 measurements for the first three principal com-

* More detailed mathematical descriptions are to be referred to the statistical textbooks or reports e. g. by ANDERSON('58), LAWLEY and MAXWELL('63), OKUNO and MASUDA('64).

** All the calculations were done on I. B. M. 7090 Electronic Computer.

Table 3. Comparison of coefficients of 30 measurements
in the first three principal components.

Measurement	The present result			MASUDA's result		
	1st P. C.	2nd P. C.	3rd P. C.	1st P. C.	2nd P. C.	3rd P. C.
Stature				0.327	-0.206	0.050
Cervical height	0.159	-0.364	-0.063	0.325	-0.205	0.055
Bust height	0.114	-0.378	-0.156			
Waist height				0.297	-0.253	0.040
Hip height	0.130	-0.311	-0.138			
Crotch height				0.261	-0.308	0.012
Posterior sleeve length	0.175	-0.254	-0.059			
Yuki				0.296	-0.167	-0.040
Hand length				0.258	-0.204	0.094
Side length	0.149	-0.331	-0.090			
Sitting height				0.260	-0.131	-0.017
Sitting cervical height	0.119	-0.293	-0.003			
Posterior waist length	0.112	-0.225	0.089			
Anterior waist length	0.138	-0.111	-0.279			
Cervical to bust point	0.187	0.041	0.181			
Shoulder depth				0.114	0.311	-0.224
Arm scye depth	0.108	-0.036	0.351			
Biacromial breadth	0.190	-0.113	0.306			
Posterior shoulder width	0.158	-0.085	0.451	0.205	-0.108	-0.366
Posterior chest width	0.176	0.074	0.216	0.168	0.091	-0.537
Anterior chest width	0.142	0.003	0.056	0.098	0.070	0.650
Bust breadth	0.190	0.187	0.010			
Waist breadth	0.221	0.150	0.016			
Hip breadth	0.223	0.018	0.005			
Bust depth	0.195	0.188	-0.070			
Waist depth	0.193	0.154	-0.059			
Hip depth	0.183	0.158	-0.202			
Neck base girth	0.199	-0.005	0.157	0.141	0.257	-0.219
Arm scye girth	0.208	0.115	-0.115			
Bust girth	0.229	0.195	-0.033	0.232	0.317	0.069
Waist girth	0.232	0.174	-0.021	0.200	0.338	0.117
Abdominal extension girth	0.235	0.143	-0.048			
Hip girth	0.245	0.098	-0.041	0.269	0.259	0.078
Maximum thigh girth				0.173	0.375	0.094
Crotch length	0.162	0.000	-0.030			
Vertical trunk girth	0.201	-0.105	-0.156			
Weight	0.270	0.051	-0.076	0.317	0.246	0.078
Shoulder slope	-0.021	-0.098	0.478			
Latent root	12.308	4.875	1.981	7.34	2.95	1.49
Percentage variance (%)	41.03	16.25	6.60	43.2	17.3	8.8
Cumulative percentage variance (%)	41.03	57.28	63.88	43.2	60.5	69.3

Table 4. Comparison of contribution ratios of the first three principal components to each measurement.

Measurement	The present result				MASUDA's result			
	1st P. C.	2nd P.C.	3rd P.C.	Total	1st P. C.	2nd P.C.	3rd P.C.	Total
Stature					78.0	12.5	0.4	90.9
Cervical height	31.1	64.7	0.8	96.6	77.5	12.4	0.5	90.4
Bust height	16.0	69.7	4.9	90.6				
Waist height					64.8	18.9	0.2	83.9
Hip height	20.8	47.2	3.8	71.8				
Crotch height					50.0	28.0	0.0	78.0
Posterior sleeve length	37.7	31.5	0.6	69.8				
Yuki					64.3	8.2	0.2	72.7
Hand length					48.9	12.3	1.3	62.5
Side length	27.3	53.5	1.6	82.4				
Sitting height					49.2	5.1	0.0	54.3
Sitting cervical height	17.5	41.9	0.0	59.4				
Posterior waist length	15.4	24.7	1.5	41.6				
Anterior waist length	23.4	6.0	15.4	44.8				
Cervical to bust point	43.1	0.8	6.5	50.4				
Shoulder depth					9.5	28.5	7.5	45.5
Arm scye depth	14.4	0.6	24.4	39.4				
Biacromial breadth	44.4	6.3	18.5	69.2				
Posterior shoulder width	30.8	3.5	40.3	74.6	30.9	3.4	20.0	54.3
Posterior chest width	38.2	2.6	9.3	50.1	20.7	2.4	43.0	66.1
Anterior chest width	24.9	0.0	0.6	25.5	7.1	1.5	63.0	71.6
Bust breadth	44.4	17.1	0.0	61.5				
Waist breadth	60.1	11.0	0.0	71.1				
Hip breadth	61.2	0.1	0.0	61.3				
Bust depth	46.8	17.2	1.0	65.0				
Waist depth	45.8	11.6	0.7	58.1				
Hip depth	41.2	12.2	8.1	61.5				
Neck base girth	48.8	0.0	4.8	53.6	14.6	19.5	7.2	41.3
Arm scye girth	53.3	6.4	2.7	62.4				
Bust girth	64.5	18.5	0.3	83.3	39.1	29.6	0.7	69.4
Waist girth	66.2	14.8	0.1	81.1	29.4	33.7	2.0	65.1
Abdominal extension girth	68.0	9.9	0.5	78.4				
Hip girth	73.9	4.6	0.4	78.9	53.1	19.8	0.9	73.8
Maximum thigh girth					22.0	41.5	1.3	64.8
Crotch length	32.3	0.0	0.1	32.4				
Vertical trunk girth	49.7	5.4	4.8	59.9				
Weight	89.7	1.3	1.2	92.2	74.2	17.9	0.9	93.0
Shoulder slope	0.5	4.7	45.2	50.4				

ponents. For instance the score of the first principal component y_1 for an individual is given by the following equation,

$$y_1 = 0.159x_1 + 0.114x_2 + \cdots + (-0.021)x_{30},$$

where $x_1, x_2, \dots, x_{30}$ denote 30 nomalized* measurements for the individual. The percentages of the variances accounted for by each principal component to the total variance and cumulative percentages of them (refer to procedure 3) are also listed in table 3.

Nature of the principal components

As shown in table 3, the first, the second and the third principal components covered approximately 41.0%, 16.3%, 6.6% and the sum of these three reached 63.9% of the total variance, respectively.

The interpretation of each principal component was made mainly on the basis of the coefficients of the measurements and also by reference to the photographs of individuals.

The first principal component: It is seen from table 3 that almost all the coefficients in the first principal component are positive. According to JOLICOEUR and MOSIMAN ('60), the first principal component for which all the coefficients are positive is designated as a size factor. One exceptional measurement, shoulder slope, is an angle measurement, and seems to contribute scarcely to the size of a human body. In addition, it's coefficient is very close upon zero. The component can, therefore, be considered to be a size factor implying the size of a human physique. This is also confirmed by the photographs in figure 1, which shows the variation of human physiques with the change of the first principal compo-

Figure 1. Variation of physique with the change of the first principal component: The first principal component score, stature, body weight and hip girth for subject A are -9.2 , 151.0cm , 37.0kg and 78.0cm , for subject B are -0.1 , 158.2cm , 49.0kg and 87.0cm , and for subject C are 9.5 , 164.0cm , 63.0kg and 100.0cm , respectively.

* Nomalized measurement x_i was computed from $x_i = \frac{X_i - \bar{X}_i}{s_i}$. It is thus ratio of the distance of the individual measurement (X_i) from the sample mean ($\bar{X}_i$), to the standard deviation (s_i).

nent. The contribution ratios in table 4 (refer to procedure 5) signify how greatly the variation of each measurement is accounted for by each principal component and the first three principal components. It will be seen from the table that the first principal component contributes more to girths and breadths than to lengths. The contribution ratio of this component to body weight is the highest (89.7%) of all measurements and makes it possible to assume body weight to be the best and the most efficient indicator of the component.

The second principal component: From table 3, it is easily noticed that the coefficients in length measurements contrast clearly to those in girth measurements. The coefficients of length measurements are negative, while those of girth measurements are positive. An individual excelling in length measurements rather than in girth measurements, *viz. lean type*, will have smaller score in the second principal component, and conversely, *obese type* will have larger score. It is held that a component in which coefficients of some measurements are positive and those of others negative expresses a shape of a human physique. The component is generally called a shape factor. The second principal component is, therefore, postulated for as a shape factor which represents lean-obese relation of a human physique. The variation of physiques shown in figure 2 confirms the view that the second principal component would be intimately associated with the body shape concerning lean-obese type. The contribution ratios of the second principal component in table 4 appears to be higher in length measurements than in girth and breadth measurements.

The third principal component: This is also a shape factor. The measurements showing relatively higher contribution ratio ($>25\%$) in table 4 are shoulder slope, posterior shoulder width, arm scye depth, biacromial breadth and an-

Figure 2. Variation of physique with the change of the second principal component: The second principal component score, stature, body weight and hip girth for subject A are -6.8 , 167.6cm , 54.0kg and 91.5cm , for subject B are -0.8 , 158.0cm , 55.5kg and 94.0cm , and for subject C are 5.5 , 147.9cm , 56.7kg and 99.0cm , respectively.

terior waist length. Among them, the coefficient of anterior waist length is alone negative. An individual with wide, sloping and forward projecting shoulders is to have a larger score in this component. Figure 3 illustrates the effect of this component on human physiques. The component may be interpreted as a shape

Figure 3. Variation of physique with the change of the third principal component: The third principal component score, shoulder slope, and shoulder width for subject A are -3.5 , 21.2° and 36.0cm , for subject B are 0.3 , 28.1° , and 39.0cm , and for subject C are 3.2 , 31.4° , and 42.5cm , respectively.

Figure 4. Bivariate distribution diagram of the first and the second principal components for 200 women. A point corresponds to an individual. The first principal component score of an individual is given on the abscissa and the second principal component score on the ordinate.

Figure 5. Variation of physiques with the change of the first and the second principal components. The component scores for subjects from A to G are given in figure 4.

factor expressing the shoulder shape of a human physique. This interpretation, however, is not so clearly defined as the first or the second principal component, because the measurements such as bust height, hip height, hip depth and vertical trunk girth in which fairly high coefficients are shown in negative direction ($>10\%$) could not be sufficiently interpreted. This problem should be checked in future researches.

The fourth and other components were omitted, since the proportion of each variance to the total variance was small, and these components seemed to be very questionable as criterions in human physique.

Now let us consider about classifying human physiques in terms of the first two or three principal components. Figure 4 is the bivariate distribution diagram of the first two principal components for 200 subjects.* Each subject is

* The scores of the principal components for an individual were calculated from the equations in procedure 4.

expressed by a point in figure 4. The configurations of subjects from A to G are given by means of the photographs in figure 5. As shown in figure 5, the physiques of the subjects vary clearly and regularly in size in the direction of vertical line and in lean-obese relation in the direction of horizontal line. Human physique can be classified in quantitative terms of the size and the lean-obese relation through dividing the diagram properly. Similarly, it will be classified in terms of the size, the lean-obese relation and the shoulder shape through dividing the 3-dimension space of the first three principal components.

DISCUSSION

In order to check the reliability of each component obtained, the present results were compared with the results of MASUDA.*

(1) As to the first and the second principal components, a perfect accordance was found between the two studies. The first principal component was regarded in both studies as a size factor, the best and the most efficient indicator of which would be body weight (contribution ratios of body weight were 89.7% for the present series and 74.2% for MASUDA's). The second principal component meant a shape factor expressing lean-obese relation of a human physique. The interpretation of these two components were also confirmed from the result by HAMMOND ('53). He, applying factor analysis to the measurements of 2967 children in Britain, concluded that the general factor for physical size indicated a general tendency to be above or below average for age in all measurements and weight was the best indicator of general size, and the first type factor was pachysome-leptosome dichotomy.

(2) As to the third principal component, the interpretations differed slightly each other. MASUDA remarked "The third principal component expresses that the shape of the human body is either of the slouching type or of that of the chest thrown out." The component in the present study seemed to express whether shoulders are wide, sloping and forward projecting or not. HAMMOND considered the second type factor, which corresponded to the third principal component in principal component analysis, as a type factor showing a tendency to develop the trunk or limbs for girls. And it is interesting that the second type factor of HAMMOND had the same interpretation as the fourth principal component of the present study, which was omitted in this paper.

(3) It will be noticed from table 4 that in the results of MASUDA the first principal component related mainly to weight and lengths, while in the present results it related to weight, girths and breadths. Measurements, the contribution

* The subjects used in his study comprised 256 soldiers of National Defence Force in Japan (mean age is about 25 years), and only 17 measurements were used in his analysis (table 3).

ratios of which were more than 60%, were weight, stature, cervical height, waist height and Yuki in the former, and in the latter they were weight, hip girth, abdominal extension girth, waist girth, bust girth, hip breadth and waist breadth. Conversely, the second principal component contributed more to girths rather than lengths in the result of MASUDA, and more to lengths in the present result. In the former, the measurements, the contribution ratios of which were more than 20%, were maximum thigh girth, waist girth, bust girth, shoulder depth and crotch height, whereas in the latter they were bust height, cervical height, side length, hip height, sitting cervical height, posterior sleeve length and posterior waist length.

(4) As shown in table 3, the percentages of variances accounted for by the first three principal component to the total variance were slightly higher in the result of MASUDA (69.3%) than in the present result (63.9%). But it should be noted that in both series the percentages were low and the measurements such as anterior chest width, crotch length, neck base girth, shoulder depth and so forth still remained uncovered even by the first three principal components.

As shown above, there were several differences of the results between two studies. It is generally believed that race, sex and age of a subject have an important effect upon a human physique. Furthermore TANNER ('47, '51) and PARNELL ('57) pointed out that the initial choice of the measurements was also an important contributing factor to the result of analysis. It could not be decided from the present study whether the differences between the two results were due to the subject or the choice of the initial measurements, because the two studies differed in each respect. It should be clarified how the result is affected by these factors. A detailed examination of the choice of the measurements as well as re-investigations on the populations classified at least according to sex and age, should be made.

But it is to be emphasized that among three studies in which both the subjects and the measurements used were utterly different, the consistency was derived concerning the interpretations of the first two principal components. The coefficients for these components derived from the measurements of female university students are by no means the representative of the general population. The coefficients should be accepted within the limitation imposed by the source of the data used in this study. The fact shown above, however, suggests the possibility of taking the first principal component, a size factor, and the second principal component, a shape factor expressing lean-obese relation, as the best two indicators of a human physique irrespective sex, race and age.

SUMMARY

(1) In order to make more comprehensive and statistically efficient indicators of a human physique, principal component analysis was applied to the anthropometric measurements. The subject used in this study comprised 200 Japanese female university students, who were measured on 30 items of measurements as well as photographed with three standardized pose. Further object of this report was to compare the results obtained with those derived from the data of 256 soldiers by MASUDA.

(2) The interpretations of the principal components were made mainly on the basis of the coefficients of measurements in each component and also by reference to the photographs of the subjects. The first three principal components were interpreted as a size factor of a human physique, as a shape factor expressing lean-obese relation, and as a shape factor expressing shoulder shape. The percentages of the variances accounted for by each principal component to the total variance and the sum of them were approximately 41.0%, 16.3%, 6.6%, and 63.9%, respectively.

(3) As to the meanings of the first two principal components, a perfect accordance was found between the present results and those of MASUDA. The interpretations were also confirmed by the result of HAMMOND, who had applied factor analysis to the data from 2967 children in Britain. The fact suggested the possibility of taking the first two principal components, that is, a size factor and a shape factor expressing lean-obese relation, as the best two indicators of a human physique irrespective race, sex and age.

(4) As to the meaning of the third principal component, and as to the contribution ratios of each principal component to 30 measurements, the present results differed slightly from the results of MASUDA. The differences may be ascribed to the nature of the subjects and the initial choice of the measurements.

ACKNOWLEDGEMENT

The work reported here was done at the Department of Clothing, Faculty of Home Economics, Ochanomizu Women's University, under the direction of Professor Sumiko YANAGISAWA. The author wishes to express her sincere gratitude to her for suggesting this investigation as well as for constant guidance in the course of the work. The author's grateful thanks are also due to Mr. Masao TODA of Electronic Technical Laboratory for his generous help regarding to the calculation by Electronic Computer.

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主成分分析法による体型判定への一考察

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従来、体型の判定方法に関する生体計測学的研究は、その多くが、個々の測度又は諸測度間の比を体型判定の尺度とすることに止まっている。最近、益田等（'64, '65）は数学的見地から、主成分分析法の生体計測値への応用例を発表した。同法は、多変量を有するデータを、統計的に最適な少数変量により表現する為の解析法であり、我々の目的——多数の生体計測値を有する生体の型を、有効に且つ総合的に把える少数の尺度によつて判定する——に適していると考えられる。そこで、益田が自衛隊員 256 名の 17 項目に関する生体計測値を資料としたのに対し、本研究に於ては、女子大学生 200 名の 30 項目（表 1）に関する生体計測値が、主成分分析法によつて分析され、その結果が、表 2・3・4 及び図 1・2・3・4・5 に示された。又、両者の結果の比較により、得られた主成分の信頼性が論じられた。

結論は以下の通りである。

- (1) 被検者の性に関係なく、体型の第 1 の主成分は、身体の大きさを表わす因子である（全変動の約 41.0% を表現）。又その最良の指標は体重と考えられる。
- (2) 被検者の性に関係なく、第 2 の主成分は、身体の肥満・痩身度を表わす因子である（全変動の約 16.3% を表現）。
- (3) 第 3 の主成分は、肩部附近の形態を表わす因子であると考えられる（全変動の約 6.6% を表現）。しかし、この結果は、益田（'65）の結果と相違する。

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