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Original

Selecting the best anthropometric variables to characterize a population of healthy elderly persons

J. Tesedo Nieto[1], E. Barrado Esteban[2] and A. Velasco Martín[1]

[1]*Department of Molecular Biology, Histology and Pharmacology. Faculty of Medicine. University of Valladolid. Valladolid. Spain.* [2]*Department of Analytical Chemistry. Faculty of Sciences. University of Valladolid. Valladolid. Spain.*

Abstract

The objective is to select the best anthropometric measurements to characterize a healthy elderly population. For that, 1030 healthy elderly persons (508 men and 522 women) living independently or in an institution (in both public and private homes) were enrolled for this population-based, cross-sectional study conducted from February 2004 to May 2005. Anthropometric measurements were made by the same investigator according to standard techniques of the WHO.

Across several age groups, men were significantly heavier and taller than women whereas skinfold thicknesses were significantly greater in women than men. Through statistical analysis we were able to identify the variables providing most information and that could also best discriminate between sex, age and independent versus institutionalized persons: height, weight, one of the skinfold thickness measurements and mid-upper arm circumference. The number of age groups in both the male and female populations could be limited to three.

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Key words: *Anthropometry. Healthy elderly. Statistical analysis.*

SELECCIÓN DE LAS VARIABLES ANTROPOMÉTRICAS MÁS ADECUADAS PARA CARACTERIZAR UNA POBLACIÓN DE PERSONAS MAYORES SANAS

Resumen

El objetivo es la selección de las variables antropométricas más adecuadas para caracterizar poblaciones sanas de personas mayores. Para ello se han seleccionado aleatoriamente 1030 de estas personas (508 hombres y 522 mujeres) institucionalizados en residencias públicas, privadas y no institucionalizados. Todas las medidas antropométricas se realizaron por parte del mismo investigador de acuerdo con las técnicas estandarizadas por la OMS.

En todos los grupos de edad se ha encontrado que los hombres son significativamente más altos y tienen un peso mayor que las mujeres, al contrario que ocurre con los distintos pliegues. Mediante el análisis estadístico de los datos hemos podido identificar las variables que proporcionan mayor información y que además permiten diferenciar los sujetos por sexo, edad y lugar de residencia: peso, altura, uno de los pliegues y la circunferencia muscular del brazo. En cuanto a los segmentos de edad, pueden reducirse a tres.

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Palabras clave: *Antropometría. Personas adultas sanas. Análisis estadístico.*

Introduction

According to the World Health Organization (WHO), anthropometry is the single most inexpensive, non-invasive and universally applicable method to assess the proportions, size, and composition of the human body.[1] Although anthropometry may be less precise than more sophisticated techniques used to assess regional body composition (e.g., computed tomography, magnetic resonance imaging, or dual-energy X-ray absorptiometry), its simple nature makes it a useful tool for examining body-composition changes over time in large population-based studies and in settings in which access to technology is limited.[2]

Elderly persons represent the fastest-growing fraction of populations throughout the world, and have the distinctive feature of being a very heterogeneous group. Different elderly populations show wide geographic and ethnic variations in height, weight, and BMI, much of which reflects differences in lifestyle

Correspondence: Enrique Barrado Esteban.
Department of Analytical Chemistry.
Faculty of Sciences. University of Valladolid.
47005 Valladolid. Spain.
E-mail: ebarrado@qa.uva.es

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and environment over the course of life, genetic differences, and, to an uncertain extent, differences in health status.[3] In a re-evaluation of the use of anthropometry at different ages to assess health, nutrition, and social well-being by an Expert Committee of the WHO, countries were encouraged to collect anthropometric data on adults aged 60 years and over through anthropometric surveys conducted at regular intervals, as well as monitoring the health and functional status of this subset of the population. It was reported that special attention should be paid to special groups of elderly persons, such as those bedridden or institutionalized, since several studies have shown that those living in nursing homes show a general reduction in body fat with age.[4,5]

Despite these recommendations, however, there is no general consensus as to the variables that should be measured or calculated, or as to the age groups of subjects that should be considered.[6] If both these issues were standardized, then it would be easier to compare the results of studies conducted in different geographical areas.

In the present study, we provide data for a population from a city of some 500,000 inhabitants in a country that is currently experiencing two substantial demographic changes. One of these is an increase in the number of native elderly persons (at present the majority population), and the other is a change in the demographic pyramid due to the large influx of immigrants, which will probably appreciably alter future data. Our study takes into account the recommendations of previous studies that we should emphasize comparisons between elderly men and women for biological, social and behavioural factors affecting changes produced with age in body composition.[7]

Materials and methods

Area of study and subjects

On January 1, 2005, the census for Valladolid (NW Spain, city and province) included 514,674 inhabitants, of whom 90,721 were 65 years of age (retirement age in Spain) or older (i.e., 17.6%). The number of homes for the elderly was 152 (24 public and 128 private) with a total number of 5,862 occupied places.

The subjects for our study were selected among elderly persons living independently or with a family member, those living in public nursing homes (subsidised by the state) and those living in a private home (i.e., more expensive, thus accommodating persons of a higher economic level).

The population was selected by random stratified sampling according to the demographics of the area. This enabled us to select in a random simple manner, several private and public centres for the institutionalized subjects, and day centres or institutions to perform measurements in the non-institutionalized subjects. Within each place, individuals were selected also by simple random sampling using the registers of the centres visited. Finally 1602 elderly persons were selected, and measurements made in 1030 (table I) of these subjects over the period February 2004 to May 2005.

The remaining 572 subjects were excluded because of diseases including behavioural disorders, deformities of the spinal cord, arms or legs, amputated limbs or sequellae from bone fractures. Subjects were also excluded if they were receiving steroids, radiotherapy, chemotherapy or if they had any disease causing dehydration or oedema, or an acute or decompensated cardiovascular disease, neuromuscular or connective tissue disorder, as well as subjects with visceromegaly. Of these 572 persons, 80 were non-institutionalized (32 men, 48 women), 306 lived in a public nursing home (109 men, 197 women) and 186 lived in a private home (81 men, 105 women).

Cutoffs for the age groups were those most frequently used according to literature recommendations and studies performed in similar or close geographical regions.[8,9]

Table I
Number of subjects (sample populations)

Age yr	*Men*				*Women*				*Total*
	Place of residence				*Place of residence*				
	Non Ins.	*Public*	*Private*	*Total*	*Non Ins.*	*Public*	*Private*	*Total*	
65/69	41	16	18	75	42	14	23	79	154
70/74	41	21	21	83	44	17	25	86	169
75/79	36	28	27	91	32	25	32	89	180
80/84	34	20	26	80	23	19	30	72	152
85/89	37	17	23	77	29	19	28	76	153
90/94	25	14	16	55	28	18	18	64	119
≥ 95	23	10	14	47	24	16	16	56	103
Total	237	126	145	508	222	128	172	522	1,030

*Non Ins. = Non-institutionalized persons.

Table II
Mean values of the direct anthropometric measurements

RES	*Nº*	*Age*	*W*	*H*	*AST*	*BST*	*SST*	*SuST*	*TST*	*MAC*
					Men					
	1	65-69	66.06	1.67	11.46	8.10	17.18	22.25	11.20	30.17
	2	70-74	65.00	1.64	11.78	7,59	16.07	22.93	11.73	29.01
	3	75-79	63.83	1.63	12.23	6.84	15.56	21.50	11.45	28.49
Non Inst.	4	80-84	61.70	1.61	10.75	6.28	15.36	20.39	10.62	28.19
	5	85-89	60.65	1.59	12.08	5.70	14.59	21.02	11.31	27.85
	6	90-95	58.04	1.56	11.30	5.62	14.91	19.90	11.20	27.57
	7	> 95	58.81	1.57	11.62	6.07	13.11	20.20	11.47	27.43
	8	65-69	68.04	1.65	13.51	7.88	18.18	20.51	11.01	28.99
	9	70-74	67.48	1.67	12.06	7.20	17.24	21.20	11.00	27.87
	10	75-79	66.21	1.62	11.75	6.58	16.27	20.18	10.88	27.38
Public	11	80-84	65.31	1.59	11.08	5.85	15.70	19.69	11.39	27.09
	12	85-89	63.35	1.58	11.44	5.31	14.97	18.38	10.45	26.88
	13	90-95	62.04	1.57	11.63	5.12	14.79	19.19	11.54	26.67
	14	> 95	61.41	1.58	11.16	5.10	14.04	19.65	10.78	25.90
	15	65-69	67.42	1.64	12.42	7.31	16.99	21.62	10.74	28.43
	16	70-74	68.12	1.63	12.04	6.90	16.81	22.11	11.19	28.50
	17	75-79	66.49	1.64	12.60	6.43	15.16	19.38	11.84	27.99
Private	18	80-84	63.96	1.60	11.95	6.01	15.68	18.36	12.07	27.22
	19	85-89	62.76	1.59	11.88	5.47	15.42	19.78	11.94	26.84
	20	90-95	60.14	1.57	11.10	5.31	14.99	19.30	10.88	26.58
	21	> 95	58.94	1.56	11.71	5.71	14.16	18.91	10.99	26.33
					Women					
	22	65-69	58.36	1.59	19.89	12.71	24.32	25.59	21.99	29.72
	23	70-74	56.48	1.57	19.51	11.78	23.84	24.91	22.20	29.40
	24	75-79	56.79	1.56	17.96	11.17	22.13	23.72	20.93	28.23
Non inst.	25	80-84	54.30	1.54	16.77	10.03	20.90	22.78	19.28	27.57
	26	85-89	53.09	1.53	15.73	10.35	20.39	22.22	18.49	26.68
	27	90-95	52.01	1.53	15.60	10.23	19.02	23.26	18.12	27.02
	28	> 95	52.10	1.54	15.24	9.69	18.37	22.50	18.21	26.70
	29	65-69	60.39	1.53	20.09	12.88	25.04	24.83	22.20	29.66
	30	70-74	57.25	1.52	18.81	12.12	22.05	24.01	21.09	27.99
	31	75-79	53.79	1.54	16.86	11.31	20.74	24.68	21.05	28.68
Public	32	80-84	53.95	1.54	16.89	9.73	19.44	23.79	19.43	27.61
	33	85-89	52.05	1.52	16.10	9.53	19.70	23.09	18.58	26.78
	34	90-95	50.46	1.51	16.35	9.62	17.89	23.04	17.59	26.97
	35	> 95	51.26	1.51	15.66	9.34	17.02	22.32	17.07	27.12
	36	65-69	59.53	1.56	20.29	12.71	22.88	25.20	21.60	30.47
	37	70-74	57.34	1.56	19.02	11.78	21.60	24.40	21.08	30.47
	38	75-79	53.83	1.54	17.25	11.17	20.39	24.10	20.51	28.06
Private	39	80-84	51.46	1.51	16.28	10.03	21.09	22.94	20.70	27.50
	40	85-89	49.78	1.52	15.21	10.35	20.09	23.31	19.64	27.08
	41	90-95	50.37	1.52	16.14	10.23	18.99	22.70	18.74	27.27
	42	> 95	49.97	1.51	15.38	9.69	18.54	22.89	18.36	27.08

Table III
Direct anthropometric measurements (mean and standard deviation)

Variable	*Men*	*Women*
Weight (W, kg)	63.6 ± 9.7	54.1 ± 4.9
Height (H, m)	1.61 ± 0.07	1.54 ± 0.05
AST (mm)	11.8 ± 5.2	17.3 ± 6.2
BST (mm)	6.5 ± 3.2	11.0 ± 4.0
SST (mm)	15.7 ± 5.3	21.0 ± 6.8
SuST (mm)	20.6 ± 6.5	23.8 ± 5.9
TST (mm)	11.3 ± 4.1	20.1 ± 5.9
MAC (cm)	27.9 ± 3.3	28.1 ± 4.0
	n = 508	*n = 522*

Anthropometric measurements

All anthropometric measurements: height (H) (m), weight (W) (kg), skinfold thicknesses abdominal (AST), triceps (TST), biceps (BST), subscapular (SST) and suprailiac (SuST) (all in mm), and mid-upper arm circumference (MAC) (cm), were made by the same investigator according to standard techniques of the WHO[2] and International Society for the Advancement of Kinanthropometry (ISAK).[10] Subjects were measured without shoes according to the procedure detailed by Chumlea.[11]

Statistic analysis was performed using MINITAB Mtb 13 and Excel software.

Results

Table II shows the mean values obtained for each of the anthropometric variables by sex, age group and place of residence for the 1,030 subjects. This table also provides the numbers assigned to the different age groups in the figures. On simple visual inspection of the table, it may be seen that differences exist between sexes and among the different age groups. Effectively, it seems that weight and height are higher in men than women and that conversely, women show greater skinfold thicknesses, especially at the sites subscapular and triceps. It may also be observed that direct anthropometric variables diminish with increasing age.

Table III summarizes the mean values obtained for all the direct variables in both the male and female populations. Using the values of each direct anthropometric variable separately, we performed a statistical analysis. First, mean values were grouped according to age and place of residence as shown in table IVa for the variable weight in men. Two-way ANOVA generates the results provided in table IVb.

Factor analysis (FA) provides an internal structure for the measurements generally not accessible in the original analysis, and helps explain the original results

Table IVa
Mean weight (kg) values recorded for the different age groups in the male population

Age (years)	*Non ins.*	*Public*	*Private*	*Global mean*
65-69	66.1	68.0	67.4	67.2
70-74	65.0	67.5	68.1	66.9
75-79	63.8	66.2	66.5	65.5
80-84	61.7	65.3	64.0	63.7
85-89	60.7	63.4	62.8	62.3
90-95	58.0	62.0	60.1	60.1
> 95	58.8	61.4	58.9	59.7
Global mean	62.0	64.8	64.0	63.6

Table IVb
Two-way ANOVA of the weights obtained for the men

Origin of variation	*SSC*	*DF*	*Variance*	*F*	$F_{(Critical)}$
Age	169.28	6	28.21	62.10	3.00
Residence type	29.27	2	14.64	32.21	3.89
Error	5.45	12	0.45		
Total	203.99	20			

SSC = Sum of Squares; DF = degrees of freedom.

by describing a series of "latent" factors, fewer in number than the original variables. Thus, we first undertook a FA of the data set shown in table II, which includes the direct anthropometric measurements. Since the numeric values of the variables differ considerably, the first step is to normalize the variables by autoscaling to unit variance. After this, we can construct a correlation matrix using these autoscaled variables (table V). The table indicates high correlation between weight and height and among the different skinfold thickness measurements: abdominal, biceps, subscapular, triceps and suprailiac yet much lower correlation for mid-upper arm circumference.

The utility of carrying out a FA of the data set can be ascertained by means of the Bartlett's sphericity test, based upon calculating the statistic:

$$X^2_{calc} = -(N_{OBJ}-1-(2\ VA + 5)/6)\ \text{In}\ [\mathbf{R}]$$

(where N_{OBJ} and VA are the number of objects and variables respectively and **R** is the correlation matrix determinant) and comparing it to X^2_{crit} obtained for VA(VA-1)/2 degrees of freedom and the required significance level. In our case X^2_{calc} was 53.74 and X^2_{crit} = 17.2 (28 degree of freedom, P = 0.05), so the null hypothesis of spherical distribution of the original variables can be rejected and the FA can be used to reduce the dimensionality of the data set. Table VI shows the results of the FA, based on extracting the "eigenvalues" and "eigenvectors" of the correlation matrix.

Table V *Correlation matrix obtained using the direct anthropometric measurements*								
	W	*H*	*AST*	*BST*	*SST*	*SuST*	*TST*	*MAC*
W	1.000							
H	0.918	1.000						
AST	-0.580	-0.577	1.000					
BST	-0.576	-0.516	0.962	1.000				
SST	-0.441	-0.423	0.943	0.954	1.000			
SuST	-0.511	-0.408	0.887	0.941	0.887	1.000		
TST	-0.728	-0.699	0.963	0.951	0.914	0.887	1.000	
MAC	0.275	0.342	0.443	0.494	0.526	0.569	0.299	1.000

$r_{critical} = 0.304$ (P = 0.05. v = 40).

Table VI *Loading the new variables obtained by factor analysis and eigenanalysis of the correlation matrix*					
	Loading the "latent" factors				
Variable	*1*	*2*	*3*	*4*	*5*
W	0.691	-0.672	-0.230	-0.039	-0.125
H	0.650	-0.725	-0.012	0.195	0.103
AST	-0.974	-0.089	-0.128	-0.084	-0.022
BST	-0.979	-0.147	-0.023	0.058	0.032
SST	-0.935	-0.242	-0.221	0.042	0.047
SuST	-0.926	-0.240	0.183	0.183	-0.130
TST	-0.988	0.086	-0.064	-0.008	0.034
MAC	-0.390	-0.875	0.208	-0.196	0.034
Eigenvalue	5.6648	1.8949	0.1998	0.1237	0.0490
Proportion	0.708	0.237	0.025	0.015	0.006
Cumulative (%)	70.8	94.5	97	98.5	99.2

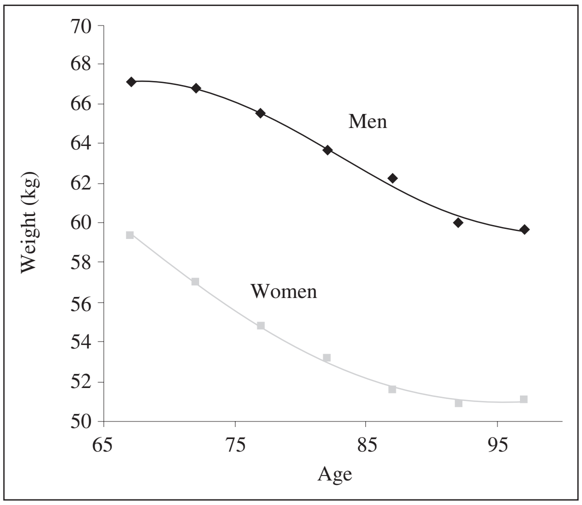

Fig. 1.—Mean weight stratified by sex and age.

Discussion

Table III creates an anthropometric picture of the population by clarifying the previous observations between sexes: men were taller and heavier and women showed greater skinfold thicknesses, while mid-upper arm muscle circumference (AMC) was similar. From the table 4 it may be deduced with 95% confidence that the variable weight serves to differentiate between the different age groups, since the value of $F_{calculated}$ (62.10) is greater than the critical value (3.00), and can also be used to distinguish the place of residence of the subjects (32.21 > 3.89). A paired sample t-test was then used to confirm significant differences between the weights of non-institutionalized and institutionalized men with no differences between those living in a private or public home.

When the same analysis was performed for the women, we found that the variable weight was capable of differentiating among the different age groups but not between institutionalized and non-institutionalized women. When comparing both populations, men and women (fig. 1), the previous observations were confirmed, i.e., that the mean weight for the men was greater across all the age groups and that in both sexes weight diminishes with increasing age.

Using the same method for the remaining direct variables we obtained the data shown in table VII. This table shows the discriminating capacity of each variable for differentiating the male and female populations as well as their age group and place of residence.

These differences can be more clearly seen when the data are subjected to multivariate treatment[12]. Table VI reveals two significant factors (with eigenvalues greater than unity) that are capable of explaining 94.5% of the variance and thus most of the information in the original data set. The new "latent" factors are obtained by linear combination of the original anthropometric measurements and their corresponding factor loadings. Hence, weight and height contribute positively, and the different skinfold thicknesses (AST, BST, SST, SuST, TST) and MAC contribute negatively to factor 1. Only the factors W, H and MAC contribute to the second

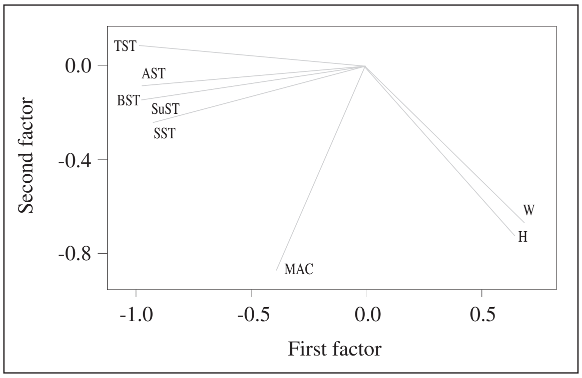

Fig. 2.—Loadings of the original variables on the first two factors (or principal components) of the direct anthropometric measurements.

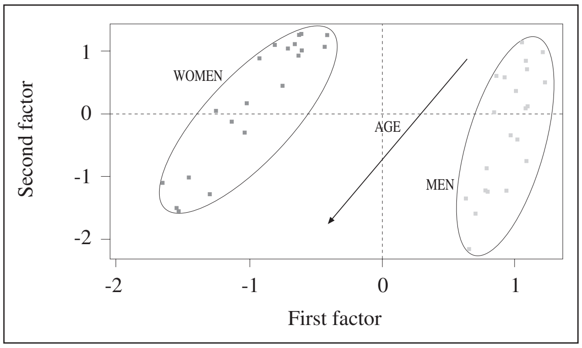

Fig. 3.—Scores of the samples on significant factors 1 and 2.

factor. Figure 2 clearly shows these contributions and groupings.

Since the new factors show a greater amount of variance than the original values, plotting these factors will provide a correspondingly greater amount of information. Figure 3 shows the plots obtained for the first two "latent" factors representing 94.5% of the global information. Two well-defined groups may be observed corresponding to the men and women. In addition, within each of these groups, a change may be seen to occur with the age of the subjects, as described in many previous reports.[8,9,13]

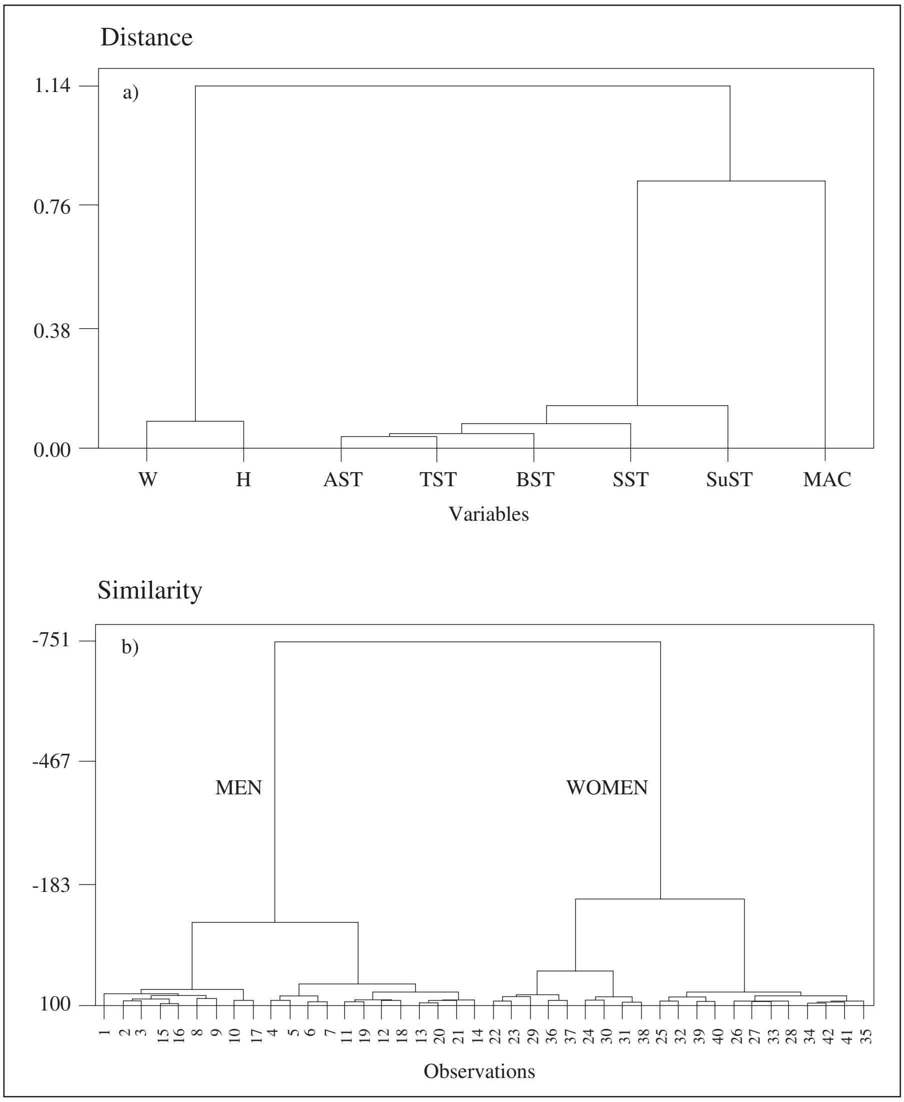

Fig. 4.—a) Dendrogram based on agglomerative hierarchical clustering by complete linkage (Ward distances) for the direct anthropometric measurements. b) Dendrogram of the observations (different populations of men and women).

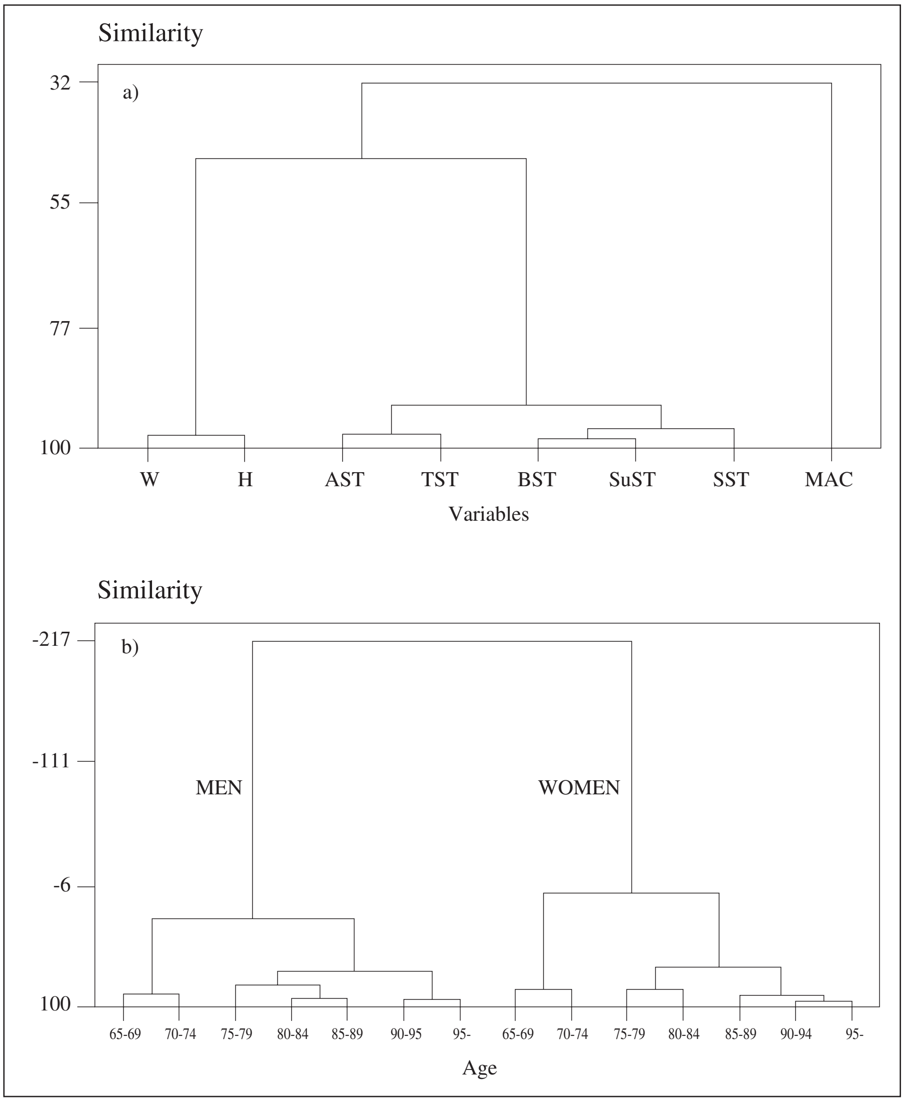

Fig. 5.—Dendrograms of the variables and observations without differentiation according to place of residence.

Table VII
Discriminating capacity of the direct anthropometric variables

Variable	*Sex*	*Age*		*Institutionalized*	
		Men	*Women*	*Men*	*Women*
Weight	Yes	Yes	Yes	Yes	No
Height	Yes	Yes	Yes	No	Yes
AST	Yes	No	Yes	No	NO
BST	Yes	Yes	Yes	Yes	No
SST	Yes	Yes	Yes	Yes	No
SuST	Yes	Yes	Yes	Yes	No
TST	Yes	No	Yes	No	No
MAC	No	Yes	Yes	Yes	No

It may therefore be concluded that direct measurements serve to perfectly differentiate the subjects according to sex since the two populations clearly separate. The values corresponding to the different groups of men appear on the right hand side of the figure (where the contribution of weight and height is greatest) and those for the women may be observed on the left hand side (where the different skinfold thicknesses contribute most).

The cluster analysis confirmed these correlations and served to complete some of these conclusions. Effectively, when variables were clustered using the Ward distance as the linkage method (fig. 4a), W-H and the different skinfold thicknesses once again formed separate groupings. In the objects cluster (fig. 4b), two groupings appear: one including values 1 to 21 (corresponding to the different subgroups of men, see table I) and the other including values 22 to 42, which correspond to the different subgroups of women. On closer inspection, we also find differences among the different age groups. However, this may be more clearly seen if we construct a new table eliminating the type of residence of the subjects differentiating only

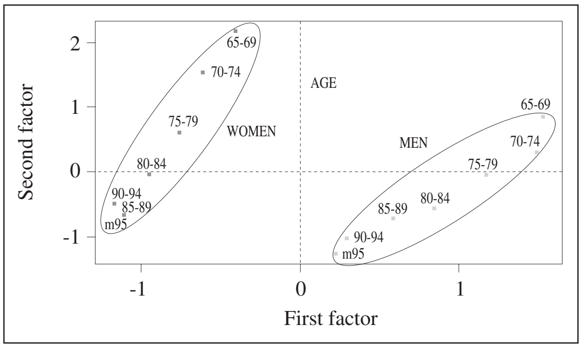

Fig. 6.—Scores of the samples on significant factors 1 and 2 using only four anthropometric measurements.

according to sex and age group. In these conditions, the cluster of variables (fig. 5a) is practically identical, but the observations cluster once again reveals two clusters corresponding to the men and women but within each of these clusters groupings by age group also emerge. Thus, for the men we find the groupings 65 to 74 years, 75 to 89 years and finally older than 90 years. These groupings for the women were 65 to 74, 75 to 84, and older than 85 years. In summary, rather than using seven age groups as often recommended in the literature, it would be sufficient to use only three in both the men and women.

The results described above and the high correlation observed for several of the direct variables prompted us to hypothesize that to describe the present population, it might not be necessary to use all the variables. Reducing the number of variables determined would have the benefit of reducing costs and saving time in this type of study. To confirm this rationale, we repeated the multivariate analysis but only included the variables weight, height, abdominal skinfold thickness and mid-upper arm circumference. The results displayed in figure 6 faithfully reproduce those obtained using the entire dataset (fig. 4), indicating that to characterize or differentiate a population, only four anthropomorphic measurements need to be determined and the population only needs to be stratified into three age groups.

Conclusions

To describe a healthy elderly population only four anthropometrical direct variables would be needed: height, weight, one of the skinfold thickness measurements and mid-upper arm circumference. The number of age groups in both the male and female populations could be also limited to three.

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