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Identification of different nutritional status groups in institutionalized elderly people by cluster analysis

María José López-Contreras[1], Maria Ángeles López[1], Manuel Canteras[2], María Emilia Candela[3], Salvador Zamora[1] y Francisca Pérez-Llamas[1]

[1]Department of Physiology. [2]Department of Socio-Sanitary Sciences. [3]Department of Plant Biology. University of Murcia. Murcia. Spain.

Abstract

Objectives: **To apply a cluster analysis to groups of individuals of similar characteristics in an attempt to identify undernutrition or the risk of undernutrition in this population.**

Methods: **Design: A cross-sectional study. Setting: Seven public nursing homes in the province of Murcia, on the Mediterranean coast of Spain. Participants: 205 subjects aged 65 and older (131 women and 74 men). Measurements: Dietary intake (energy and nutrients), anthropometric (body mass index, skinfold thickness, mid-arm muscle circumference, mid-arm muscle area, corrected arm muscle area, waist to hip ratio) and biochemical and haematological (serum albumin, transferrin, total cholesterol, total lymphocyte count). Variables were analyzed by cluster analysis.**

Results: **The results of the cluster analysis, including intake, anthropometric and analytical data showed that, of the 205 elderly subjects, 66 (32.2%) were overweight/obese, 72 (35.1%) had an adequate nutritional status and 67 (32.7%) were undernourished or at risk of undernutrition. The undernourished or at risk of undernutrition group showed the lowest values for dietary intake and the anthropometric and analytical parameters measured.**

Conclusions: **Our study shows that cluster analysis is a useful statistical method for assessing the nutritional status of institutionalized elderly populations. In contrast, use of the specific reference values frequently described in the literature might fail to detect real cases of undernourishment or those at risk of undernutrition.**

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Keywords: *Undernutrition. Malnutrition. Elderly. Nursing-home. Cluster analysis.*

Correspondence: Francisca Pérez-Llamas.
Department of Physiology.
University of Murcia.
30100 Murcia. Spain.
E-mail: frapella@um.es

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IDENTIFICACIÓN DE GRUPOS DE PERSONAS MAYORES INSTITUCIONALIZADAS CON DIFERENTE ESTADO NUTRICIONAL MEDIANTE UN ANÁLISIS DE CONGLOMERADOS

Resumen

Objetivos: **Aplicar un análisis de conglomerados (cluster analysis) para grupos de individuos de características similares en un intento de identificar la desnutrición o el riesgo de desnutrición en esta población.**

Métodos: **Estudio transversal llevado a cabo en 205 sujetos de 65 años (131 mujeres y 74 hombres), residentes en siete centros públicos de la Región de Murcia, localizada en la costa mediterránea de España. Se valoró ingesta dietética (energía y nutrientes), medidas antropométricas (índice de masa corporal, pliegues cutáneos, circunferencia muscular del brazo, área muscular del brazo, área muscular del brazo corregida, relación cintura-cadera) y parámetros bioquímicos y hematológicos (albúmina, transferrina, colesterol total, recuento total de linfocitos). Las variables se analizaron mediante análisis de conglomerados.**

Resultados: **Los resultados del análisis de conglomerados, incluyendo la ingesta, datos antropométricos y analíticos mostraron que, de los 205 sujetos ancianos, 66 participantes (32,2%) presentaron sobrepeso/obesidad, 72 (35,1%) tenían un estado nutricional adecuado y 67 (32,7%) estaban desnutridos o en riesgo de desnutrición. El grupo con desnutrición o en riesgo de desnutrición mostró los valores más bajos de la ingesta dietética y los parámetros antropométricos y clínicos.**

Conclusiones: **El estudio muestra que el análisis de conglomerados es un método estadístico útil para evaluar el estado nutricional de las poblaciones de ancianos institucionalizados. Por el contrario, el uso de los valores de referencia específicos, descritos con frecuencia en la literatura, podría no detectar situaciones reales de desnutrición o en riesgo de desnutrición.**

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Palabras clave: *Desnutrición. Malnutrición. Residencias públicas. Personas mayores. Análisis de conglomerados.*

Abbreviations

BMI: body mass index.
CAMA: corrected-arm muscle area.
E: energy.
MAC: mid-arm circumference.
MAMA: mid-arm muscle area.
MAMC: mid-arm muscle circumference.
RDI: Recommended Dietary Intake.
TSF: Triceps skinfolds.
WHR: waist to hip ratio.

Introduction

Malnutrition is an overall term used for different deviations from the normal nutritional status. As such it can refer to subjects who are either over- or under-nourished. Undernutrition is the state produced by the intake of insufficient macronutrients or micronutrients: protein-energy malnutrition or vitamin and mineral deficiency[1]. However, the causes of poor nutritional status in older people are complex, and may be a result of poor dietary intake or a secondary consequence of acute or chronic disease[2].

Malnutrition in the elderly is a frequent and multi-factorial problem, more prevalent in hospitals and nursing homes where it is rarely recognised and treated. It is also associated with massive healthcare expenditure[3,4]. The effects of malnutrition are especially dramatic in older people, who tend to be the most vulnerable, fragile and dependent[5-7]. However, several studies have shown that nutritional therapies can substantially improve the nutritional status of the elderly[8-12].

A suitable evaluation of the nutritional status of elderly people and its associated factors should help reduce the prevalence of undernutrition, improving the quality of life, reducing the number of hospitalized and institutionalized persons, and cutting the public expense of providing health and social care for this population group[4,13].

Undernutrition in most developed countries ranges between 5 and 20% for the free-living elderly, but may be more frequent in nursing home residents and hospital patients (19-65%)[14,15]. However, although undernutrition is a common problem in the elderly, no gold standard exists for evaluating nutritional status.

Data from recent studies concerning the prevalence of undernutrition in the elderly population vary greatly between studies and depend on the characteristics of the subjects studied, as well as the nutritional screening tool and the cut-off values considered for identifying the disorder[16-20]. In a study conducted by our group, we found that the prevalence of undernutrition in the same population studied varied between 2 and 57% according to the ten nutritional screening tools used[18]. In another recent study, Poulia et al. (2012)[19] found that the prevalence of undernutrition in the elderly ranged from 42.7 to 97.6%, depending on the six nutritional screening tools used.

In view of the variability in the nutritional screening tools used, and the different parameters and normal values considered in the literature to define the nutritional status of older people, the aim of the present study was to assess nutritional status by means of a cluster analysis in an institutionalized elderly population from seven public nursing-homes from the province of Murcia (southeast Spain), in an attempt to identify undernutrition or the risk of undernutrition in this population.

Experimental methods

Subjects

The present was study was carried out in the province of Murcia (southeast Spain). The age of the subjects ranged from 65 to 96 years and all lived in seven public nursing homes from urban areas. The inclusion and exclusion criteria were previously described[18]. A total of 205 subjects (131 women and 74 men) participated in the present study. The mean age ± standard deviation was 78.6 ± 7.5 years.

Study design

Dietary intake, and anthropometric and biochemical measurements were assessed in all the participants in a cross-sectional study. The survey was conducted in a 24-month period starting in May 2007.

Dietary intake

Food intake was assessed using a previously validated 4-day weighed-food record of all food and fluids consumed during each meal. All subjects were also asked about any food consumed other than in the dining-room of the nursing home. The mean daily intake of energy and nutrients was estimated using GRUNUMUR software[21]. Data were compared with the Recommended Dietary Intake (RDI) for the Spanish elderly population and the dietary balance (percentage of total energy from each macronutrient) was compared with Mediterranean diet recommendations[22-25].

Anthropometric measurements

Weight and height measurements were previously described[18]. Body mass index (BMI) was calculated as weight (kg)/height (m)^2.

Skinfold thickness was measured on the left side of the body, in triplicate to the nearest 0.2 mm using a calliper (GPM, Zurich, Switzerland) with a constant pressure of 10 g/mm^2. Triceps (TSF) and biceps skinfolds (mm) were

pinched in the front and back part of the arm, midway between the tip of the acromion and the olecranon process. Subscapular skinfold (mm) was pinched at an angle of about 45º to the vertical. Suprailiac skinfold (mm) was pinched just above the iliac crest in the mid-axillary line. Abdominal skinfold (mm) was measured vertically at about 2 cm left of the umbilicus.

Circumferences were measured in triplicate using a flexible non-stretch tape measure calibrated in mm. The mid-arm circumference (MAC, cm) was measured on the left arm midway between the tip of the acromion and the olecranon process. The mid-arm muscle circumference (MAMC) was calculated according to the following formula[26]: MAMC (cm) = MAC (cm) – 0.1 × π × TSF (mm). The mid-arm muscle area (MAMA) was calculated from the formula[27]: MAMA (cm^2) = [MAC (cm) – 0.1 × π × TSF (mm)]^2/4π. The corrected-arm muscle area (CAMA) was calculated according to the following equations[28]:

$$CAMA = [(MAC - 0.1 \times \pi \times TSF)^2/4\pi] - 10 \quad \text{(men)}$$
$$CAMA = [(MAC - 0.1 \times \pi \times TSF)^2/4\pi] - 6.5 \quad \text{(women)}$$

The waist-circumference was obtained midway between the lower rib margin and the iliac crest, following gentle expiration. The hip-circumference was measured over the widest part of the great trochanter. The waist to hip ratio (WHR) was obtained by dividing the values of both circumferences.

The anthropometric parameters were compared with those of the Spanish elderly population[29-30]. BMI was compared with the normal range for elderly people (24-29 kg/m^2)[31]. The WHR and waist circumference were compared with the normal values for adults[32, 33].

Blood collection and biochemical measurements

Fasting blood samples were obtained from all subjects during the early morning. Serum concentrations of albumin, transferrin and total cholesterol were measured using commercial kits (Roche Diagnostic, Mannheim, Germany) on an automated sequential multiple analyser (Roche Diagnostics, Mannheim, Germany). Total lymphocyte counts were made with a Sysmex XE-2100L Model Automated Cell Counter (Roche Diagnostics, Mannheim, Germany). Cut-off criteria for normal values of serum albumin, transferrin, cholesterol concentrations and the total lymphocyte count (35-53 g/l, 200-385 mg/dl for men and 185-405 mg/dl for women, 150-230 mg/dl and 1-4 × 10^9/l, respectively) used in the present study were defined in accordance with the recommended laboratory values from the 'Virgen de la Arrixaca University Hospital' (Murcia, Spain).

Ethics

The study protocol was performed in accordance with The Helsinki Declaration of Human Studies and approved by the Ethical Committee of the University of Murcia. All participants provided their written informed consent.

Statistical analysis

Data are presented as mean ± standard deviation or as percentages of subjects. The Gaussian distribution of variables was confirmed by the Kolmogorov-Smirnov test and homogeneity of variances by the Levene test. For parametric data, the differences in variables between sexes were analyzed by Student's t-test, and differences in variables between the 3 groups were analyzed by one-way analysis of variance (ANOVA) and subsequent post hoc Bonferroni. For nonparametric data the Mann-Whitney test was used to analyze differences in variables between sexes, and the Kruskal-Wallis test was applied for testing the differences between the three groups. Further testing with Mann-Whitney U test was carried out when significant differences were found. Chi-squared analysis and the analysis of corrected residuals were used to test whether there were significant differences in the proportion of people between different groups. The level of significance was set at 5% for all analyses. The multivariate statistical technique of cluster analysis was used to identify groups within this population that showed similar patterns of nutritional status. Analytical and anthropometric parameters frequently used in the literature to assess nutritional status (BMI, CAMA, serum albumin, transferrin, total cholesterol and total lymphocyte count), and dietary intake data (daily energy and protein intake) were used in this analysis. If clustering variables have scales of very different ranges, the variables with larger values will overwhelm those with smaller values. To make the contribution of all variables to the distance measure more comparable, the variables included in the analysis were standardized. In this study, cluster analysis was performed using the K-means method, in which the number of clusters needs to be preselected. Since no information was available on the appropriate number of clusters in the data set, a series of steps was taken to select the most suitable number. Firstly, several cluster analysis runs were conducted with a varying number of clusters (from two to five). Secondly, the analysis of variance tables of each analysis and the F-statistics of the group variables were inspected to identify cluster solutions with well separated clusters. Thirdly, the size of the emerging clusters and the differences in the variables across individual clusters from each run were examined. With the variables used, all three cluster solutions produced reasonably sized and well separated clusters of different nutritional status, and were therefore selected. The reliability of the cluster solutions was tested by discriminate analysis using the stepwise method. All the data were analysed using SPSS for windows (version 19.0, SPSS Inc., Chicago, USA).

Results

Average dietary intakes of energy and protein fulfilled the Recommended Dietary Intake (RDI) for Spanish elderly subjects. The balance of the diet (percentage of energy from each macronutrient) was well equilibrated (14.5% from proteins, 31.3% from lipids and 53.3% from carbohydrates). The studied subjects showed deficient intakes for zinc, folate and vitamins A, D and E.

The gender-related values of the anthropometric and biochemical parameters recorded in the 205 subjects are shown in table I. In general, the mean values of the anthropometric parameters were considered acceptable for an elderly Spanish population. BMI was within the normal range for such a population. WHR was at the limit of cardiovascular risk in both men and women. Waist circumference was higher than the recommended value for younger adults. The mean values of the biochemical parameters were within the local normal ranges.

Three groups of elderly people (A, B and C) were identified by the cluster analysis. The level of agreement between group membership identified by cluster analysis and predicted group membership using discriminate analysis was 95.1%, indicating a good stability for the cluster solutions. Of the 205 elderly subjects, 66 (32.2%) were assigned to group A, 72 (35.1%) to group B, and 67 (32.7%) to group C, each group representing a different nutritional status. There were no statistical differences for the variable gender among groups.

Table II shows daily dietary intake, and table III shows age, anthropometric and biochemical data for the three cluster groups. There were significant differences among the three groups for the variables included in the cluster analysis and also for the rest of the studied variables that were not included, except for vitamin D intake, WHR and abdominal skinfold thickness.

Group A showed the highest intake of energy and other components of the diet, the energy intake in this case being greater than the RDI for Spanish elderly people. Group B showed adequate energy intake, while group C showed the lowest intake of energy, being below the RDI for Spanish elderly people. In the three groups, protein intake appeared to cover the RDI for Spanish elderly people. The balance of the diet (percentage of energy from each macronutrient) was adequate for the three groups and agreed with Mediterranean diet recommendations. Group C showed the lowest energy percentage from lipids and the highest from carbohydrates. Group C also showed deficiencies in vitamin B_6 intake, which was suitably covered in the other two groups. All three groups showed deficient intakes for zinc, folate, and vitamins D, A and E. Only group A fulfilled the magnesium RDI.

Age was significantly different among groups, group C being the oldest. Group A showed the highest anthropometric data, whereas group C showed the lowest. The percentages of subjects with TSF, MAMC, MAMA values below the 10th percentile and CAMA values of ≤ 21.4 and ≤ 21.6 cm^2, for men and women, respectively, are shown in figure 1. These percentages were significantly higher in group C.

Table I
*Anthropometric and biochemical data for the elderly population**

Parameters	*Total (n = 205)*	*Men (n = 74)*	*Women (n = 131)*	*p‡*
Age (y)	78.6 ± 7.5	75.4 ± 7.7	80.3 ± 6.9	0.001
Weight (kg)	68.1 ± 14.1	71.6 ± 13.5	66.0 ± 14.2	0.006
Height (cm)	154.3 ± 8.3	162.8 ± 6.5	149.4 ± 4.3	0.001
BMI (kg/m^2)	28.4± 5.9	26.9 ± 4.4	29.3 ± 6.4	0.003
MAC (cm)	30.0 ± 4.7	28.9 ± 3.9	30.6 ± 5.1	0.009
MAMC (cm)	24.1 ± 3.2	24.5 ± 2.9	23.9 ± 3.4	0.268
MAMA (cm^2)	47.2 ±12.6	48.3 ± 11.1	46.5 ± 13.4	0.343
CAMA (cm^2)	39.4 ± 12.6	38.3 ± 11.1	40.0 ± 13.4	0.341
Waist (cm)	100.2 ±13.4	100.2 ± 11.9	100.1 ± 14.3	0.983
Hip (cm)	104.7 ± 11.9	100.5 ± 9.4	107.6 ± 12.7	0.001
WHR	0.95 ± 0.14	1.00 ± 0.07	0.91 ± 0.16	0.001
Bicipital (mm)	10.9 ± 5.5	8.1 ± 3.5	12.5 ± 5.8	0.001
Tricipital (mm)	18.6 ± 7.1	14.1 ± 5.0	21.1 ± 6.8	0.001
Subscapular (mm)	19.6 ± 7.6	17.9 ± 5.6	20.7 ± 8.5	0.010
Suprailiac (mm)	19.3 ± 9.6	13.5 ± 6.9	23.0 ± 9.3	0.001
Abdominal (mm)	24.7 ± 12.3	15.8 ± 6.3	31.0 ± 11.6	0.001
Albumin (g/l)	39.9 ± 4.3	40.6 ± 4.1	39.5 ± 4.4	0.077
Transferrin (mg/dl)	246 ± 43	249 ± 43	244 ± 43	0.386
Cholesterol (mg/dl)	196 ± 42	189 ± 40	200 ± 43	0.082
Lymphocytes (× 10^9/l)	2.00 ± 0.71	1.98 ± 0.69	2.02 ± 0.73	0.882

*Data are presented as mean values ± standard deviation. BMI: body mass index; MAC: mid-arm circumference; MAMC: mid-arm muscle circumference; MAMA: mid-arm muscle area; CAMA: corrected-arm muscle area; WHR; waist to hip ratio. ‡Student s *t*-test or Mann-Whitney test were used to compare means between genders.

Table II
*Dietary intake for the three cluster groups and differences among groups**

Intake/d	*Group A (n = 66)*	*Group B (n = 72)*	*Group C (n = 67)*	*p‡*
Energy (kJ)	9238 ± 1494[a]	7782 ± 1230[b]	6937 ± 1481[c]	0.001
Proteins (%E)	15.2 ± 2.3[a]	13.8 ± 2.1[b]	14.5 ± 3.1[ab]	0.003
Proteins (g)	83.6 ± 17.2[a]	64.0 ± 12.6[b]	60.1 ± 17.6[b]	0.001
Lipids (%E)	31.9 ± 5.7[a]	33.3 ± 5.0[a]	28.5 ± 4.7[b]	0.001
Lipids (g)	78.4 ± 19.5[a]	68.9 ± 15.8[b]	52.5 ± 14.4[c]	0.001
Carbohydrates (%E)	52.2 ± 5.8[a]	51.7 ± 5.7[a]	56.1 ± 5.4[b]	0.001
Carbohydrates (g)	288.8 ± 53.8[a]	240.3 ± 45.7[b]	232.7 ± 52.4[b]	0.001
Fiber (g)	24.2 ± 8.0[a]	17.7 ± 6.6[b]	16.3 ± 6.2[b]	0.001
Calcium (mg)	1031 ± 242[a]	860 ± 267[b]	919 ± 341[ab]	0.002
Phosphorus (mg)	1644 ± 412[a]	1244 ± 376[b]	1281 ± 502[b]	0.001
Iron (mg)	15.3 ± 3.7[a]	11.7 ± 3.5[b]	11.0 ± 3.5[b]	0.001
Zinc (mg)	8.3 ± 2.6[a]	6.3 ± 2.0[b]	5.8 ± 2.5[b]	0.001
Magnesium (mg)	347 ± 86[a]	266 ± 71[b]	259 ± 79[b]	0.001
Vitamin B_1 (mg)	1.74 ± 0.49[a]	1.38 ± 0.42[b]	1.34 ± 0.48[b]	0.001
Vitamin B_2 (mg)	1.78 ± 0.38[a]	1.43 ± 0.39[b]	1.47 ± 0.47[b]	0.001
Niacin (mg)	23.67 ± 6.30[a]	17.10 ± 5.23[b]	16.52 ± 7.15[b]	0.001
Vitamin B_6 (mg)	2.14 ± 0.47[a]	1.65 ± 0.41[b]	1.56 ± 0.50[b]	0.001
Folate (µg)	258 ± 73[a]	195 ± 70[b]	184 ± 74[b]	0.001
Vitamin B_{12} (µg)	4.89 ± 3.34[a]	3.86 ± 2.20[b]	3.69 ± 1.90[b]	0.011
Vitamin C (mg)	200 ± 72[a]	147 ± 67[b]	138 ± 58[b]	0.001
Vitamin A (µg)	830 ± 296[a]	688 ± 303[b]	645 ± 282[b]	0.001
Vitamin D (µg)	3.36 ± 2.13	2.83 ± 2.41	3.67 ± 2.90	0.125
Vitamin E (mg)	8.71 ± 3.42[a]	6.89 ± 2.49[b]	5.66 ± 2.31[c]	0.001

*Data are presented as mean values ± standard deviation. E, energy.
‡ANOVA or Kruskal-Wallis test followed by a post hoc Bonferroni or Mann-Whitney *U* test, respectively, were used to compare means between groups. [a,b,c]Means with the same letter are not significantly different from each other.

Table III
*Anthropometric and biochemical data for the three clusters groups and differences among groups**

Intake/d	*Group A (n = 66)*	*Group B (n = 72)*	*Group C (n = 67)*	*p‡*
Age (y)	76.5 ± 6.4[a]	79.3 ± 8.2[ab]	79.9 ± 7.4[b]	0.020
Weight (kg)	80.5 ± 10.1[a]	64.9 ± 10.8[b]	59.1 ± 12.1[c]	0.001
Height (cm)	157.5 ± 8.7[a]	152.1 ± 6.7[b]	153.5 ± 8.4[b]	0.001
BMI (kg/m^2)	32.6 ± 4.8[a]	28.1 ± 4.4[b]	24.6 ± 5.5[c]	0.001
MAC (cm)	33.9 ± 3.9[a]	29.5 ± 3.4[b]	26.5 ± 3.6[c]	0.001
MAMC (cm)	27.2 ± 2.3[a]	23.4 ± 2.4[b]	21.9 ± 2.5[c]	0.001
MAMA (cm^2)	59.2 ± 10.1[a]	43.9 ± 9.2[b]	38.8 ± 8.6[c]	0.001
CAMA (cm^2)	51.1 ± 10.7[a]	36.4 ± 9.1[b]	31.1 ± 8.5[c]	0.001
Waist (cm)	108.8 ± 12.0[a]	97.8 ± 10.7[b]	93.5 ± 13.1[b]	0.001
Hip (cm)	112.4 ± 9.7[a]	103.3 ± 10.8[b]	96.2 ± 9.7[c]	0.001
WHR	0.93 ± 0.20	0.96 ± 0.08	0.97 ± 0.08	0.960
Bicipital (mm)	14.1 ± 6.3[a]	10.9 ± 4.2[b]	7.8 ± 3.8[c]	0.001
Tricipital (mm)	21.5 ± 7.6[a]	19.5 ± 5.9[a]	14.6 ± 5.8[b]	0.001
Subscapular (mm)	23.2 ± 8.4[a]	19.7 ± 6.6[b]	15.6 ± 5.9[c]	0.001
Suprailiac (mm)	22.5 ± 10.8[a]	20.0 ± 8.6[a]	15.3 ± 8.1[b]	0.001
Abdominal (mm)	24.6 ± 13.0	27.4 ± 12.5	19.6 ± 9.5	0.062
Albumin (g/l)	40.2 ±3.0[a]	42.8 ± 3.3[b]	36.5 ± 4.0[c]	0.001
Transferrin (mg/dl)	242 ± 33[a]	274 ± 42[b]	219 ± 36[c]	0.001
Cholesterol (mg/dl)	189 ± 40[a]	221 ± 34[b]	176 ± 38[a]	0.001
Lymphocytes (× 10^9/l)	1.93 ± 0.60[a]	2.39 ± 0.74[b]	1.66 ± 0.59[c]	0.001

*Data are presented as mean values ± standard deviation. BMI, body mass index; MAC, mid-arm circumference; MAMC, mid-arm muscle circumference; MAMA, mid-arm muscle area; CAMA, corrected-arm muscle area; WHR, waist to hip ratio.
‡ANOVA or Kruskal-Wallis test followed by a post hoc Bonferroni or Mann-Whitney *U* test, respectively, were used to compare means between groups. [a,b,c]Means with the same letter are not significantly different from each other.

Serum albumin, transferrin, total cholesterol concentrations and the total lymphocyte count were significantly lower in group C. The percentages of subjects in each group with values for these parameters below the normal range are shown in figure 2. Group C showed the highest percentage of subjects below the normal range for all the biochemical parameters.

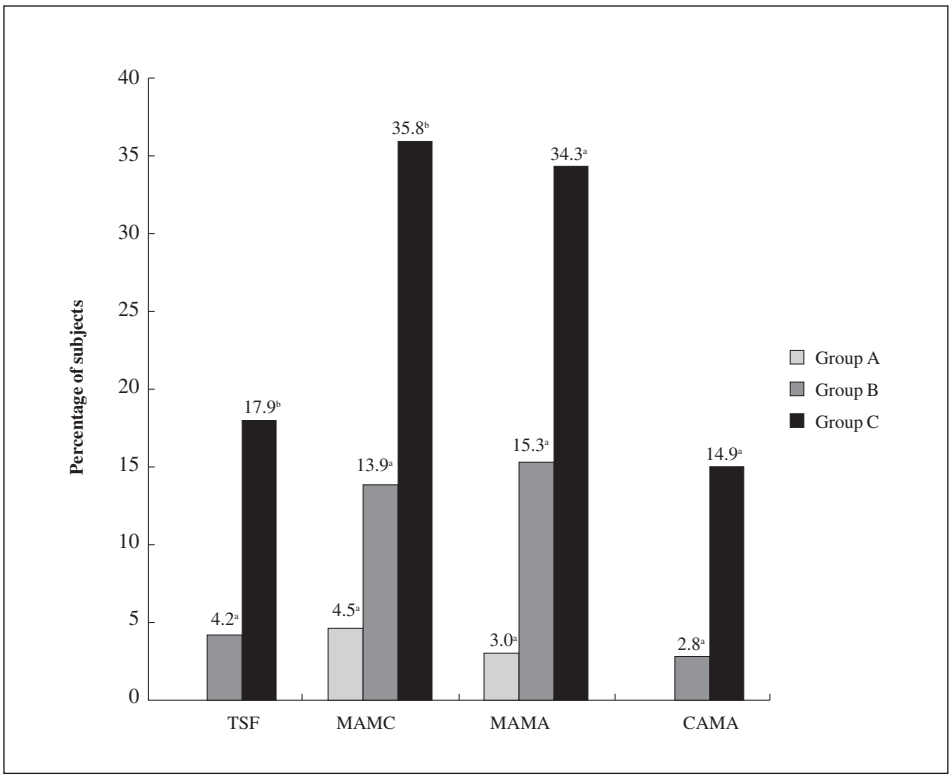

Fig. 1.—Percentage of subjects for the three clusters groups with triceps skinfold thickness (TSF), mid-arm muscle circumference (MAMC) and mid-arm muscle area (MAMA) under the percentile 10 of the Spanish elderly population and subjects with corrected-arm muscle area (CAMA) values of ≤ 21.4 and ≤ 21.6 cm², for men and women, respectively. [a,b,c]Percentages with the same letter are not significantly different from each other, determined by Chi-squared test and the analysis of corrected residuals. Group A: n = 66; Group B: n = 72; Group C: n = 67.

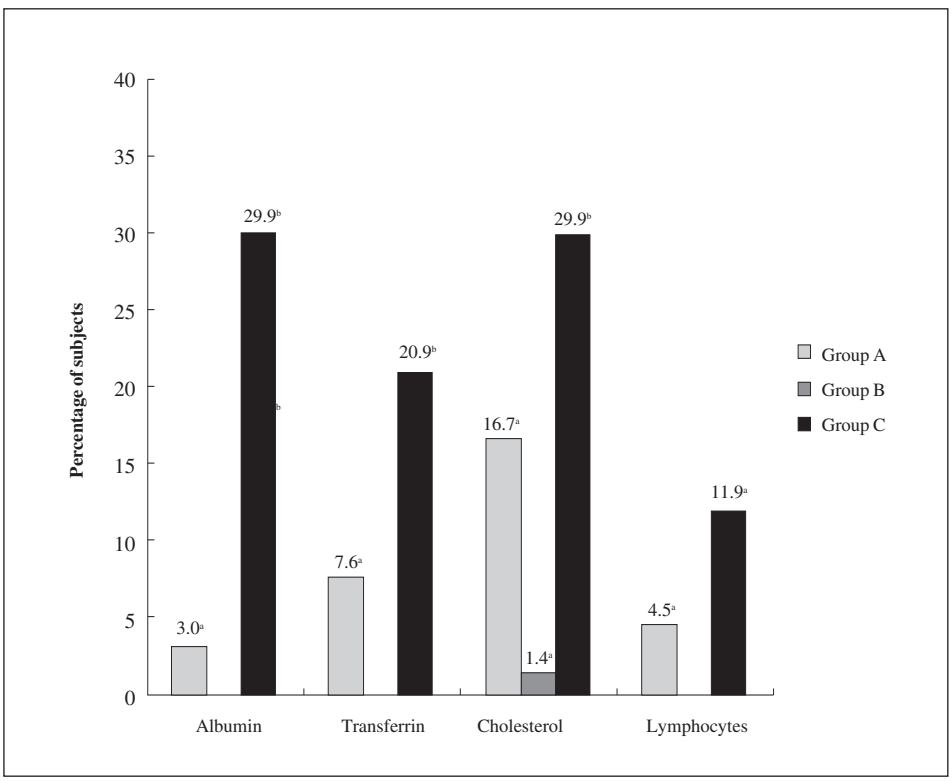

Fig. 2.—Percentage of subjects for the three clusters groups with serum albumin, transferrin, cholesterol concentration and total lymphocyte count values under the normal range in the three groups (Normal ranges: 35-53 g/l for albumin, 200-385 mg/dl for men and 185-405 mg/dl for women for transferrin, 150-230 mg/dl for cholesterol and 1-4 × 10⁹/l for total lymphocyte count). [a,b,c]Percentages with the same letter are not significantly different from each other, determined by Chi-squared test and the analysis of corrected residuals. Group A: n = 66; Group B: n = 72; Group C: n = 67.

Discussion

More than seventy tests or tools are currently available for detecting undernutrition all differing in their criteria, cut-off points, ease of use and acceptability[34,35]. Since no single nutritional measurement or lower reference limit can be considered to diagnose undernutrition beyond doubt, a cluster analysis was used to identify undernourished subjects in the present study. Besides the anthropometric and biochemical parameters used frequently in other studies for the diagnosis of undernutrition, we also used dietary intake data, because dietary deficit intake is the primary cause of undernutrition[36].

Our results showed that the three groups had different nutritional statuses, differing significantly in dietary intake and anthropometric and biochemical variables.

Group A showed the highest energy intake, which was higher than the RDI. This excessive energy intake was accompanied by the highest anthropometric values. People in group A showed the greatest BMI (32.6 ± 4.8 kg/m^2), a value that was above than the normal range for elderly populations (24-29 kg/m^2)[31]. The total population studied showed a higher than recommended waist circumference, indicating abdominal obesity, although, group A showed a higher value than groups B and C. Despite these high values, given the selective survival and the reduced risk of overweight in old age[37,38], it is not likely that this population is at great cardiovascular risk. The percentage of people in group A whose biochemical parameters were below the normal ranges may have been due to the presence of several illnesses but not to undernutrition. In view of these results, it might be said that group A was malnourished or at risk of malnutrition because of an excessive energy intake and overweight/obesity.

Group B could be considered as having an adequate nutritional status, an adequate energy intake, a BMI within the normal range for elderly populations and adequate values for the biochemical parameters.

Undernutrition is a dynamic process characterized by depletion of lean body mass, visceral proteins and body fat. It starts with inadequate nutrient intake, followed by a progressive series of metabolic, functional and body composition changes[39]. The undernourished or at risk of undernutrition group (Group C) showed an energy intake below the RDI for Spanish elderly people, mainly because of a reduced lipid intake. This reduction in energy intake was also accompanied by a reduction in micronutrient intake. Consequently, muscle mass and fat deposits had the lowest values. Similar results have been described by other authors[40-42].

Values of TSF, MAMC and MAMA below the 5th or 10th percentiles have been used as indicators of undernutrion in elderly people[43]. Friedman et al. (1985)[44] showed that CAMA values of ≤ 16.0 and ≤ 16.9 cm^2 for men and women, respectively, and even values close to these (≤ 21.4 and ≤ 21.6 cm^2, for men and women, respectively) suggested nutritional risk. However, in the present study, a low percentage of people in group C showed values that might indicate nutritional risk for these CAMA values. A high percentage of undernourished people might not have been detected if a specific reference value had been used to diagnosis undernutrition.

Serum albumin, transferrin and total cholesterol concentrations and the total lymphocyte count are also considered indicators of nutritional status[3,18,45,46]. In the present study, these parameters showed the lowest values in group C. However, a high percentage of people in this group showed values within the normal range, as have been previously described in other studies[47]. We believe that low values of these parameters, although within the normal range, should be considered unfavourable when they are accompanied by low energy intake or low values for the anthropometric parameters.

On the other hand, biochemical parameters can be altered by certain diseases[45,48]. Anthropometric measurements, especially BMI, can be affected by dehydration or edema, and arm anthropometry is less accurate because of the physical changes with age: redistribution of fat from subcutaneous to deep adipose tissues, decreased elasticity of skin, alterations in skin thickness, and atrophy of subcutaneous adipocytes[44]. An undernourished person could show an adequate energy intake, while the development of undernutrition may be due to increased metabolic demands or increased nutrient losses, because illness is frequent in the elderly[49]. We believe that three groups of data should be used to diagnose undernutrition: intake, and anthropometric and analytical variables.

In conclusion, our study shows that cluster analysis is a useful statistical method for assessing the nutritional status of institutionalized elderly populations. In the studied population, we found that the overall prevalence of undernutrition or risk of undernutrition was 32.7%, whereas 32.2% of the studied subjects were malnourished or at risk of malnutrition because of an excessive energy intake, showing overweight/obesity. The undernourished or at risk of undernutrition group showed the lowest values for dietary intake and the anthropometric and analytical parameters measured. Some of the specific reference values used in the literature, on the other hand, might have failed to detect many of the undernourished or people at risk identified by cluster analysis.

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References

1. Omran ML, Morley JE. Assessment of protein energy malnutrition in older persons, part I: history, examination, body composition, and screening tools. *Nutrition* 2000; 16: 50-63.
2. Bourdel-Marchasson, I, Rollandb, C, Jutand, MA, Egeab, C, Baratchart, B, Barberger-Gateau, P. Undernutrition in geriatric institutions in South-West France: policies and risk factors. *Nutrition* 2009; 25: 155-64.
3. Volkert D, Saeglitz C, Gueldenzoph H, Sieber CC, Stehle P. Undiagnosed malnutrition and nutrition-related problems in geriatric patients. *J Nutr Health Aging* 2010; 14: 387-92.
4. Álvarez-Hernández J, Planas M, León-Sanz M, García de Lorenzo A, Celaya-Pérez S, García-Lorda P, Araujo K, Sarto B; on behalf of the PREDyCES® researchers. Prevalence and costs of malnutrition in hospitalized patients; the PREDyCES® Study. *Nutr Hosp* 2012; 27(4): 1049-59.
5. Pérez-Llamas F. Risk of desnutrition in the Spanish population. Evaluation of the current situation and need for a nutritional intervention. *Med Clin* (Barc) 2012; 139: 163-4.
6. Álvarez J, Gonzalo I, Rodríguez JM. Envejecimiento y nutrición. *Nutr Hosp Supl* 2011; 4(3): 3-14.
7. Cuesta FM, Matía P. Detección y evaluación del anciano con desnutrición o en riesgo. *Nutr Hosp Supl* 2011; 4(3): 15-27.
8. Wouters-Wesseling W, Wouters AE, Kleijer CN, Bindels JG, de Groot CP, Van Staveren WA. Study of the effect of a liquid nutrition supplement on the nutritional status of psycho-geriatric nursing home patients. *Eur J Clin Nutr* 2002; 56: 245-51.
9. Smoliner C, Norman K, Scheufele R, Hartig W, Pirlich M, Lochs H. Effects of food fortification on nutritional and functional status in frail elderly nursing home residents at risk of malnutrition. *Nutrition* 2008; 24: 1139-44.
10. Sánchez-Campillo M, Torralba C, López MA, Zamora S, Pérez-Llamas F. Strategies for improving nutritional value of the meals offered by public nursing homes for the elderly. *Nutr Hosp* 2010; 25: 1014-9.
11. Ordóñez J, De Antonio JA, Pou C, Navarro J, Rubio J, Marcos S, López M. Effect of an oral hyperproteic nutritional supplement in malnourished elderly patients in nursing homes. *Nutr Hosp* 2010; 25: 549-54.
12. Pérez-Llamas F, Moregó A, Tobaruela M, García MD, Santo E, Zamora S. Prevalence of malnutrition and influence of oral nutritional supplementation on nutritional status in institutionalized elderly. *Nutr Hosp* 2011; 26: 1134-40.
13. Saunders J, Smith T, Stroud M. Malnutrition and undernutrition. *Medicine* 2011; 39: 45-50.
14. Bauer JM, Vogl T, Wicklein S, Trögner J, Mühlberg W, Sieber CC. Comparison of the Mini Nutritional Assessment, Subjective Global Assessment, and Nutritional Risk Screening (NRS 2002) for nutritional screening and assessment in geriatric hospital patients. *Z Gerontol Geriat* 2005; 38: 322-7.
15. Burgos R, Sarto B, Elío I, Planas M, Forga M, Cantón A, Trallero R, Muñoz MJ, Pérez D, Bonada A, Saló E, Lecha M, Enrich G, Salas-Salvadó J; on behalf of the Group for the Study of Malnutrition in Hospitals in Catalonia. Prevalence of malnutrition and its etiological factors in hospitals. *Nutr Hosp* 2012; 27 (2): 469-76.
16. Camina MA, Barrera S, Domínguez L, Cruceiro C, Mateo B, Redondo del Río MP. Presencia de malnutrición y riesgo de malnutrición en ancianos institucionalizados con demencia en función del tipo y estadío evolutivo. *Nutr Hosp* 2012; 27(2): 434-40.
17. Isenring EA, Banks M, Ferguson M, Bauer JD. Beyond Malnutrition screening: appropriate methods to guide nutrition care for aged care residents. *J Acad Nutr Diet* 2012; 112: 376-81.
18. López-Contreras MJ, Torralba C, Zamora S, Pérez-Llamas F. Nutrition and prevalence of undernutrition assessed by different diagnostic criteria in nursing homes for elderly people. *J Hum Nutr Diet* 2012; 25: 239-46.
19. Poulia KA, Yannakoulia M, Karageorgou M, Gamaletsou M, Panagiotakos DB, Sipsas NV, Zampelas A. Evaluation of the efficacy of six nutritional screening tools to predict malnutrition in the elderly. *Clin Nutr* 2012; 31:378-85.
20. Milà R, Formiga F, Duran P, Abellana R. Prevalence of malnutrition in Spanish elders: systematic review. *Med Clin* (Barc) 2012; 139: 502-8.
21. Pérez-Llamas F, Garaulet M, Torralba C, Zamora S. Development of a current version of a software application for research and practice in human nutrition (GRUNUMUR 2.0). *Nutr Hosp* 2012; 27: 1576-82.
22. Moreiras O, Carvajal A, Cabrera L, Cuadrado C. Tablas de Composición de Alimentos, 15th edn. Ediciones Pirámide, Madrid, 2011.
23. Pérez-Llamas F, Zamora S. La dieta mediterránea. In: Pérez-Llamas F, Zamora S (eds) Nutrición y alimentación humana, Universidad de Murcia, Murcia, 2002, pp. 157-169.
24. Arbonés G, Carbajal A, Gonzalvo B et al. Nutrition and dietary recommendations for the elderly. "Public Health" Working Group of the Spanish Nutrition Society. *Nutr Hosp* 2003; 18: 109-37.
25. Pérez-Llamas F, Martínez C, Carbajal A, Zamora S. Concepto de dieta prudente. Dieta Mediterránea. Ingestas recomendadas. Objetivos nutricionales. Guías alimentarias. In: Carvajal A, Martínez C (eds), Manual Práctico de Nutrición y Salud. Alimentación para la prevención y el manejo de enfermedades prevalentes, Exlibris Ediciones, Madrid, 2012, pp. 65-81.
26. Jelliffe DB. The assessment of the nutritional status of the community (with special reference to field surveys in developing regions of the world). *Monogr Ser World Health Organ* 1966; 53: 3-271.
27. Gurney JM, Jelliffe DB. Arm anthropometry in nutritional assessment: nomogram for rapid calculation of muscle circumference and cross-sectional muscle and fat areas. *Am J Clin Nutr* 1973; 26: 912-5.
28. Heymsfield SB, McManus C, Smith J, Stevens V, Nixon DW. Anthropometric measurement of muscle mass: revised equations for calculating bone-free arm muscle area. *Am J Clin Nutr* 1982; 36: 680-90.
29. Alastrué A, Sitges A, Jaurrieta E, Puig P, Abad JM, Sitges A. Anthropometric assessment of the nutritional status: undernutrition and obesity patterns. *Med Clin* (Barc) 1983; 80: 691-9.
30. Esquius M, Schwartz S, López J, Andreu AL, García E. Reference values for anthropometric parameters in the elderly population. *Med Clin* (Barc) 1993; 100: 692-8.
31. Beck AM, Ovesen L. At which body mass index and degree of weight loss should hospitalized elderly patients be considered at nutritional risk? *Clin Nutr* 1998; 17: 195-8.
32. Lean ME, Han TS, Morrison CE. Waist circumference as a measure for indicating need for weight management. *BMJ* 1995; 311: 158-61.
33. Salas-Salvadó J, Rubio MA, Barbany M, Moreno B, Grupo Colaborativo de la SEEDO. SEEDO 2007 Consensus for the evaluation of overweight and obesity and the establishment of therapeutic intervention criteria. *Med Clin* (Barc) 2007; 128: 184-96.
34. Green SM, Watson R. Nutritional screening and assessment tools for use by nurses: literature review. *J Adv Nurs* 2005; 50: 69-83.
35. Durán P, Milà R, Formiga F, Virgili N, Vilarasau C. Assessing risk screening methods of malnutrition in geriatric patients; Mini Nutritional Assessment (MNA) versus Geriatric Nutritional Risk Index (GNRI). *Nutr Hosp* 2012; 27(2): 590-8.
36. Mowé M, BØhmer T, Kindt E. Reduced nutritional status in an elderly population (> 70 y) is probable before disease and possibly contributes to the development of disease. *Am J Clin Nutr* 1994; 59: 317-24.
37. de Groot CPGM, Enzi G, Perdigao AL, Deurenberg P. Longitudinal changes in anthropometric characteristics of elderly Europeans. *Eur J Clin Nutr* 1996; 50 (Supl. 2): S9-S15.
38. Visscher TL, Seidell JC, Molarius A, van der Kuip D, Hofman A, Witteman, JC. A comparison of body mass index, waist-hip ratio and waist circumference as predictors of all-cause mortality among the elderly: the Rotterdam study. *Int J Obes Relat Metab Disord* 2001; 25: 1730-5.
39. Brugler L, Stankovic A, Bernstein L, Scott F, O'Sullivan-Maillet J. The role of visceral protein markers in protein calorie malnutrition. *Clin Chem Lab Med* 2002; 40: 1360-9.

40. Ruiz-López MD, Artacho R, Oliva P, Moreno-Torres R, Bolaños J, de Teresa C, López MC. Nutritional risk in institutionalized older women determined by the Mini Nutritional Assessment test: what are the main factors? *Nutrition* 2003; 19: 767-71.
41. Margetts BM, Thompson RL, Elia M, Jackson AA. Prevalence of risk of undernutrition is associated with poor health status in older people in the UK. Eur J Clin Nutr 2003, 57: 69-74.
42. Ödlund A, Koochek A, Ljungqvist O, Cederholm T. Nutritional status, well-being and functional ability in frail elderly service flat subjects. *Eur J Clin Nutr* 2005; 59: 263-70.
43. Omran ML, Morley JE. Assessment of protein energy malnutrition in older persons, part II: laboratory evaluation. *Nutrition* 2000; 16: 131-40.
44. Friedman PJ, Campbell AJ, Caradoc-Davies TH. Prospective trial of a new diagnostic criterion for severe wasting malnutrition in the elderly. *Age Ageing* 1985; 14: 149-54.
45. Hu P, Seeman TE, Harris TB, Reuben DB. Does inflammation or undernutrition explain the low cholesterol-mortality association in high-functioning older persons? MacArthur studies of successful aging. *J Am Geriatr Soc* 2003; 51: 80-4.
46. Iizaka S, Jiao L, Sugama J, Minematsu T, Oba M, Matsuo J, Tabata K, Sugiyama T, Sanada H. Evaluation of nutritional status and skin condition among elderly residents in a long-term care hospital. *J Nutr Health Aging* 2012; 16: 107-11.
47. Sergi G, Coin A, Enzi G, Volpato S, Inelmen EM, Buttarello M, Peloso M, Mulone S, Marin S, Bonometto P. Role of visceral proteins in detecting malnutrition in the elderly. *Eur J Clin Nutr* 2006; 60: 203-9.
48. Bernstein LH, Ingenbleek Y. Transthyretin: its response to malnutrition and stress injury. Clinical usefulness and economic implications. *Clin Chem Lab Med* 202; 40: 1344-8.
49. Corish CA, Kennedy NP. Protein-energy undernutrition in hospital in-patients. *Br J Nutr* 2000; 83: 575-91.