ANTHROPOLOGIE • XLI/1–2 • pp. 127–133 • 2003

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BMI RELATED TO FAT PATTERNING IN UNIVERSITY STUDENTS FROM THE BASQUE COUNTRY (SPAIN)

ABSTRACT: Evaluating the nutritional status of individuals and populations groups is a tool of vital importance in public health and a feasible indicator of the standards of living. In this sense, establishing ranges of body mass index (BMI) in order to diagnose malnutrition is very important. This index can also be related to other variables such as caloric intake, socio-economic level, physical activity and adiposity. The aim of the present study was to examine the relationship between BMI and fat patterning in a sample of 549 young adult students (159 males and 390 females) between 18 and 29 years of age, who were attending the University of the Basque Country (Spain). The following measurements were taken following the IBP criteria: height, weight and four skinfolds (triceps, subscapular, suprailiac and medial calf). BMI was calculated as the relationship weight (kg)/ height^2 (m). Fat distribution was assessed by PCA for the total sample. Variables in the analysis were four indices (ratios) of relative fat distribution, which have the ability of maximising the contrast between trunk and extremity fat. Following the SEEDO´2000 classification on overweight and obesity more than 70% of males and about 80% of females were classified with an appropriate BMI. Mean BMI was significantly higher (p<0.001) in males (23.63) than in females (22.27). Two components were extracted from the PCA, accounting together for 88.26 % of the variance. The first factor accounted for 81.44 % and the second for 6.82%. The first component reflects a trunk-limb pattern of fat distribution. This factor was used to identify two groups of fat distribution, centripetal and peripheral. In both sexes, the central fat distribution was associated with higher BMI values, which in females were close to the highest limit of normal weight (24.96). Even BMI does not exactly reflect body composition, it can be a good indicator of the development of a centripetal fat pattern, even later studies in overweight and obese samples should confirm our observations.

KEY WORDS: BMI – Fat patterning – PCA – Obesity – University students

INTRODUCTION

The study of adiposity has been an important field of research in human biology due to its influence on physical activity (Mueller *et al.* 1986), its association with feminine fertility (Frisch, McArthur 1974), its role in the biological adaptation to climate (Shepard *et al.* 1974), and above all, due to its close relation with nutritional status and illness. The interest of anthropologists on the researches related with adiposity has mostly been motivated by its relation with chronic diseases, particularly of the cardiovascular system and of the glucose metabolism. Clinical and epidemiological data indicate that fatness, *per se*, has a great influence on these diseases during adulthood (Gasser *et al.* 1994). In addition, body fatness distribution has revealed to be also an interesting factor, moderately correlated with adiposity and chronic diseases (Lapidus *et al.* 1988, Schapira *et al.* 1990). Particularly male (android) pattern of fat, which is characterised by a higher deposition of trunk and abdominal fat compared with limbs fat, is associated with a greater tendency to metabolic complications (Fujimoto *et al.* 1990). Central body fat is also an important predictor of cardiovascular diseases, surely as much or even more than the excess of total body fatness (Björntrop 1990). As well as environmental factors, as those related with socio-economic status and nutritional adequacy, the role of the inheritance on human fatness variation seems to be important, on the quantity but above all, on its distribution (Bouchard *et al.* 1988, Selby *et al.* 1990).

Adiposity can be estimated indirectly, through weight-for-height ratio, the BMI, the skinfolds, the somatotype, or through the estimation of body density, among other methods. Fat distribution can be identified through anthropometrical indices, as the Centripetal Fat Ratio (CFR), or the waist-to-hip ratio (WHR), and also through the assessment of the fat patterning derived by Principal Component Analysis (PCA, Mueller, Reid 1979, Ramírez, Mueller 1980). PCA can include absolute measurements of skinfolds, but also ratios of skinfolds (Hattori *et al.* 1987, Rosique *et al.* 1994, Rebato *et al.* 1998). In spite of the criticisms by some authors (Ross *et al.* 1996, Roubenoff *et al.* 1995, Wellen *et al.* 1996) about the relationship of the BMI and body fat percentage, this index is one of the most used indicators of overweight and obesity in the studies on the evaluation of the nutritional status of large samples of population. In fact, many studies have shown that BMI is a reasonable index of adiposity (Bray 1993, Frisancho 1990, Must *et al.* 1991, Deurenberg *et al.* 1998) because it correlates highly with percentage of the body weight as fat (fat percentage) and lowly with height (Norgan 1994). Correlation between BMI and total body fatness or the percentage of fat is rather high (0.6–0.8) for large and heterogeneous population samples (Bouchard 1993), even though the number of data regarding its possible relation with distribution patterns is scarce.

The purpose of this study was to establish the ranges of body mass index (BMI) in order to diagnose malnutrition in a sample of young university adults, and to examine the relationship between BMI and the relative anatomic distribution of subcutaneous fatness (fat patterning) assessed by PCA for the total sample.

MATERIAL AND METHODS

Subjects

A sample of 549 university students volunteers, 159 males and 390 females between 18 and 29 years of age (mean age for males, 21.5 years and 21.3 years for females), who were attending the University of the Basque Country (Spain), were selected. This study is framed in a research project designed to evaluate the nutritional status of the university population of the Basque Autonomous Community, through several anthropometrical parameters, the analysis of bioelectrical impedance (BIA), some biochemical data and nutritional questionnaires, as well as on the self-perception of the body image in this group of population. The sampling was conducted by both the Laboratory of Physical Anthropology and the Laboratory of Nutrition of the University of the Basque Country.

Anthropometry

The following measurements were taken, following the IBP criteria (Weiner, Lourie 1981): height, weight and four skinfolds (triceps, subscapular, suprailiac, and medial calf). BMI was calculated as the relationship weight (kg)/ height^2 (m). Replicate measurements were taken on 21 subjects of both sexes, selected at random, and intra-observer technical errors of measurement were calculated (Cameron 1986). The errors ranged from 1.83 mm for the suprailiac to 0.46 cm and 0.29 kg for the height and body weight, respectively; errors for the other skinfolds were intermediate.

Procedures

Fat distribution was assessed by PCA for the total sample. Variables in the analysis were four indices (ratios) of relative fat distribution. The inclusion of indices in the PCA to study the fat patterning was previously used by other authors (Hattori *et al.* 1987, Rosique *et al.* 1994, Rebato *et al.* 1998). The selected indices, a variant of the ratios used by Baumgartner *et al.* (1990), have the ability of maximising the contrast between trunk and extremity fat. Four indices were used:

TRI = Triceps / (Subscapular+Suprailiac)
CAL = Calf / (Subscapular+Suprailiac)
SUB = Subscapular / (Triceps+Calf)
SUP = Suprailiac / (Triceps+Calf)

The Kaiser criterion of normalisation was applied to extract components, and only components with an eigenvalue greater than 1 were considered. After the extraction of the components, factor scores were computed to identify individuals with different ratings of centralised or peripheral fat distribution by sex. Such identification permits further BMI comparison between different subsamples of fat distribution. Comparisons of BMI average values by sex were made with Student's unpaired t test. Within each sex, comparison of BMI by fat distribution categories was made by using an analysis of variance (ANOVA oneway). Prevalence of different categories of BMI between sexes was compared using a chi-squared test (5 d.f.). $P < 0.05$ was accepted as statistically significant. Data were analysed using SPSS software, version 11.0.

RESULTS

Descriptive statistics for age and anthropometrical variables by sex are reported in *Table 1*. Values of height, weight and BMI were higher in males meanwhile females showed higher values in the 4 skinfolds. Differences were statistically significant in all variables ($p<0.001$), except

TABLE 1. Descriptive statistics of age and anthropometrical variables in University students from the Basque Country.

	Males					Females				
Variables	**Sample size**	**Mean**	**S.D.**	**Minimum**	**Maximum**	**Sample size**	**Mean**	**S.D.**	**Minimum**	**Maximum**
Age (yrs)	159	21.51	2.14	18.09	29.45	390	21.29	2.43	18.31	29.77
Height * (cm)	159	175.51	6.63	158.80	194.80	389	162.38	6.06	147.00	188.00
Weight * (kg)	159	72.85	10.00	44.50	114.40	389	58.51	8.73	40.10	94.80
Triceps * (mm)	159	11.19	5.32	4.00	30.00	389	19.40	5.43	6.00	39.60
Subscapular (mm)	159	13.99	5.75	6.00	43.00	389	15.01	5.72	3.00	40.00
Suprailiac * (mm)	159	16.21	8.05	5.00	53.00	389	18.30	7.34	5.00	44.50
Calf* (mm)	159	11.73	5.94	3.00	36.00	389	20.56	5.70	7.00	42.00
BMI* (kg/m^2)	159	23.63	2.90	17.47	38.56	389	22.27	2.85	16.66	34.15

*Sex difference, p<0.001

TABLE 2. Distribution of BMI in the University students according to the classification proposed by the SEEDO'2000.

	Males		Females		Total	
BMI categories (*SEEDO'2000)	n	%	n	%	n	%
Underweight (BMI< 18.5)	2	1.3	16	4.1	18	3.3
Normal weight (BMI 18.5–24.9)	117	73.6	311	79.7	428	78.1
Overweight grade I (BMI 25–26.9)	26	16.4	37	9.5	63	11.5
Overweight grade II (BMI 27–29.9)	7	4.4	19	4.9	26	4.7
Obesity type I (BMI 30–34.9)	5	3.1	6	1.5	11	2.0
Obesity type II (BMI 35–39.9)	2	1.3	–	–	2	0.4
Obesity type III (BMI 40–49.9)	–	–	–	–	–	–
Obesity type IV (BMI >50)	–	–	–	–	–	–

* Spanish Society for the Study of Obesity

TABLE 3. Principal components analysis factor matrix.

Index	Factor	
	1	2
TRI	–0.89	0.39
CAL	–0.90	–0.33
SUB	0.90	0.07
SUP	0.91	–0.02

subscapular skinfold, which was close to the limit of significance (p=0.06). In *Table 2*, the distribution of BMI value in the studied sample was displayed according to the overweight and obesity classification proposed by the SEEDO'2000 (Spanish Society for the Study of Obesity). The most part of the studied sample (78.1%) presented a normal weight, the percentage being slightly higher in females (79.7%) than in males (73.6%). The latter showed 16.4% of overweight grade I, meanwhile the prevalence of this category was notably lower in females (9.5%). The percentage of overweight grade II was similar in both sexes (4.4% and 4.9% in males and females, respectively), while males doubled the percentage of females in obesity type I (3.1% vs. 1.5%), and they also showed a low percentage of obesity type II (1.3%) not found among women. On the other hand, these last showed a higher frequency of underweight (4.1%) than males (1.3%). Comparisons between sexes of the obtained percentages in each BMI category were statistically significant (p<0.001).

Fat distribution and BMI

PCA was performed on the four indices already described. Two components (factors) were extracted, accounting together for 88.26% of the variance. The first accounted for 81.44% and the second for 6.82%. After extraction, the non-rotaded solution has been adopted, as the biological meaning of the factors did not improve with the rotation. *Table 3* displays the non-rotated factor matrix. Indices showing a trunk or central fat deposition (SUB and SUP) have a high positive correlation on component 1, while indices showing a peripheral fat deposition (TRI and CAL) have a high negative correlation with this component. The first component reflects a trunk-limb pattern of fat distribution, and can be considered as a "centripetal pattern

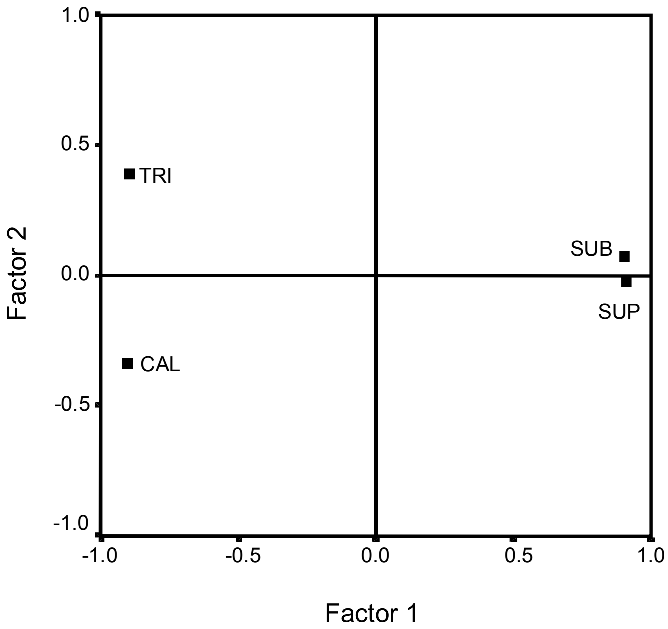

FIGURE 1. Plot of the four fat distribution indices on the PCA bidimensional space.

of fat distribution". The second component is correlated only with limb skinfolds and shows a contrast between upper limb (TRI) and lower limb (CAL) fat. It, therefore, reflects an "upper-lower limb pattern" *(Figure 1)*.

Standardised fat factor scores were computed by each subject to identify patterns of fat distribution. Only the first component was used. Factor scores for the first component indicate central body fat distribution: the higher the fat factor score, the higher the rating of central fat distribution. In contrast, the lower the fat factor score, the lower the rating of centripetal fat distribution, that is, more peripheral. Since individuals show a wide range of fat patterning, only those who showed a clearly developed pattern of fat distribution were selected to study the association between fat distribution and BMI. Identification of these individuals was done with the first factor score. Individuals below the 25th percentile showed lower ratios of trunk fat relative to limb fat (peripheral fat distribution), and those above the 75th percentile showed lower ratios of limb fat relative to trunk fat (centralised fat distribution). In other words, only correlations equal or higher than +0.5 (or correlations equal or lower than –0.5) were considered. This criterion was adopted in order to exclude individuals with moderate development of fat distribution and to obtain a consistent biological meaning of the factor (Rosique *et al.* 1994, Rebato *et al.* 1998).

Table 4 shows the percentages of centralised and peripheral individuals, in each sex, the average BMI for factor score groups and the minimum and maximum values for the index. The proportion of centralised individuals was clearly greater in males than in females. Centralised males accounted for 71% of the total sample of males, while peripheral males only represented 2.5%. In contrast, centralised females represented 9.3% and peripheral 41.4% of the total sample of females. Both, centralised males and females have higher values of BMI than peripherals (23.9 vs. 19.4 in males, 24.9 vs. 21.2 in females). Differences in BMI between the fat distributions groups of the same sex were highly significant ($p<0.001$).

DISCUSSION

Evaluating the nutritional status of individuals and populations groups is a tool of vital importance in public health and a feasible indicator of standards of living. In this sense, establishing ranges of BMI in order to diagnose malnutrition is very important. This index is a valuable epidemiological tool, but it does not distinguish clearly between an increase of fat and an accumulation of muscle (Trudeau *et al.* 2003), even if it depends on the age of the individuals. Thus, in middle-aged subjects BMI is a good estimator of body fatness (Rogucka, Bielicki 1999), but its meaning seems to be more ambiguous in young-adults samples. In populations of young individuals BMI reflects lean body mass (particularly in males) as well as body fat, so we are not always referring to obesity (excess of fat which causes an increase of body mass) when BMI is high. In fact, the WHO (1995) has decided to express the values of this index as overweight instead of obesity, which implies a knowledge of body composition. However, other classifications, as the one used in this research, make use of the term obesity (SEEDO'2000). Nevertheless, the BMI continues to be used widely on an international basis (Cole *et al.* 2000) and it has been described as a "…useful index for characterising and monitoring the onset, development, and degree of overweight and obesity from childhood to adulthood" (Guo *et al.* 2002).

TABLE 4. Mean BMIs of extreme fat distribution groups in males and females.

Males (n=159)	**n (%)**	**Mean**	**SD**	**Minimum**	**Maximum**
Centralised	113 (71.07)	23.91	3.05	19.89	38.56
Peripheral	4 (2.52)	19.44	1.33	17.47	20.27
Females (n=389)	**n (%)**	**Mean**	**SD**	**Minimum**	**Maximum**
Centralised	36 (9.30)	24.96	3.50	20.07	33.24
Peripheral	161(41.40)	21.25	2.28	16.66	29.87

The results obtained in our research, based on the prevalence of the different categories proposed by the SEEDO'2000 for BMI, indicate that young university population presents, in general, a good nutritional status, since more than 70% of males and about 80% of females were classified with an appropriate BMI. We must emphasise, however, the higher frequency of overweight grade I of males compared with females (16.4% vs. 9.5%) and the similar prevalence of overweight grade II in both sexes. The obesity prevalence, defined as a BMI =30 (Seidell, Flegal 1997), was higher in males than in females (4.4% vs. 1.5%), meanwhile these last showed a higher frequency of underweight (4.1% vs.1.3%). Obesity prevalence among young university students was lower than that of the whole Spanish population of 25–60 years (11.5% in males and 15.2% in females) and also regarding the group of population of a comparable range of age: in the group of 25–34 years-old, the data of the Spanish population indicate frequencies of obesity of 6.04% and 4.49% for males and females, respectively (SEEDO'2000). We must take into account that the studied sample corresponds to a segment of population that, due to its range of age, cannot be considered as representative of the whole adult Spanish population nor, maybe, of other young people, non university students, of the same age, due to several factors related with socio-economic and cultural status. These factors have an influence on the eating habits and physical activity, and in short, on the quantity of fat and its distribution. On the other hand, university women presented lower values of obesity than males, meanwhile data concerning the whole Europe and, particularly Spain, indicate the opposite tendency (SEEDO'2000). It may be hypothesised that, in our sample, young women are more concerned and involved in controlling body mass and fatness than men. This fact could be related with a more distorted perception of height and weight by females (Rocandio *et al.* 2003), which seems to be confirmed through the higher frequency of low weight when compared with males.

Regarding fat patterning obtained by PCA, results agree with previous studies (Malina *et al.* 1995, Rebato *et al.* 1998) where it was noted that interindividual differences in subcutaneous fat distribution are focused mainly in the contrast between trunk and extremities subcutaneous fat. In our research, central body fat comprises most of the variance in body fat distribution in both sexes compared to upper-lower extremity pattern. The prevalence of centralised fat distribution was greater in males than in females, being more peripheral in females. In fact, the centripetal pattern is a masculine characteristic associated with sex hormone levels. In both sexes, average BMI of centralised subjects was significantly higher than average BMI of peripherals. Centralised males showed a wide range of BMI variation *(Table 4)* ranging from 19.89 to 38.51, that is, between an appropriate weight and obesity type II. A high BMI associated with a central body fatness pattern can be considered as an additional risk factor for several cardiovascular and metabolic diseases. On the contrary, peripheral males showed less variability of this index (BMI ranging between 17.47 and 20.27) and an insufficient weight at the low limit. We must take into account, nevertheless, the reduced number of males which presented this kind of fat patterning in the analysed sample. Concerning females, the centralised ones showed a variability ranging from normal weight (minimum BMI=20.07) to obesity type I (maximum BMI=33.24), these last ones having, *a priori*, a higher cardiovascular and metabolic risk. On the other hand, women with a peripheral pattern, whose range of variation was from 16.66 to 29.87 showed, as in males, some cases of low weight, even though some individuals with overweight grade II were also found. Considering only extreme values of the observed variability range of BMI, we can conclude that those individuals classified as obese (BMI=30), independently of their sex, showed a central body fatness distribution pattern, whereas underweighted individuals (BMI=18.5) were associated with a peripheral pattern.

In the analysed sample of university students, central fat distribution seems to be more closely associated with a high mean BMI than peripheral distribution, in both sexes. The development of a centralised obesity can involve an excess of both fat and lean body mass. Some authors (Baumgartner, Roche 1988) suggest that centripetal fat patterning in females can be associated with increasing mesomorphy as a consequence of the actuation of masculine hormones. The association between Sheldonian mesomorphy and centripetal fat patterning has also been observed by Mueller and Joos (1985) in adult obese males. A research conducted in children and youth of the Basque Country, aged 8-19 years (Rosique *et al.* 1994) has showed that in boys and girls mesomorphy was related to a centripetal fat distribution. In addition, using relative BMI as criterion of obesity, this phenotype was absent among subjects with a peripheral pattern. Our results agree with this observation.

An important question can be withdrawn from our results: Which would be the meaning of the high values of BMI in those subjects with a central fat patterning? According to the above discussion, and considering that BMI in young adults may theoretically be indicative not only of fatness but a strongly muscular, "mesomorphic" physique (Kopelman 2000), this research could be showing an excess of lean body mass in these individuals, so the highest BMIs of the centralised individuals could be due to a greater muscle component and not to the amount of fat. The existence of a factor of sexual dimorphism, besides other factors related with exercise and food habits, can also be possible, so later researches taking into account these sources of variation as well as the analysis of total body fat could be useful to support our observations.

ACKNOWLEDGEMENTS

This work was supported by a research project of the University of the Basque Country (UPV 00154.310-E-13972/2001).

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