Relationship of weight and height with waist circumference, body mass index and conicity index in adolescents*

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Summary

Obesity or overweight in adolescents are a public health issue. Waist circumference (WC) body mass index (BMI), and conicity index (CI) have been used to assess these conditions and the risks involved. The aim of this study was to assess the influence of weight and height on WC, BMI and CI in adolescents. Student t test, ANOVA, Pearson correlations and binary correspondence were used. At 13-14 years, BMI (r = 0.89; r = 0.92) and WC (r = 0.85; r = 0.83) showed high correlations with weight. C had a low correlation with weight and lesser dependence on height. Binary correspondence analysis, showed that high values of weight were associated with high values of CI. In this sample, CI is not an indicator of body mass as a whole, yet it shows that heavy weight is associated with centripetal fat distribution as measured by this indicator and in this sense, it can be used as an index of fat distribution.

Key words *waist circumference, body mass index, conicity index, body composition, adolescents, Venezuela*

Introduction

Obesity and/or overweight in children and adolescents are a matter of concern in public health, both at individual and population levels. Overweight in young age is associated with overweight in adulthood (1,2). This condition affects about 33% of USA adult population (3), and the prevalence in youths has increased in the latest national health survey (4). The same tendency is also found in Venezuela where by 1999, the condition has reached 13% of youths (5). Furthermore, the nutrition transition in low-income countries, a condition where under and overnutrition exist simultaneously, is occurring very rapidly (6).

Screening over time for overweight and pattern of fat distribution is becoming an important aspect of pediatric care, given its potential long term health implications (7-9). In recent years the height-weight ratio, expressed as body mass index (BMI; kg/m^2) is increasingly used as a reliable and valid indicator of obesity (10,11). Nevertheless, studies conducted in adults have also advocated that waist circumference (WC) and conicity index (CI), are valid indicators of obesity and risk factors of cardiovascular disease (12-14).

The evidence for children and youths is less compelling for BMI, WC and CI. Flodmark et al. (15) support the idea that WC is somehow related to a potentially atherogenic lipoprotein profile in obese children, whereas Freedman et al. (7) found, in the Bogalusa Heart Study, that the prevalences for dyslipidemia, hyperinsulinemia and hypertension increased at the same time as

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BMI. On the other hand, data on conicity are limited. However, CI is associated with risk the of high levels of tryglicerides in Venezuelan females adolescents (16) and with other risk factors of coronary and heart diseases (14,17).

Although the ideal index to assess leanness and obesity should strongly correlate with body weight and minimize the influence of height (18), there is no clear consensus on what method should be used in children and adolescents, considering individual differences in maturity, timing and tempo. Therefore, the aim of this study was to assess the mediating influence of weight and height on WC, BMI and CI in Venezuelan adolescents, 11-16 years of age, seeking the best index to evaluate body composition at these ages.

Materials and methods

The data were obtained from a cross-sectional study of 394 adolescents, 11-16 years of age from Caracas, capital city of Venezuela. The sample included 186 males and 208 females. Environmental, cultural and social conditions of the families of the youths included in the study classified them as of low socioeconomic status. This integrated analysis concerning growth, nutritional status and body composition, along with socioeconomic factors in this sample, has been reported previously (19,20).

Anthropometry

The survey was carried out by a well trained group with quality controls being provided during the field work. The anthropometrical measurements were made in the morning, using portable equipment and following standard procedures (21); individuals wore minimal clothing. Height was appreciated to the nearest 0.1 cm with the subject in standing position, bare footed and with the head held in the Frankfort plane. A gentle pressure was applied on the mastoid process during measurement. On the other hand, weight was measured to the nearest 0.1 kg. Minimum waist, taken directly on the skin, was made to the nearest 0.1 cm, using a flexible non-elastic steel tape* with the subject standing, at the minimal abdominal girth, approximately midway between the xiphoid process and the umbilicus.

BMI was assessed as weight (kg) divided by the square of height (m) (22). CI was calculated according to the formula of Valdez et al. (23), as follows:

$$C = \frac{\text{WC (m)}}{0.109\sqrt{\text{wt (kg)/ht (m)}}}$$

as a measure of central adiposity, is based on quantifying the deviation from the circumference of an imaginary cylindrical shape derived from the weight and height of the individual. In comparison with other indices, it has been claimed to be easier to obtain and requiring less undressing besides being independent of hip circumference (24).

Statistical analysis

Statistical analysis was carried out with the SPSS program (25). The sample was divided into three age groups: 11-12, 13-14 and 15-16 years. Analytic methods included Student t tests to identify sexual differences, and one way analyses of variance (ANOVA), to test for differences between age groups within each sex. In addition, Scheffé post hoc test was used to identify which pairs of age groups differed significantly. Two linear regressions were also performed with height and weight as independent variables. The line of best fit was determined by least squares method. Analysis of correspondence (26) was also performed to measure the degree of association among categories defined according to references and constructed intervals. Weight, height and BMI were classified as low ($x < P10$), average ($P10 \geq x \leq P90$) and high ($x > P90$) according to percentile cut off points of a national reference (27). After verifying normality with the Kolmogorov-Smirnov-Lilliefors test, ($p > 0.05$), and in absence of national references, toler-

* Hoechst mass, West Germany

Table I Descriptive anthropometric statistics by age and sex

Age groups	No.	Weight	Height	WC	BMI	CI
Boys						
11-12						
Mean	70	34.44*	141.26*	60.21	17.16	1.12*
CV (%)		20.05	5.36	9.81	14.51	4.78
13-14						
Mean	64	46.59	156.95	64.44	18.66*	1.10*
CV (%)		24.70	6.33	12.00	17.03	5.82
15-16						
Mean	52	54.94	165.57*	67.78	19.90*	1.09*
CV (%)		17.91	5.01	8.91	12.03	5.52
Girls						
11-12						
Mean	80	37.12*	145.21*	59.03	17.49	1.08*
CV (%)		19.34	5.20	8.76	13.74	4.71
13-14						
Mean	75	48.68	155.00	64.60	20.16*	1.06*
CV (%)		18.87	3.78	10.59	14.85	5.65
15-16						
Mean	53	52.55	155.44*	67.18	21.72*	1.06*
CV (%)		12.21	3.28	7.27	10.07	4.37

Legend: WC = waist circumference; BMI = body mass index; CI = conicity index
CV (%): coefficient of variation in percentage
* ($p < 0.05$) sexual dimorphism

ance intervals for WC and CI were constructed and classified, as low ($< \bar{x} + s_x$), average ($\bar{x} \pm s_x$) and high ($> \bar{x} + s_x$).

Results

Table I presents means and coefficients of variations for weight, height, WC, BMI and CI by age groups and sex. All variables values except CI increased with age. Also they differed significantly between sexes, specially CI that attained differences at all age groups. On the other hand WC, was the only variable that did not show sexual dimorphism.

Results of ANOVA and Scheffé tests (not shown in the text) indicated differences by age groups as follows:

a) weight and WC in all age groups in both sexes;
b) BMI in boys and in girls at 11-12 years compared to the other two age groups;
c) CI differences in boys between the younger and the two older groups, but no differences in girls;
d) height differs significantly in boys in all age groups;
e) the two older age groups of girls do not differ in height, BMI and CI.

Tables II and III depict results of the linear regression, with weight and height as independent variables. WC, BMI and CI were first regressed onto weight, and the resulting estimated coefficient models were statistically significant for both, WC and BMI ($p < 0.05$). In both sexes WC had a high significant correlation with weight, ($r = 0.73$ to 0.85) and BMI (0.83 to 0.92) in boys and girls. On the other hand, WC and BMI were related to height to a lesser extent, but the correlations were significant for WC (0.35 to

Table II *Results of simple linear regression of waist circumference, body mass index and conicity index on weight and height, by age group in boys*

Age groups		Independent variable: Weight				Independent variable: Height			
		Estimate	p-value	r	r^2	Estimate	p-value	r	r^2
				Waist circumference (WC)					
11-12	b_0	35.798	0.000	0.829*	0.687	21.432	0.092	0.352*	0.124
	b_1	0.709	0.000			0.274	0.003		
13-14	b_0	37.841	0.000	0.849*	0.722	4.696	0.730	0.489*	0.239
	b_1	0.571	0.000			0.381	0.000		
15-16	b_0	43.049	0.000	0.734*	0.538	23.146	0.150	0.371*	0.137
	b_1	0.450	0.000			0.270	0.007		
				Body mass index (BMI)					
11-12	b_0	6.742	0.000	0.839*	0.703	8.613	0.125	0.184	0.034
	b_1	0.302	0.000			0.06050	0.128		
13-14	b_0	7.184	0.000	0.892*	0.795	–3.919	0.495	0.450*	0.202
	b_1	0.246	0.000			0.144	0.000		
15-16	b_0	8.393	0.000	0.861*	0.741	1.481	0.813	0.386*	0.149
	b_1	0.209	0.000			0.111	0.005		
				Conicity index (CI)					
11-12	b_0	1.113	0.000	0.043	0.002	1.259	0.000	0.134	0.018
	b_1	0.00034	0.721			–0.00095	0.268		
13-14	b_0	1.097	0.000	0.006	0.000	1.312	0.000	0.215	0.046
	b_1	–0.00003	0.963			–0.00138	0.088		
15-16	b_0	1.135	0.000	0.148	0.022	1.449	0.000	0.304*	0.092
	b_1	–0.00090	0.293			–0.00219	0.028		

Legend: $Y_1 = b_0 + b_1$weight, $Y_2 = b_0 + b_1$ height
* Correlate statistically significant

0.49), but not consistent for BMI (0.01 to 0.45). CI had negligible correlations with weight (0.01 to 0.15), and slightly higher with height (0.07 to 0.30).

At 13-14 years, weight accounted for 72-69% of waist variability and for 80-85% of BMI variability, while regression of height was not good enough to explain variability on these variables. Weight and height, on the other hand, were not strong enough to explain the variability of the CI.

When the indices are plotted in relation to body weight and height, based on the best regression fit, the best r^2 are attained at 13-14 years of age in boys and girls, $r^2 = 0.795$ and 0.847, for BMI and WC respectively. On the other hand, in this group WC appears as the most dependable variable on height, with r^2 of 0.239 and 0.141, for boys and girls. Generally speaking, boys and girls were similar in terms of patterns followed by the regression lines of best fit, describing the plot of the variables for the age-groups against weight (tables II, III and figure 1).

These results suggest that in the sample of 13-14 years old adolescents, BMI met the criteria as a satisfactory index, in that there was a strong correlation with weight, and a negligible correlation with height. The second best index according with this criteria was WC. CI does not show a satisfactory relationship owing to the structure of the index itself.

Table III *Results of simple linear regression of waist circumference, body mass index and conicity index on weight and height, by age group in girls*

Age groups		Independent variable: Weight				Independent variable: Height			
		Estimate	p-value	r	r^2	Estimate	p-value	r	r^2
Waist circumference (WC)									
11-12	b_0	37.055	0.000	0.822*	0.676	15.989	0.120	0.433*	0.187
	b_1	0.592	0.000			0.296	0.000		
13-14	b_0	34.582	0.000	0.828*	0.685	−0.378	0.864	0.376*	0.141
	b_1	0.617	0.000			0.439	0.001		
15-16	b_0	35.220	0.000	0.799*	0.639	15.835	0.421	0.346*	0.119
	b_1	0.608	0.000			0.330	0.011		
Body mass index (BMI)									
11-12	b_0	6.182	0.000	0.859*	0.738	4.378	0.387	0.284*	0.080
	b_1	0.288	0.000			0.09030	0.011		
13-14	b_0	5.558	0.000	0.920*	0.847	−4.815	0.586	0.315*	0.100
	b_1	0.300	0.000			0.161	0.006		
15-16	b_0	6.821	0.000	0.832*	0.692	20.914	2.243	0.012	0.000
	b_1	0.284	0.000			0.00521	0.087		
Conicity index (CI)									
11-12	b_0	1.118	0.000	0.153	0.023	1.245	0.000	0.172	0.030
	b_1	−0.00108	0.175			−0.00116	0.127		
13-14	b_0	1.033	0.000	0.091	0.008	1.170	0.000	0.068	0.005
	b_1	0.00059	0.440			−0.00069	0.563		
15-16	b_0	1.004	0.000	0.153	0.023	0.827	0.000	0.166	0.028
	b_1	0.00101	0.274			0.00151	0.235		

Legend: $Y_1 = b_0 + b_1$weight, $Y_2 = b_0 + b_1$ height
* Correlate statistically significant

The factorial axis of the correspondence analysis (figures 2, 3 and 4) showed the pattern of behavior of WC, BMI and CI adjusted to weight and height. Figure 2 showed the typical U-shaped associations of waist circumference that were similar and consistent, but of variable statistical significance for weight in boys and girls, respectively, in all age groups. For height there was a near direct association for the total sample in both sexes. However, in girls, when the information is analyzed by age, this pattern is discontinued for low values.

BMI (figure 3) was also in close association with weight in both sexes as a whole (U-shape) and by age groups. Similarly, although less strictly, BMI was related to height in boys, especially in the 13-14 year age group. In girls the BMI acted more independely on height, although high values of height are found in correspondence with high values of the BMI.

The CI (figure 4) showed low association with weight for the whole group in both boys and girls. However, in 13-14 year old girls, there was a correspondence between high values of CI and weight. On the other hand referring to height, there was an inverse relationship in boys; it was found that high values of CI were associated with low height values and viceversa. That is to say that the boys of our sample, aged 13-14 years and with low height tend to be more centripetal in their body fat distribution.

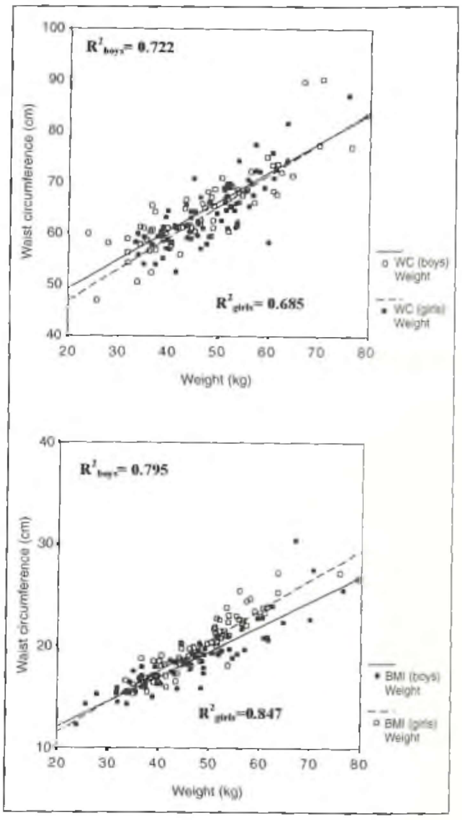


Figure 1 *Scatterplots of waist circumference, body mass and conicity index, adjusted by height and weight in 13-14 year old Venezuelan youths.*

Discussion

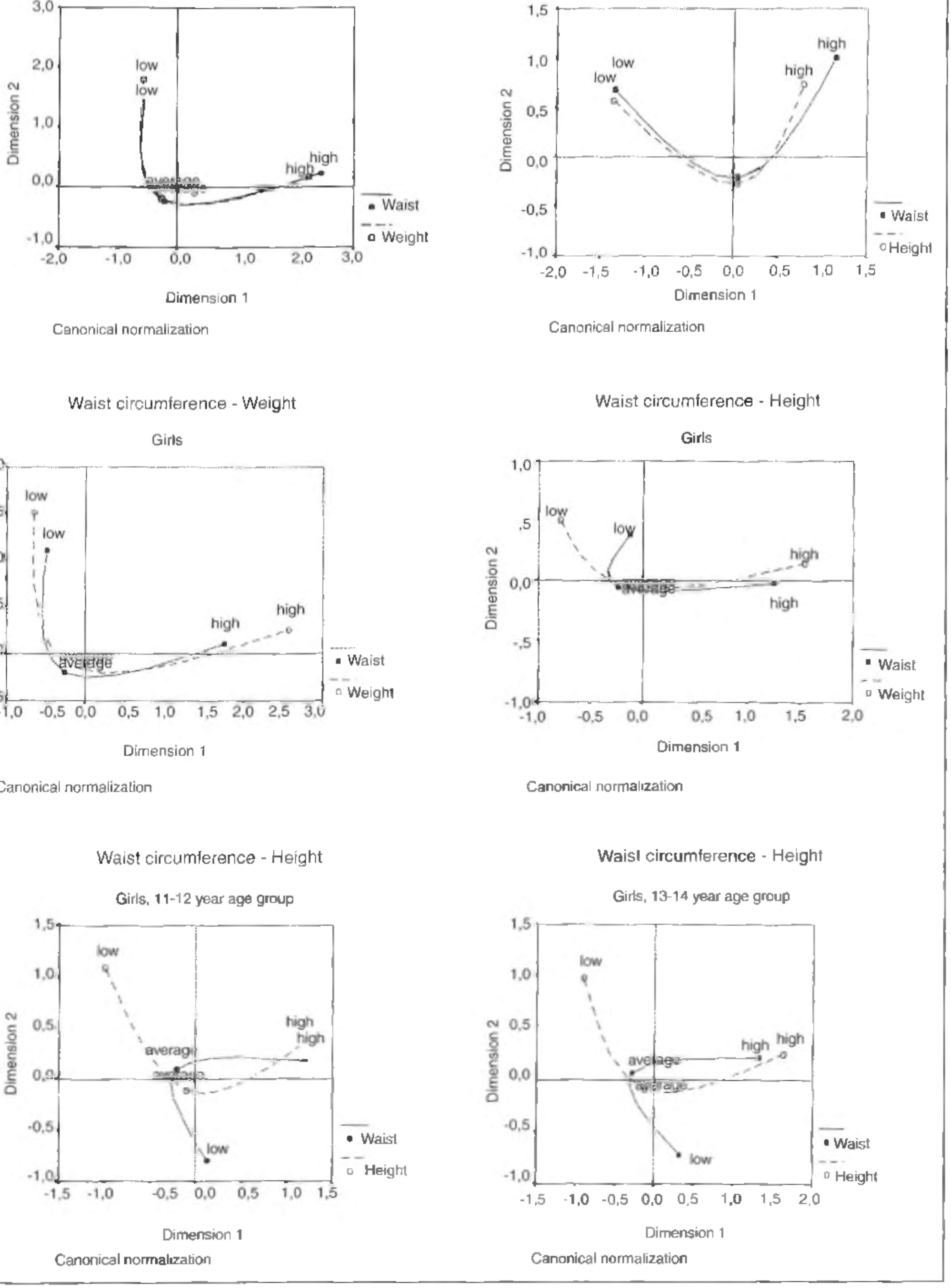
Overweight and/or obesity in children and adolescents are a prevalent worldwide multifactorial health problem, whose causes have been attributed to different etiologies. Gene-environment-culture interaction appears important. A list of environmental causes has been outlined: eating disorders, away-from-home eating, dietary energy consumption that overcomes energy expenditure, lack of energy expenditure through physical activities, among others (3,28).

The present results show that WC is closely related to weight (r^2 = 0.722; r^2 = 0.685) for boys and girls specifically at 13-14 years of age. WC showed a similar pattern for both sexes, having strong correlation with weight and moderate although statistically significant correlation with height.

Studies carried out in adult males and females in The Netherlands suggest that waist circumference is gaining support as a good anthropometric indicator to predict fatness and is of clinical and public health use, (13). In addition it is a simple yet sensitive method for screening both overweight and topography of fat distribution, when accurately classifying 83% of the female sample aged 16-80 years (29). A review made by Vanitallie (30) over a period from 1914 up to date, reports the reliability of WC, both as a measure of adiposity and a predictor of risk of obesity related to metabolic and cardiovascular diseases.

Several studies have examined at the correlations of BMI with weight, and Roche et al. (31) found that this relationship is a good predictor of obesity, based on estimated body fat. The long-term follow-up studies of BMI, like that of Rolland-Cachera et al. (32), indicated that BMI accounts more than skinfold measurements. Cole (22), also noted that BMI is a very useful tool to identify both obesity and malnutrition in children and adults. However, owing to the very skew distribution of the index during childhood and early adulthood, (even skewer than weight); the index should be transformed in order to approximate to a more normal distribution.

A primary finding in the current analysis confirms that BMI scaled strongly (r^2 = 0.847, $p < 0.05$) and positively (b = 0.30) to weight (table III, figure 1). Although BMI includes a mixture of both fat mass and lean body mass (18,33) the positive slope indicate that a higher BMI is attained at increasing levels of weight. In boys more pronounced U-shaped curves were apparent for both WC and BMI in relation to weight. The results reported by Pietrobelli et al. (10), who worked with an unadjusted association of



e 2 Factorial axis of the correspondence analysis for waist circumference referred to weight and . Total groups and selected ages.

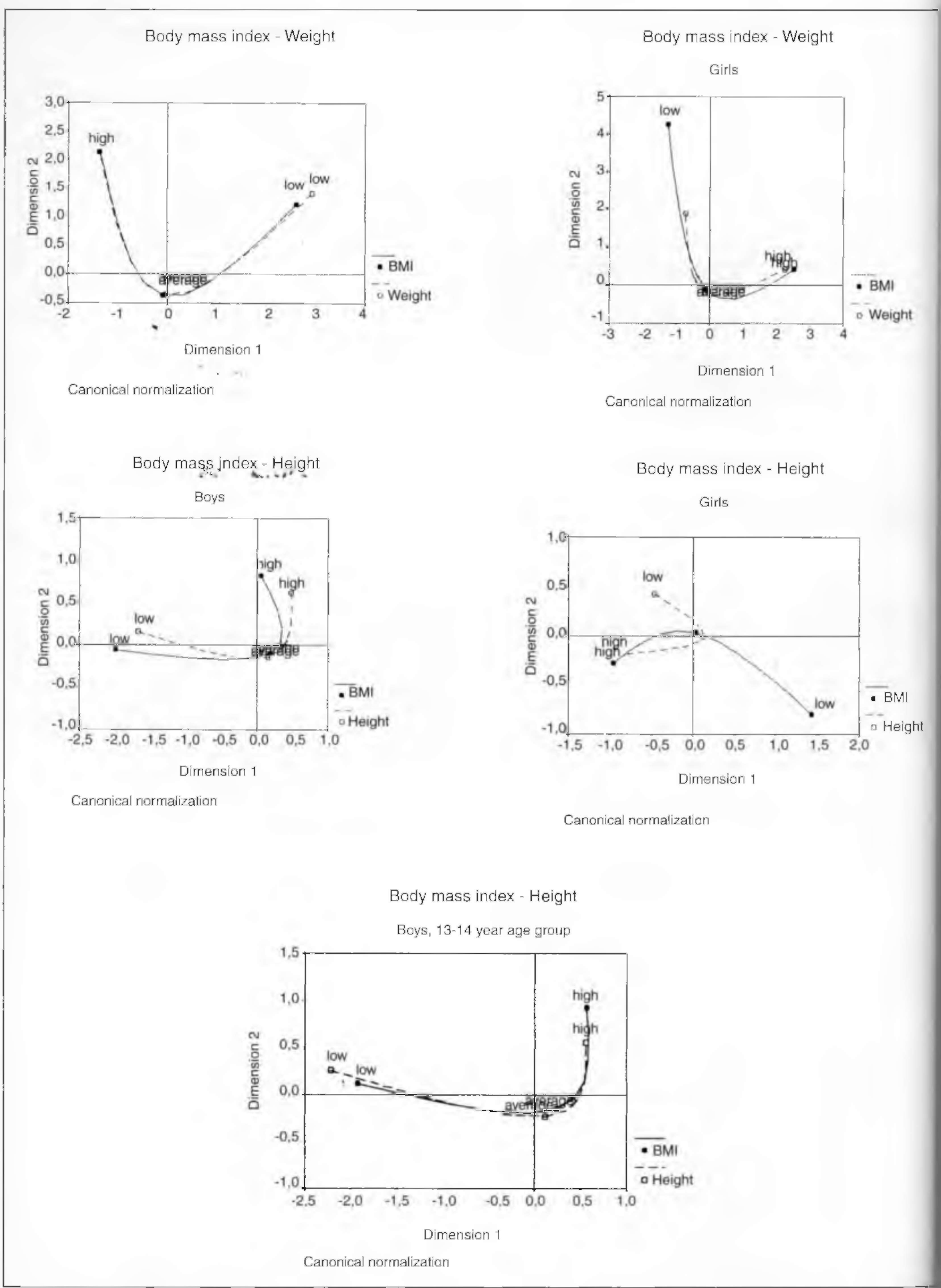


Figure 3 *Factorial axis of the correspondence analysis for body mass index referred to weight and height. Total groups and selected ages.*

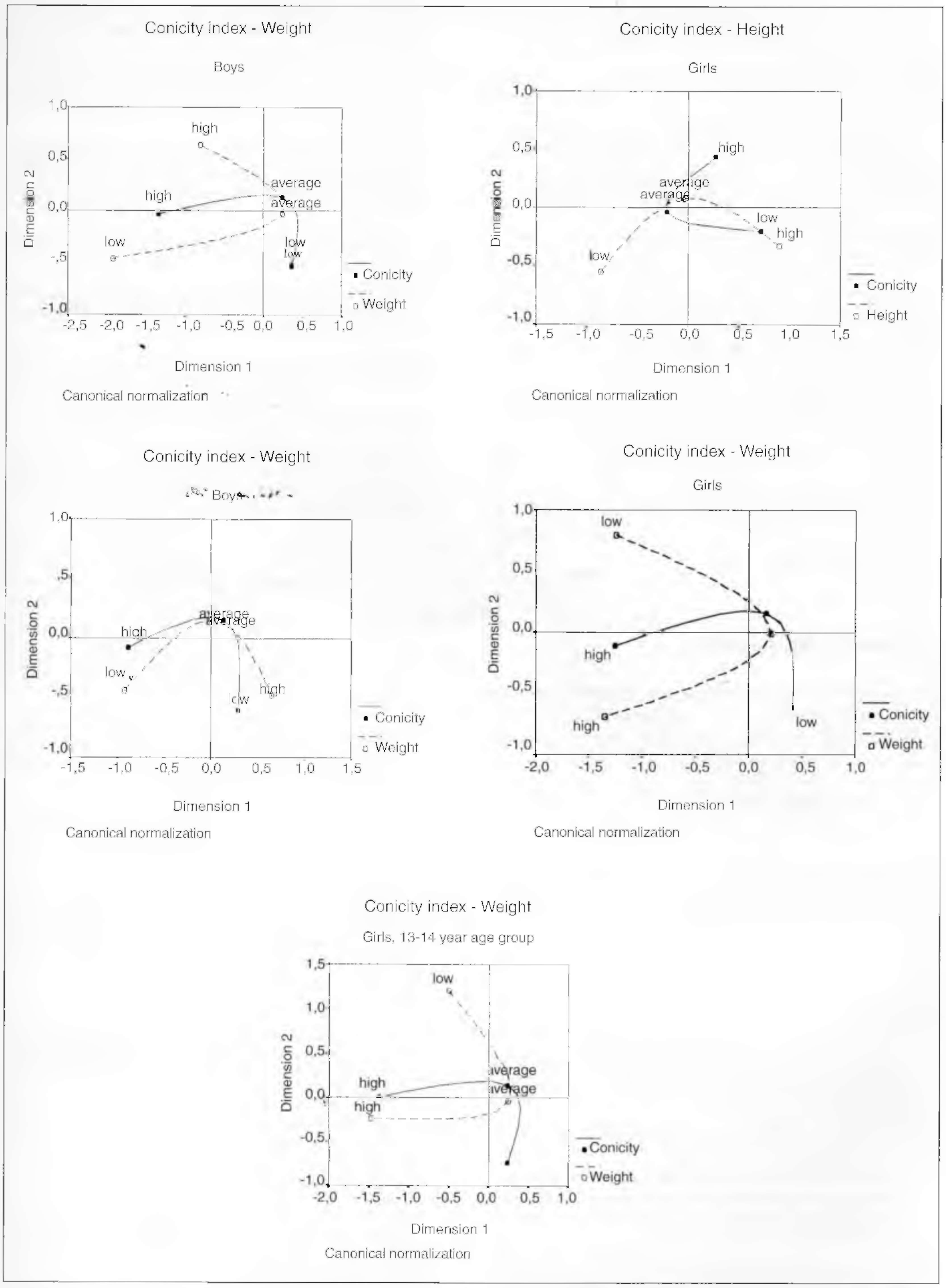


Figure 4 *Factorial axis of the correspondence analysis for body conicity index referred to weight and height. Total groups and selected ages.*

BMI, with total body fat and percentage of body fat, also pointed out a strong association between BMI and total body fat.

C showed a poor relation to weight (r^2 = 0.008; b = 0.005) in this sample of Venezuelan adolescents, yet, at the same time, this fact also suggests a negligible dependence of height (r^2 = 0.018; b = –0.00095), although in this group, boys with low height showed some tendency towards centripetal distribution, and high height values were associated with peripherical shape. In this group of Venezuelan adolescents, CI is not a good predictor of overweight. However, a closer insight through correspondence analysis revealed, particularly in girls, some close correlation between abdominal adiposity, as measured by the CI, and high values of weight. These findings could lead to investigate maturation related effects in their body composition.

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