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SEXUAL DIMORPHISM IN SCHOOLCHILDREN AND ITS RELATION WITH NUTRITIONAL STATUS

ABSTRACT: To analyze if sexual dimorphism is modified by nutritional status (undernutrition or overweight-obesity) of individuals from the same population. If so, to determine which components or tissues are implied. Height, weight, arm circumference, and triceps and subscapular skinfolds were measured in 816 schoolchildren of Brandsen (Buenos Aires, Argentina) aged from 3 to 16, grouped in two categories: prepubertal and pubertal. Data were transformed to z-scores using NHANES I and II references. Prevalences of stunting and wasting were calculated by z-scores below –2. Overweight was defined by BMI > 85 percentile. The sample was divided into four subsamples: normal, underweight, stunting and overweight. Data were processed by one way analysis of variance and Kruskal-Wallis test. In normal prepubertal and pubertal children 78% of the variables showed sexual dimorphism. Sexual differences were inhibited both by chronic and acute undernutrition (45% in prepubertal and 34% in pubertal). In overweight prepubertal children sexual dimorphism was inhibited only in 11% of the variables. The remaining variables were even more dimorphic than normal children. At change, during pubertal period, sexual dimorphism was inhibited by about 56%. Both deficiencies and excess of nutrients interfere with the full expression of normal dimorphism based on gender, male growth being more affected than female growth. Although almost all tissues are implied in such modification of sexual dimorphism, the adipose tissue appears to be more sensitive to environmental stress. This study suggests that populations under nutrition transition – in which undernutrition coexists with obesity – may display a marked variation of sexual dimorphism.

KEY WORDS: Sexual dimorphism – Malnutrition – Undernutrition – Overweight

INTRODUCTION

About 3 billion people suffer some kind of malnutrition (Gardner, Halweil 2000). In developing countries, 25% of children are underweight, 5% stunted and 35% wasted (de Onis *et al.* 1993). In many of those countries, the progressive urbanization has generated a contradictory scenery, where high prevalence of obesity and undernutrition coexist (Albala *et al.* 2002, Monteiro *et al.* 2002). In a previous study, we found that fifty percent of the school population of Brandsen was represented by healthy children and the remaining percentage by similar prevalence of undernourished and overweight children. Such coexistence of undernutrition and overweight is characteristic of many developing countries in nutrition transition (Popkin *et al.* 1996).

Many factors intervene to modify the magnitude to which the genetic determinants are translated into phenotypic traits of the adult. Desai *et al.* (1996) found that during periods of inadequate nutrition, selective changes in the growth rates of specific organs might differ between sexes. In that sense, sexual dimorphism of both stature and muscle size has been demonstrated to be influenced under conditions of such long-term and/or severe malnutrition (Stini 1972, Himes *et al.* 1976, Oyhenart *et al.* 2000), acute food shortages due to war (Markowitz 1955) and chronic socioeconomic deprivation (Bogin, Sullivan 1986).

Sexual dimorphism varies among populations (Bogin *et al.* 1990) probably because they are exposed to different environmental stresses. However, it is unknown if this interpopulational variation is also seen within a population.

The aim of this study was to analyze if the expression of sexual dimorphism may be modified by nutritional status (undernutrition/overweight-obesity) of individuals from the same population.

MATERIAL AND METHODS

Population

The participants in the study were 816 individuals (414 males and 402 females) aged from 3 to 16 years, who attend public schools of the city of Brandsen (Buenos Aires province, Argentina). The children participated in the study upon written consent of their parents or legal guardian. The schools were located in the suburbs of the city, and schoolchildren were coming from families inhabiting those suburbs. More than 80% of children belonged to poor families, as a consequence of the closure of factories and absence of permanent employment. At school children received daily food assistance (breakfast and lunch). Such characteristics allow defining this population to be of low socioeconomic status.

Anthropometry

The measurements were made at the local school by one of the trained authors (M.F.T), from October to November 2002. The survey was carried out following standard protocols (Lohman *et al.* 1988). Body weight (BW) was measured in kilograms on a lever scale (100g of accuracy) with subjects lightly clothed. Height (H) was measured in centimetres using a movable vertical anthropometer (1mm of accuracy). Head circumference (HC) and upper arm circumference (UAC) were measured in centimetres using a flexible steel tape (1mm of accuracy). Triceps and subscapular skinfolds (TS and SS respectively) were measured in millimetres with a Lange calliper (1mm of accuracy). Body mass index (BMI), upper arm muscle area (UMA) and fat area (AFA) were calculated according to Frisancho (1990). Scale and skinfold calliper were calibrated before each measurement session.

Children were grouped into two categories: prepubertal (3–10 years of age for males and 3–9 years of age for females) and pubertal (11–16 years of age for males and 10–16 years of age for females).

All data were transformed into z-scores using the NHANES I and NHANES II references (Frisancho 1990). Z-score values of less than –2 for weight-for-age and height-for-age, were used to determine the prevalence of underweight and stunting (Gorstein *et al.* 1994). Overweight was defined by BMI > 85 percentile. Thus, the sample was constituted by four sub-samples: normal (N), underweight (U), stunting (S) and overweight (O) (*Table 1*). Percentages of normal, underweight, stunted and overweight in prepubertal and pubertal children are shown in *Table 2*.

Statistical analysis

The goodness of fit for the frequency distributions was estimated by the Kolmogorov-Smirnov test for one sample. Except subscapular skinfold, all variables showed normal distribution. Data were processed by one way analysis of variance (ANOVA) or two samples Kruskal-Wallis test (KW). The statistical work was made by the SPSS 7.0 program.

For graphical comparisons, mean values were standardized by the Relative Difference between Means (RDM %). For sexual comparisons: RDM= 100*(X1–X2)/X1, being X1=mean values in males and X2=mean values in females. This standardization method has been frequently employed (see Oyhenart *et al.* 1998). In its current form, it reduces any difference to a percent value which cannot be affected by scaling and sense.

TABLE 1. Sample composition.

Nutritional status	Prepubertal		Pubertal		Total
	Males	Females	Males	Females	
Normal	146	105	81	115	447
Underweight	29	24	28	30	111
Stunting	56	45	24	38	163
Obesity	43	23	7	22	95
Total	274	197	140	205	816

TABLE 2. Prevalences according to nutritional status.

Nutritional status	Prepubertal	Pubertal
Normal	53.3%	56.8%
Underweight	11.3%	16.8%
Stunting	21.4%	18.0%
Obesity	14.0%	8.4%

RESULTS

Table 3 presents statistical differences between sexes. For prepubertal and pubertal normal children there were significant differences in body weight, height, head circumference, both skinfolds and upper arm muscle area. BMI was dimorphic only in prepubertal and AFA in pubertal.

Underweight children showed significant differences in tricipital and subscapular skinfolds and fat area in pre and pubertal categories, while body weight, BMI, head circumference and muscle area were dimorphic in pubertal children.

In the stunted, head circumference, tricipital and subscapular skinfolds were sexually dimorphic in both categories. Pubertal boys and girls only differed in arm fat area.

Overweight children showed prepubertal and pubertal dimorphism in head circumference and muscle area, while body weight, BMI, arm circumference and height were dimorphic in prepubertal.

DISCUSSION

Human sexual dimorphism is a complex phenomenon strongly linked to growth and development (Loth, Henneberg 1996). It appears that whereas the potential for sexual differences in growth has been established during prenatal development, that potential remains latent until the hormonal shifts associated with puberty occur (Stini 1985). Our study indicated that in healthy children, significant gender differences in body composition were evident, well before the onset of puberty as well as after puberty. In both categories 78% of the variables, which represent the growth in body mass (body weight, body mass index), skeletal (height, head circumference), adipose (skinfolds and fat mass) and muscle (muscle mass), displayed sexual differences (*Figure 1*). Such sexual dimorphism results in a greater growth in males than in females, except the adipose mass which is greater in girls. These results are in accordance to those by Malina (1969, 1978), who reported that adipose tissue comprises approximately 15% of body weight in males and about 27% in females. Females are systematically fatter than males during lifespan. This sex difference in fatness increases slowly from birth to puberty (Bailey 1982). Accordingly, during the pubertal period sex differences in body composition especially in fat mass, increased about 24%. Sex differences in muscle tissue also became more pronounced during pubertal period, muscle mass being greater in boys than in girls.

Sexual dimorphism was inhibited by chronic and acute undernutrition, in both prepubertal (45%) and pubertal (34%) categories. Growth retardation in weight, height, head circumference and muscle mass lead to changes of normal sexual dimorphism as a consequence of relatively lower male growth, which became closer to female growth pattern. However, while some sexual differences decreased significantly, those related to adipose tissue became more dimorphic, i.e. boys lost more fat than girls. Similar results were obtained in past and modern Argentinian populations of different ethnic background (Baffi, Cocilovo 1989, Pucciarelli *et al.* 1993, Oyhenart *et al.* 2000, Torres *et al.* 2000). Differences between boys and girls in the rate of change of anthropometric variables are supported by earlier findings reported by Stinson (1985). She suggested that the growth performance of boys is more negatively affected by an impairment of living conditions than that of girls. Thus, females are better "buffered" against environmental determinants of growth than males (Stini 1982). The reasons for this phenomenon are still unclear. Nevertheless, the nutritional hypothesis states that anatomical, physiological, and metabolic requirements of pregnancy and breastfeeding promoted an evolution of hormonal mechanisms in females, which limits the influence of nutritional stress on body size, particularly in energetic reserves such as body fat stores (Brauer 1982, Buffa *et al.* 2001).

Overweight modified prepubertal sexual dimorphism at a lower grade than undernutrition. Sexual differences were inhibited in 11% of the variables, affecting the adipose tissue. At variance, those variables that represent

TABLE 3. Analysis of variance and Kruskal-Wallis (KW) tests for sexual comparisons.

Variables	Normal				Underweight				Stunting				Obesity			
	Prepubertal		Pubertal		Prepubertal		Pubertal		Prepubertal		Pubertal		Prepubertal		Pubertal	
BW	7.52	**	5.27	*	0.49		5.74	*	3.90		0.02		7.84	**	1.15	
BMI	6.95	**	0.56		0.52		4.11	*	1.61		0.52		6.27	*	0.00	
UAC	1.25		1.21		0.83		3.32		0.08		0.21		5.76	*	0.03	
H	4.57	*	9.05	**	0.14		3.52		2.40		0.93		7.69	**	2.32	
HC	37.03	**	14.19	**	1.28		16.28	**	8.30	**	4.34	*	15.84	**	6.99	*
TS	6.44	**	29.77	**	11.53	**	35.54	**	5.67	*	11.89	**	0.46		1.08	
SS (KW)	7.92	**	17.17	**	8.09	**	10.43	**	8.90	**	8.70	**	0.16		0.75	
AFA	2.19		19.96	**	9.16	**	16.20	**	2.65		7.60	**	2.00		0.59	
UMA	10.84	**	20.95	**	1.17		14.51	**	3.17		2.84		8.63	**	0.38	*

* p<0.05
** p<0.01

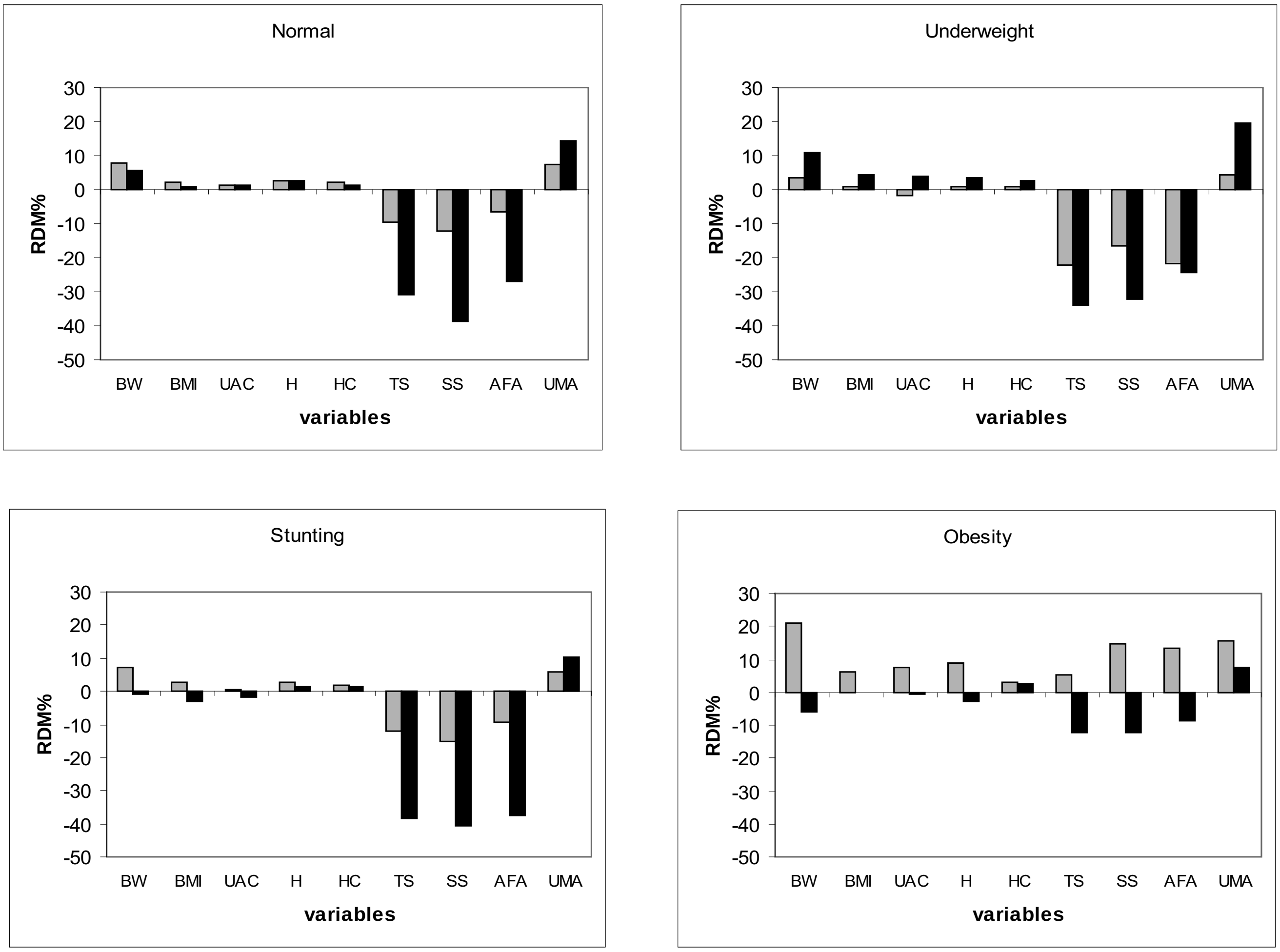

FIGURE 1. Comparison between sexes by Relative Differences between Means (RDM%) during prepubertal (grey bars) and pubertal (black bars) periods. BW: body weight; BMI: body mass index; UAC: Upper arm circumference; HC: head circumference; TS: Tricipital skinfold; SS: subscapular skinfold; AFA: Upper arm fat area; UMA: Upper arm muscle area.

the overall growth, as well as skeletal and muscle growth, were more dimorphic than in normal children. This opposite behaviour, i.e. inhibition and increase of sexual differences, can be explained by a relatively greater growth in males compared with females. During pubertal period, sexual dimorphism was inhibited by about 56% due to a relatively greater female growth in weight and stature. Additionally, overweight boys accumulated relatively more fat than girls. This fact reverted the normal fat pattern commonly associated to the pubertal growth spurt (timing determined by sexual maturation stage), in which female body composition undergoes a significant deposition of energy reserves (Kanbur *et al.* 2002).

CONCLUSIONS

Both deficiencies and excess of nutrients interfere with the full expression of normal dimorphism based on gender, male growth being more affected than female growth. Although almost all tissues are implied in such modification of sexual dimorphism, the adipose tissue appears to be more sensitive to environmental stress.

This study suggests that populations under nutrition transition – in which undernutrition coexists with obesity – may display a marked variation of sexual dimorphism.

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