Original Article

Association between chronic undernutrition and hypertension

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Abstract

In developing countries nutritional deficit during prenatal and continuing in post-natal life is very common. This condition leads to stunting and important metabolic changes. Over 30% of children in the world are stunted. The metabolic resultants of nutritional deficit during growth are classically known to aim at energy conservation. This review summarizes data from Brazil, a developing country undergoing the double burden of obesity and undernutrition, especially among the poor, and suggests that stunting or chronic undernutrition increases the risk of obesity and hypertension later in life. Around 60 million people are under the poverty line in Brazil. In São Paulo, the richest city of the country, 20% of the population live in slums and in Maceió, the capital of one of the poorest states, this percentage reaches 50%. Undernutrition in this population is around 20% among children, with high frequency of infections, anemia, and parasitic infestations, associated with poor sanitation. Among stunted adolescents, we found a high prevalence of hypertension (21%) that is a considerably higher estimate compared to non-stunted adolescents (less than 10%). The prevalence of hypertension in undernourished pre-school children, or in those who recovered from undernutrition, was higher than that in controls (29%, 20% and 2%, respectively, $P < 0.001$). Among stunted adults eating no more than 66% of the requirements (adjusted for stature), overweight/obesity was 35% in women and 25% in men. The prevalence of hypertension was 44% among stunted women and 18% among stunted men. Fifty per cent of stunted and obese women had hypertension. These data reinforce the important association between undernutrition and hypertension from childhood through adulthood. Health policies for preventing and combating childhood undernutrition should have an impact on the morbidity and mortality related to hypertension during adulthood.

Keywords: stunting, chronic malnutrition, undernutrition, obesity, hypertension, food intake.

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Poverty and undernutrition

Undernutrition is still considered one of the major problems in public health in many countries (Sedgh *et al.*, 2000) affecting 30% or more of children under 5 years of age (Kabir *et al.*, 1998); being the most important mortality cause (55%) in this age group in developing countries (UNICEF, 1998).

The socioeconomic condition of a country determines the quality of life of its citizens. In the last decades, the great difficulties in living conditions found in rural areas in most developing countries has led to large migration to urban areas, promoting the increase of slums. In Brazil, in 2000, 82% of the population lived in urban areas (IBGE, 2000). The increase of the urban population was not followed by an improvement at the same speed in infrastructure, creating a deficit of urban facilities, such as water, electricity and sewage supply. In addition, this demographic explosion brought to the cities a great number of people with a low level of education and therefore unsuitable for the growing complexity of the working market.

Worldwide, the most frequent type of undernutrition is stunting caused by chronic undernutrition, most frequently starting prenatally (Allen & Gillespie, 2001). Nutritional stunting is caused by insufficient maternal nutrition, intrauterine undernutrition, lack of breastfeeding until 6 months of age, later introduction of complementary feeding, inadequate (quantity and quality) complementary feeding, and impaired absorption of nutrients owing to infectious diseases (Allen & Gillespie, 2001).

In recent years a growing body of evidence has shown that prenatal undernutrition or stunting is related to non-communicable diseases later (Barker, 1994; Velasquez-Melendez *et al.*, 1999; Sichieri *et al.*, 2000). Studies linking early nutrition with adulthood disease have focused on fetal nutrition. However, childhood undernutrition remains extremely common in many developing countries and associations with later disease need to be established. The present review describes data from slum populations in Brazil showing an association between stunting/short stature and hypertension and obesity, without an apparent excess of food or fat intake.

Stunting and hypertension among adolescents living in slums in the city of São Paulo

Twenty-two per cent of the Brazilian population live in the state of São Paulo, and 28% of these are concentrated in the city of São Paulo (IBGE, 2000). It has been estimated that 20% of the population of the city of São Paulo live in slums (SEHAB, 1994). Sanitation is very precarious in these environments. The majority of the constructions are in unhealthy and inappropriate land near rivers and subjected to constant floods.

We investigated the nutritional and health conditions of 53 adolescents (10–16 years of age, 27 boys and 26 girls, Tanner stage 2, 3, 4 and 5) living in slums. There was a large number of dwellings made of wood planks (49%), as well as reduced availability of city sewage (21%), and frequent use of untreated water (68%). Almost all families were under the poverty line for income (less than a dollar per capita per day). Mean height for girls was 149.8 cm, 5 cm below the mean National Center for Health Statistics (NCHS) value, and mean height for boys was 149.3 cm, 7 cm below the NCHS value (-0.8 ± 1.1 and -1.0 ± 1.4 z-score respectively). The mean body mass index (BMI) for girls was 18.8 kg m^{-2} and for boys 17.6 kg m^{-2}, values within the normal range for this age group (mean age = 13 years) (Fernandes *et al.*, 2003).

Table 1 shows the percentage of children with blood pressure (BP) above the 90th and 95th percentiles adjusted for height percentiles according to the Update Second Task Force from 1996 (National High Blood Pressure Education Program Working Group on Hypertension Control in Children and Adolescents, 1996). BP was measured using a mercury column sphygmomanometer, following the guidelines of this Task Force. More detailed description of the procedure was described elsewhere (Fernandes *et al.*, 2003). In the literature, BP above the 90th percentile and below or equal to the 95th percentile represents a risk of hypertension. There was a high percentage of adolescents with diastolic hypertension (values above the 95th percentile). For systolic BP, no patient was above the 95th percentile. Considering the group of patients as a whole, the overall preva-

Table 1. Blood pressure values in relation to the 90th and 95th percentiles for boys and girls according to the stature percentile (National High Blood Pressure Education Program Working Group on Hypertension Control in Children and Adolescents, 1996)

Variable	Boys (Total n = 27) n (%)	Girls (Total n = 26) n (%)	Total n (%)	P-value*
P90 < SBP < P95 (mmHg)	0	3	3 (6)	0.11
SBP > P95 (mmHg)	0	0	0	
P90 < DBP < P95 (mmHg)	9 (33)	7 (27)	16 (30)	0.83
DBP > P95 (mmHg)	5 (19)	6 (23)	11 (21)	0.94

SBP, systolic blood pressure; DBP, diastolic blood pressure; P90, 90th percentile; P95, 95th percentile; *P value for the comparison between boys and girls.
Taken from Fernandes *et al.* (2003).

lence of diastolic arterial hypertension was 21% with a 95% confidence interval of 10% to 32%. No significant difference was observed between sexes. The prevalence of cases with systolic or diastolic BP above the 90th percentile was 51% ($n = 27$), with a 95% confidence interval of 37% to 65%. Six percent ($n = 3$) of these individuals had simultaneously systolic and diastolic arterial hypertension. Figure 1 illustrates the levels of diastolic BP found in this group of adolescents. Almost 100% of both boys and girls showed values of diastolic BP above the 50th percentile, being distributed around the 90th percentile.

Short stature, insufficient food intake, obesity and hypertension among adults living in slums in the city of Maceió

Alagoas, in the north-eastern region of Brazil, is one of the poorest states of the country and has the highest income concentration (social exclusion index = 72.4%) and the worst human development index. This means that only 27.6% of the population is provided with basic public services. One-third of its population is below the line of poverty (less than 1 US$ per capita per day), infant mortality stands at 68.4 per 1000 live births (IBGE, 2000). It was estimated that 50% of the people living in its capital, Maceió, live in slums.

We performed a census of the adult population of a slum community (age > 18 and <60 years) in the city of Maceió. All the 315 shacks and 532 adults were
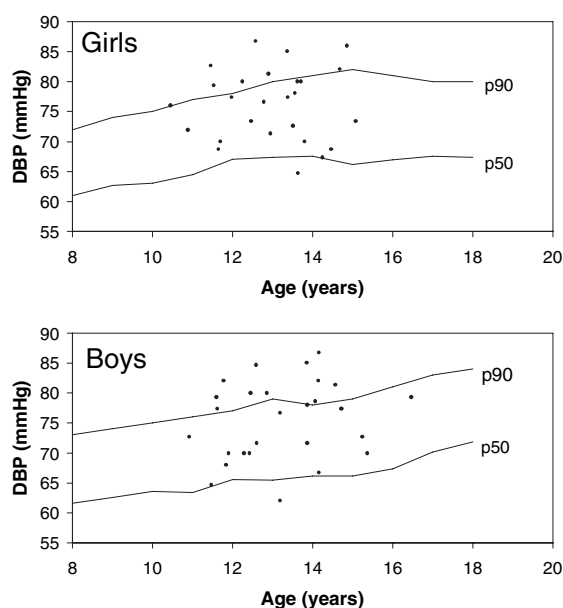

Fig. 1. Diastolic blood pressure of 53 boys and girls recruited from population surveys of three slums in the city of São Paulo, Brazil. Mean ± SD of weight, stature and Body Mass Index (Z score), respectively: boys = −0.9 ± 1.0, −1.0 ± 1.4, −0.5 ± 0.5; and girls = −0.5 ± 0.9, −0.8 ± 1.1, −0.3 ± 0.7 (for more details see Fernandes *et al.*, 2003). DBP, diastolic blood pressure.

investigated (after excluding pregnant women, the physically handicapped and those with prostheses, the final number was 416 individuals, 43% men and 57% women). The individuals who did not take part in the study (refusal, closed home, etc.) accounted for 11.8% of the population. Short stature was found in 22.6% of the adults, and overweight or obesity in 32% of women and 18% of men (Florêncio *et al.*, 2001).

Assessment of food intake in this slum population revealed some intriguing results (Tables 2 and 3). The methodology for this evaluation was recall inquiry applied to the entire adult population, on any given day, to provide information on the respondent's food intake during a single 24-h period. The use of the Manual of Photographic Record for Dietary Inquiries by Zabotto (1996) was made, which illustrates the different servings, shown in grams and household measures. Detailed description of the methodology is given elsewhere (Florêncio *et al.*, 2003). The average energy intake was very much below the requirements (66% for men and 60% for women). After adjusting for stature, the adequacy in energy intake for non-stunted individuals reached only 78%, and 70% for stunted individuals. Stunted overweight and obese women consumed only 65% of the energy requirement adjusted to stature (Table 2).

Table 3 shows the distribution of macronutrients according to their contribution to the total energy intake. The figures for all subgroups were similar. The total energy intake of the population was as follows: 18% protein, 58% carbohydrates and 24% lipids. The percentage of energy intake from fat was

Table 2. Adequacy of energy intake in an adult population residing in a slum according to sex and anthropometric characteristics. Maceió, Alagoas – Brazil

Sex	Energy (kJ)	Stunted				Non-stunted			
		U	A	O	Total	U	A	O	Total
Male	Intake	5882	6812	7226	6640	6501	7815	8373	7563
	% adequacy*	54	63	66	61	60	72	77	70
	Requirement adjusted to stature	8987	8987	8987	8987	9614	9614	9614	9614
	% adequacy	65	76	80	74	68	81	87	79
Female	Intake	4527	5029	4686	4747	5560	5497	6556	5871
	% adequacy*	53	58	54	55	65	64	76	68
	Requirement adjusted to stature	7234	7234	7234	7234	7640	7640	7640	7640
	% adequacy	62	69	65	66	73	72	86	77

U, underweight (BMI < 20); A, average weight (BMI ≥ 20 < 25); O, overweight + obesity (BMI ≥ 25); *Compared to the numbers established for the recommended dietary allowances (RDAs), taking 10878 and 8619 kJ as the mean values for men and women respectively.
Taken from Florêncio *et al.* (2003).

Table 3. Macronutrient intake and respective percentage contribution in relation to total energy consumption, compared with gender and nutritional classification. Adult population residing in a slum, Maceió, Alagoas – Brazil

Gender	Nutrient	Stunted				Non-stunted			
		U	A	O	Total	U	A	O	Total
Male	Protein (g)	52 (14.8)	81 (19.9)	76 (17.6)	70 (17.5)	73 (18.6)	88 (18.8)	96 (19.2)	86 (18.8)
	Carbohydrate (g)	212 (60.4)	218 (53.6)	268 (62.1)	233 (58.7)	225 (57.9)	262 (56.1)	269 (53.8)	252 (56.0)
	Fat (g)	39 (24.8)	48 (26.5)	39 (20.3)	42 (23.8)	41 (23.5)	52 (25.1)	60 (27.0)	51 (25.2)
Female	Protein (g)	46 (17.0)	51 (17.0)	52 (18.6)	50 (17.5)	65 (19.6)	65 (19.8)	77 (19.7)	69 (19.7)
	Carbohydrate (g)	157 (58.0)	173 (57.6)	165 (58.9)	165 (58.2)	184 (55.4)	180 (54.8)	209 (53.4)	191 (54.5)
	Fat (g)	30 (25.0)	34 (25.5)	28 (22.5)	31 (24.3)	37 (25.0)	37 (25.4)	47 (27.0)	40 (25.8)

U, underweight (BMI < 20); A, average weight (BMI ≥ 20 < 25); O, overweight + obesity (BMI ≥ 25).
The number in parentheses indicate the percentage of the respective macronutrient in relation to energy consumption.
Taken from Florêncio *et al.* (2003).

less than 30%, even for obese and overweight men or women.

The results obtained pointed to the non-existence of differences in fat intake for stunted and obese men and women, when compared to their normal or undernourished counterparts, although they all ingested fewer calories than their respective current requirements. Therefore, it appears that the higher risk of obesity observed among stunted individuals cannot be explained by a higher fat or energy intake. On the other hand, the type of carbohydrate ingested has been considered as one important factor that could elevate the risk of obesity (Bray *et al.*, 2004).

Obesity is acknowledged to be one of the main risk factors for non-communicable diseases and is associated with an increased incidence of arterial hypertension (Stamler *et al.*, 1978; Hsuch & Buchanan, 1994; Whelton, 1994). Particularly, the association between abdominal obesity and hypertension has been well documented (Bjorntorp & Rosmond, 2000; Bray & Champagne, 2004).

We have explored the association of short stature with hypertension and obesity in this adult population. The prevalence of hypertension was 28.5%, although the prevalence was strikingly different in men (18.4%) and women (38.5%). After stratification by stature quartiles, hypertension remained statistically significantly different, in both sexes, in the first two quartiles in comparison with the last two: 21.1% versus 14.6%, respectively ($P = 0.01$) in men; and

42.4% versus 34.6%, respectively ($P = 0.013$) in women (Table 4). Logistic regression was used to assess the odds ratio of arterial hypertension through the stature quartiles. Women in the 1st quartile showed an odds ratio of hypertension significantly greater than in the 4th quartile (2.23, 95% confidence interval: 1.67–2.90), although this result has not been observed in men. Table 5 shows the analysis of BP based on stature and BMI. Short-stature obese women showed a higher prevalence of hypertension than the obese women in the other stature quartiles. Again, this pattern was not observed in men (Florêncio *et al.*, 2004).

Hypertension in undernourished children and in those with nutritional recovery

There is scant literature regarding BP in pre-school children with growth retardation (Gaskin *et al.*, 2000). We investigated the association between increased BP and undernutrition in pre-school children of low socioeconomic level. Additionally, the BP of a group of children who had recovered from undernutrition was assessed.

In a cross-sectional study we assessed the BP of 172 children older than 2 years living in slums in the city of São Paulo. Ninety-one children were undernourished (height-for-age (H/A) or weight-for-age (W/A) Z-score below –1 of the NCHS references). Among

Table 4. Prevalence (%) and odds ratio for arterial hypertension, based on stature quartiles in men and women living in a slum, Maceió, Alagoas–Brazil

Stature quartiles	Men				Women			
	Median height (cm)	*n*	Prevalence of hypertension (%)	Odds ratio (95% CI)	Median height (cm)	*n*	Prevalence of hypertension (%)	Odds ratio (95% CI)
1st	158.2	42	18.0	1.12 (0.77–1.63)	147.1	59	44.2	2.23 (1.67–2.90)
2nd	164.3	38	26.3	1.21 (0.97–1.51)	152.4	56	40.7	2.16 (1.66–2.85)
3rd	168.5	52	12.2	1.03 (0.80–1.31)	156.4	54	35.3	1.93 (1.53–2.45)
4th	174.2	47	17.0	1.0	161.6	68	33.9	1.0
Total	166.3	179	18.4		154.3	237	38.5	

Taken from Florêncio *et al.* (2004).

Table 5. Prevalence of arterial hypertension in overweight or obese[a] men and women, living in a slum, Maceió, Alagoas –Brazil

Stature quartiles	Men				Women			
	Median height (cm)	n	Prevalence of hypertension (%)	Odds ratio (95% CI)	Median height (cm)	n	Prevalence of hypertension (%)	Odds ratio (95% CI)
1st	157.8	10	10.0	0.92 (0.50–1.78)	146.4	20	50.0	1.98 (1.32–2.96)
2nd	164.0	8	25.0	1.16 (0.87–1.48)	152.6	20	35.0	1.63 (1.06–2.49)
3rd	168.0	7	14.3	1.03 (0.56–1.68)	156.3	17	35.3	1.65 (1.08–2.52)
4th	176.0	6	16.7	1.0	160.9	21	37.6	1.0
Total	166.3	31	16.5		154.3	78	39.5	

[a]Body Mass Index ≥ 25Kg/m^2.
Taken from Florêncio *et al.* (2004).

Table 6. Blood pressure (BP) of undernourished, recovered and control children. Mean values for systolic and diastolic BP, and numbers referring to the 90th and 95th percentiles[a]

Blood pressure	Undernourished n = 91	Recovered n = 20	Controls n = 61
Systolic BP[b] (mmHg)	98.7 ± 1.0	99.4 ± 2.2	96.4 ± 1.2
Diastolic BP[b] (mmHg)	65.2 ± 0.6†	66.5 ± 1.5†	61.8 ± 0.8
Systolic BP			
>P90 and ≤P95	11(12)†	3 (15)*	0 (0)
>P95	6 (7)	1 (5)	0 (0)
Diastolic BP			
>P90 and ≤P95	29 (32)†§	1 (5)	12 (20)
>P95	22 (24)†	3 (15)*	1 (2)
Systolic or diastolic BP			
>P90 and ≤P95	38 (42)†‡·c	3 (15)d	12 (20)
>P95	26 (29)†·c	4 (20)*	1 (2)

P90, 90th percentile; P95, 95th percentile; [a]Values are expressed as mean ± SE, or number (%); [b]Adjusted for age, sex, race, birthweight, current weight and height; [c]Two individuals had increased values of both systolic and diastolic BP; [d]One individual had increased values of both systolic and diastolic BP.
*$P < 0.05$, †$P < 0.01$ versus control; ‡$P < 0.05$, §$P < 0.01$ versus recovered.
Taken from Sesso *et al.* (2004).

these, 26 (29%) had a W/A Z-score < –1; 12 (13%) had a H/A Z-score < –1, and 53 (58%) had both indices < –1. Twenty children had recovered from undernutrition (at the time of reevaluation both H/A and W/A scores were greater than –1 Z score) after an average time of 6.4 years. A control group of 61 non-undernourished children was randomly selected among children living in the same neighbourhood as the cases and matched for age to the currently undernourished group (Sesso *et al.*, 2004).

Mean systolic and diastolic BP, adjusted for several factors, were higher in the undernourished and recovered groups compared to the controls; however, the values were statistically significant only for diastolic BP (Table 6). No difference was detected between the two former groups.

A greater percentage of children in the undernourished and recovered groups had increased BP, particularly diastolic, compared to the controls. Considering alterations in systolic and/or diastolic BP

(above the 95th percentile of the Update of the 2nd Task Force references) after adjusting for age, sex, race, height, birthweight, current weight and height, a significantly greater percentage of undernourished and recovered children had high BP compared to controls (29%, 20%, and 2%, respectively, $P < 0.001$). No significant difference was detected between undernourished and recovered children. The undernourished group had a greater proportion of children at a higher risk of hypertension (BP value above the 90th percentile and below or equal to the 95th percentile) than the other two groups (Table 6).

In univariate analysis there was a significantly positive correlation between systolic BP and age ($r = 0.29$), weight ($r = 0.30$) and height ($r = 0.23$), but not with birthweight ($r = -0.04$). The corresponding coefficients for diastolic BP were $r = 0.46$, $r = 0.38$, $r = 0.41$ and $r = -0.02$ respectively.

Multivariate regression analysis was performed to predict systolic and diastolic BP and all available variables were tested as independent ones. In these analyses, current weight was the only independent predictor variable affecting systolic BP. Nutritional group (undernourished or recovered compared to controls) significantly influenced diastolic BP controlling for several factors.

In a multivariate logistic regression analysis considering as dependent variable systolic or diastolic BP above the 95th percentile, nutritional group was the only significantly independent variable in the model. The odds ratio (95% confidence interval) of high BP in the undernourished and recovered groups compared to the controls was 29.17 (2.70–315) and 42.48 (2.37–763), respectively, after adjusting for age, gender, race, height, weight and birthweight.

Overall, a strikingly high percentage of the undernourished children in our study were found to have high BP, particularly diastolic. The prevalence rates of undernourished children with BP above the 90th percentile and below or equal to the 95th percentile (42%), and above the 95th percentile (29%) were remarkably greater than those in controls [20% and 2%, respectively (Table 6)], and considerably higher than the hypertension rates reported in other large national studies on children without nutritional alterations, which ranged from 0.8% to 7.2% (Bastos *et al.*,

1993; Oliveira *et al.*, 1999). Several authors have reported the association between prenatal undernutrition, as indicated by low birthweight, and hypertension in adult life (Barker *et al.*, 1989a, 1989b; Law & Shiell, 1996; Whincup *et al.*, 1999; Eriksson *et al.*, 2000). A fewer number of studies did not confirm these findings (Seidman *et al.*, 1991; Lucas & Morley, 1994; Rahiala *et al.*, 2002). In our study, birthweight was not a significant predictor of BP. In addition, we found that nutritional deficit during childhood was associated with high BP independently of birthweight (Sesso *et al.*, 2004). Our data lend support to the hypothesis that undernutrition, not only prenatal as indicated in other studies, but also occurring during childhood, may be a risk factor for the development or aggravation of hypertension.

More interestingly, the findings that recovered (after 6.4 years) children tend to have higher BP levels than controls and values not significantly different from those currently undernourished suggest that the effects of undernutrition on BP may be persistent. The strength of this inference may be lessened by the small sample size of patients studied in this group, the cross-sectional nature of this study design and the possibility that other factors related to undernutrition, such as the low socio-economic status, may have contributed for this association.

Final remarks

The findings described in this review emphasize the need for monitoring BP in undernourished children. Undernutrition should be more often recognized as a factor associated with increased BP in childhood. It is suggested that not only intrauterine undernutrition but also its occurrence during childhood may influence the incidence of hypertension in adulthood.

There are a number of pathogenic mechanisms reported in both experimental and human studies, by which undernutrition intrautero or early in life could initiate or further increase higher BP: (1) activation of the renin-angiotensin system (Godard *et al.*, 1986; Kingdom *et al.*, 1993); (2) alterations in vascular structure, function and compliance (Yoshida *et al.*, 1995; Zureik *et al.*, 1996); (3) increased sympathetic nervous activity (Phillips & Barker, 1997; Leon-

Quinto *et al.*, 1998); (4) increased insulin sensitivity (Somova & Moodley, 2000); (5) plasma insulin-like growth factor-1 levels (Fall *et al.*, 1995); (6) high plasma glucocorticoid concentrations (Jacobson *et al.*, 1997; Langley-Evans, 1997); and (7) reduction in nephron number (renal mass) associated with retarded fetal growth (Brenner & Chertow, 1994).

Physicians and other health care professionals practicing in developing countries and in large urban centers with low income populations should be aware of the association between early in life undernutrition and hypertension for a timely detection and treatment of hypertension, and to keep monitoring these individuals throughout their life. We also found a marked association between short stature, obesity and hypertension, mainly among adult women, living in poor conditions (Florêncio *et al.*, 2001). Therefore, this group of people should deserve particular attention. Health policies for preventing and combating childhood undernutrition may have an impact on the morbidity and mortality related to hypertension during adulthood.

Acknowledgements

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