Circulating Proteins and Iron Status in Blood as Indicators of the Nutritional Status of 10- to 12-Year-Old Bolivian Boys

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Abstract

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The purpose of the present study was to evaluate the nutritional status of children based on anthropometric measurements, biochemical indicators of protein energy malnutrition as well as hematological variables. The subjects were 93 10- to 12-year-old Bolivian boys: 12 HAHSES, 28 HALSES, 36 LALSES, and 17 LALSES (see Introduction to this Supplement).

The overall nutritional status of the boys was evaluated by anthropometric indicators (weight for age [W/A], height for age [H/A], and weight for height [W/H]). The biochemical indicators included proteins total, albumin, prealbumin, orosomucoid and protein C-reactive (for MPE) as well as hematocrit (Ht), hemoglobin (Hb), serum iron, serum ferritin, and transferrin saturation (TS). The prevalence of growth retardation of LSES boys at HA as well as at LA was found to be high when the 3rd percentile was used as the cutoff point. The corresponding prealbumin levels were found to be lower in LSES than in HSES boys at both altitudes.

The study shows that LSES boys at both altitudes have significantly lower prealbumin levels than HSES boys. The socioeconomic factor seems to be more critical for the nutritional status of prepubertal boys than altitude.

The study also shows that all the boys had hematological parameters within normal range. The HA boys of both SES had higher hemoglobin concentration and hematocrits than the LA boys, a fact that is explained by high-altitude hypoxia. The hematological data do not provide evidence of malnutrition among the boys.

Key words

Malnutrition, biochemical indicators, prepubertal, boys, altitude, socioeconomic status, Bolivia

Introduction

In children, nutritional status is commonly assessed by noninvasive anthropometric criteria such as weight for age (W/A), height for age (H/A), and weight for height (W/H). W/A and H/A according to Waterlow (40) show impairment of growth alterations of body proportions and composition and reflect the current nutritional status (5). However, in order to detect exhaustion of protein supplied as well as metabolic alterations related to the malnutrition of tissues, invasive techniques such as measurements of biochemical indicators are required. The most widely used chemical indicators in the MPE are visceral circulating proteins secreted by the liver (16, 30, 31).

Several studies (11, 13, 21, 28) have shown that these proteins, especially those with a quick turnover and a medium short life, are useful for detecting subclinical and early stages of MPE. To evaluate the nutritional status, several investigators introduced the simultaneous evaluation of nutrition proteins and proteins existing during the acute phase of inflammation such as the C-reactive protein (CRP) and the orosomucoid protein.

On the other hand, in order to identify the cause of protein-caloric malnutrition, several authors suggest associating biochemical and anthropometric variables for a more precise assessment of the nutritional status (7, 8). Iron status can be assessed by numerous biochemical indicators which permit the diagnosis of iron deficiency long before effects on hematopoiesis are present.

These indicators reflect the changes that occur in different body compartments during varying stages of iron deficiency. Some reflect iron reserves (serum ferritin), others show iron uptake and transport to erythropoietic tissues (serum iron, transferrin, red blood cell protoporphyrin), or the total of iron deficiency (19). The present study intends to evaluate various visceral proteins and hematological variables that are commonly used to identify the protein energy malnutrition and nutritional anemia in prepubertal boys of high and low SES living at HA and LA.

*This paper is dedicated to the memory of Aida Quintela deceased August 5, 1993.

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The aim is to correlate biochemical visceral variables with anthropometric measurements in order to select the biochemical variables that are most sensitive for assessing marginal nutrition.

Subjects and Methods

12 HAHSES, 28 HALSES, 36 LAHSES and 17 LALSES boys were studied. For the evaluation of the nutritional status, the anthropometric ratios weight for age (W/A), height for age (H/A), and weight for height (W/H) were used.

With the children being in a resting state and having fasted for at least 8 h, blood samples were obtained from the antecubital vein. The blood sample was distributed in a dry tube and in a tube with sodium heparin. Proteins related to the nutritional status and those related to inflammation were measured simultaneously by colorimetric and immunochemical (Behring) methods.

Quality was checked during each phase of the analytical process. Total proteins (biuret method), albumin (immunoturbidimetrics), prealbumin (radial immunodiffusion), orosomucoid, and CRP (immunoturbidimetrics) were measured. The iron status was assessed by measuring the following parameters: hematocrit (Ht, microhematocrit method), serum iron (spectrophotometry), serum ferritin (enzyme linked immunoassay, ELISA), and total iron binding capacity (TIBC, colorimetric method). The transferrin saturation (TS) was calculated from serum iron divided into TIBC.

Results

When using the 15th percentile (P15) as the cutoff point of W/A, which is recommended as an indicator of malnutrition by the Bolivian System of Epidemiological Nutritional Vigilance (SVEN) (35), malnutrition was found to have a prevalence of 38.1 % in HALSES boys and 28.5 % in LALSES boys (Table 1).

Table 1 Prevalence of malnutrition from weight for age of prepubertal boys living at different altitudes with high and low socioeconomic status (classification according to SVEN).

	HA		LA	
	HSES	LSES	HSES	LSES
n	12	28	36	17
		< P15		
W/A	—	38.1 %	—	28.5 %

HA = high altitude; LA = low altitude; HSES = high socioeconomic status; LSES = low socioeconomic status; n = number of subjects; P15 = 15th percentile (cutoff point, SVEN); W/A = weight for age

When using the 3rd percentile (P3) as the cutoff point as recommended by the National Center of Health Statistics standards (NCHS) (18), malnutrition is found in HALSES boys with a prevalence of 2.9 % for W/A and 38.2 % for H/A (Table 2).

Table 2 Prevalence of malnutrition from weight for age, weight for height, and height for age of prepubertal boys living at different altitudes with high and low socioeconomic status (classification according to NCHS).

	HA		LA	
	HSES	LSES	HSES	LSES
n	12	28	36	17
		< P3		
W/A	—	2.9 %	—	—
W/H	—	—	—	—
H/A	—	38.2 %	—	21.4 %

HA = high altitude; LA = low altitude; HSES = high socioeconomic status; LSES = low socioeconomic status; n = number of subjects; P3 = 3rd percentile (cutoff point NCHS); W/A = weight for age; W/H = weight for height; H/A = height for age.

Table 3 shows that neither altitude nor socioeconomic status have any effect on total protein concentration and CRP. The albumin concentration and orosomucoid are significantly ($p<0.05$ and $p<0.002$, respectively) higher at high altitude compared to low altitude.

However, socioeconomic status has no effect and no interactions exist between altitude and socioeconomic status (A × S). Finally, for prealbumin concentrations, a significant effect of socioeconomic status was found ($p<0.003$), but no effect of altitude and no interactions of these two factors existed.

The correlation between the five biochemical parameters and the three anthropometric ratios calculated for all four groups was slightly positive ($r = 0.185$, $p<0.05$) only for prealbumin and W/A. The hematological parameters are presented in Table 4.

Hematocrit and hemoglobin followed a similar pattern with a highly significant effect of altitude ($p<0.001$). However, there is a moderate but significant effect of socioeconomic status ($p<0.05$) and no significant interactions between A and SE. For serum iron and ferritin concentrations, there existed a highly significant effect of socioeconomic status ($p<0.001$), a moderate effect of altitude ($p<0.05$), and no significant interactions between A and SES. For transferrin saturation, there were highly significant effects of socioeconomic status ($p<0.001$) and altitude ($p<0.001$) but no significant interactions between A and SES.

Discussion

Studies in which children were small compared to their age concluded that retarded growth was due to malnutrition, especially to infant malnutrition (27,34). In this study it could be the case for LSES boys, since altitude does not seem to be related to retarded growth. Anthropometric criteria show that HSES children at both altitudes are well-nourished and that the growth of LSES boys is retarded at both altitudes.

According to epidemiological criteria, in developing countries in which the prevalence of undernutrition is high, it is recommended that a high cutoff point be used in the reference population, for instance the P15 for W/A, in order

	HA		LA		
n	HSES 12	LSES 28	HSES 36	LSES 17	2-way ANOVA probability
Protein total (g/l)	74.7 (6.6)	75.5 (7.4)	75.3 (4.3)	77.0 (4.0)	A: NS SE: NS A×S: NS
Albumin (g/l)	47.4 (3.5)	47.3 (4.2)	46.6 (3.9)	45.6 (3.3)	A: $p<0.05$ SE: NS A×S: NS
Prealbumin (mg/l)	224.1 (62.7)	194.4 (68.7)	235.7 (35.8)	199.8 (33.7)	A: NS SE: $p<0.003$ A×S: NS
Orosomucoid (mg/l)	899.3 (251.9)	855.9 (217.5)	718.6 (196.5)	709.1 (192.5)	A: $p<0.002$ SE: NS A×S: NS
CRP	0	0	0	0	A: NS SE: NS A×S: NS

Values are means and (SD); n = number of subjects; HA = high altitude; LA = low altitude; HSES = high socioeconomic status; LSES = low socioeconomic status; CRP = C-reactive protein; ANOVA = analysis of variance; A = altitude; SE = socioeconomic status; NS = not significant

Table 3 Biochemical variables of prepubertal boys living at different altitudes with high and low socioeconomic status.

	HA		LA		
n	HSES 12	LSES 28	HSES 36	LSES 17	2-way ANOVA probability
Hematocrit (%)	45.9 (2.8)	45.7 (2.1)	42.4 (2.3)	39.9 (2.2)	A: $p<0.001$ SES: $p<0.05$ A×S: NS
Serum iron (µg/l)	1660 (700)	1340 (320)	1540 (540)	1060 (330)	A: $p<0.05$ SES: $p<0.001$ A×S: NS
Hb (g/l)	153 (8)	150 (9)	135 (9)	128 (12)	A: $p<0.001$ SES: $p<0.05$ A×S: NS
Ferritin (µg/l)	77 (49)	52 (30)	58 (41)	33 (18)	A: $p<0.05$ SES: $p<0.01$ A×S: NS
TS (%)	39 (14)	29 (6)	30 (9)	25 (7)	A: $p<0.001$ SES: $p<0.001$ A×SE: NS

Values are means and (SD); n = number of subjects; HA = high altitude; LA = low altitude; HSES = high socioeconomic status; LSES = low socioeconomic status; Hb = hemoglobin; TS = transferrin saturation; ANOVA = analysis of variance; A = altitude; SE = socioeconomic status; NS = not significant

Table 4 Hematological parameters of four groups of 10-to 12-year-old boys living at high and low altitude and with high and low socioeconomic status.

to also identify marginally undernourished people for comparison with the population of the study. In the present study, malnutrition reaches a prevalence of 38.13% using P15 as the cutoff point, but the prevalence is only 2.94% when P3 is used as the cutoff point for W/A. At LA the prevalence of malnutrition assessed by the W/A relationship reaches 28.5% when the P15 is used but no malnutrition is found when using P3 as the cutoff point. However, W/A biases the study results since it does not indicate whether malnutrition is acute or chronic.

The analysis and interpretation of the results of the biochemical variables have their limitations since comparison with other studies is difficult due to the fact that most of the papers which relate biochemical parameters and nutritional status are based on studies of age groups different from ours and affected by severe protein-energy malnutrition. However, the mean values of the different biochemical variables in our study are in general comparable to the values reported by other authors of studies in adolescents and adults (1,3,28).

In our study, the comparison of malnourished LSES boys with well-nourished HSES boys as defined by anthropometric criteria shows no significant differences of total protein levels or of serum albumin between these groups. This finding can be explained by the fact that both proteins are not sensitive to light or moderate forms of protein-caloric malnutrition. This low sensitivity is partly due to variations in its distribution in the body between the vascular and interstitial space, partly to the existence of an important pool, which is emptied only after many weeks, and to a long biological life span of 10 to 12 days of albumin. Total proteins similarly have low or no specificity and sensitivity stemming from a wide variability of their levels in cases of increase of immunoglobulins in patients with secondary infections and malnutrition (31).

The lower prealbumin levels in LSES boys in comparison with HSES boys show this biochemical parameter as an early indicator of malnutrition. In fact, since 1972 prealbumin is considered to be an early indicator of malnutrition. Its sensitivity is attributed to the fact that its synthesis in the liver depends on the energy intake, on the content of Zn, its short life span, the availability of free tryptophan, an essential amino acid which is the most vulnerable of all amino acid pools in mammals (23). Therefore, a fall of circulating prealbumin can indicate an intrinsic deficiency of amino acids and/or a deficiency of one of the necessary cofactors for optimal protein synthesis as a consequence of poor intake in quantity or quality of proteins (32,23). This could be the case in the LSES boys.

On the other hand, the simultaneous analysis of prealbumin and proteins existing during the acute phase of inflammation which were found to be within normal range in all four groups suggests that the malnutrition present in the LSES boys is a pure protein malnutrition and outside of any stage of inflammation or infection. Wade et al. (39) in experiments with animals have shown that prealbumin diminishes during protein caloric restriction without concomitant inflammation or infection as proven by simultaneous quantification of proteins of inflammatory reaction.

In our study, the low prealbumin levels of the LSES boys would confirm the presence of malnutrition as defined by the anthropometric criteria. On the other hand, they would mean a reactivation of the status of malnutrition at the time of our study since this protein reflects partially the present state of the metabolism of visceral protein. The statistical analysis of prealbumin gives evidence of a closer relationship with the socioeconomic status and not with altitude; however, we cannot confirm the sensitivity of the protein due to its small positive correlation ($r = 0.185$, $p < 0.05$) with W/A and also because of the necessity of support by the measurement of other visceral proteins.

In conclusion, this study shows that the association of anthropometric criteria and biochemical variables has made it possible to define a state of pure protein-caloric malnutrition marked by growth retardation in prepubertal LSES boys at HA and LA. The variations in prelabumin concentration seem to be due more to SES than to altitude, whereas the variations of albumin and orosomucoid concentrations seem to be more influenced by altitude, a situation which cannot be explained yet. The iron status was assessed in this study by means of specific parameters (2,6). A moderate but significant ($p < 0.05$) effect of socioeconomic status on hematocrit and hemoglobin concentrations was found. However, in all four groups, these variables were within the normal range for well-nourished children of the same age studied at high (25,41) and low (9,15) altitudes, respectively. A significant effect of altitude ($p < 0.001$) on these parameters also existed. This finding is in accordance with previous studies which reported higher hemoglobin concentrations and hematocrit values in highland boys than in boys living at low altitude (6,16). This finding is one of the best known features of high-altitude adaptation: an increased red blood cell production (polycythemia) due to hypobaric hypoxia. A significant effect of socioeconomic status ($p < 0.001$) was found for all other hematological parameters. However, all boys had values for serum iron, ferritin, and TS within the limits of those reported for well-nourished children (10,14,27,33,38). Therefore, no evidence of iron deficiency anemia existed in any of the four groups of boys studied.

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