Nutritional Assessment of Preschool Children Inhabiting at High Geographical Altitude in the Antofagasta de la Sierra Department, Catamarca, Argentina

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Abstract: The growth and development of children are profoundly influenced by dietary habits, lifestyles, and environmental factors, which begin to shape early in ontogeny. In high-altitude populations, geographical stressors, such as permanent hypoxia, add further complexity and cannot be modified by human intervention. This study aimed to describe the nutritional status of preschoolers in a high-altitude area of northwestern Argentina.

A cross-sectional and descriptive study was carried out in 59 children aged 4 and 5 years from the towns of El Peñón and Antofagasta de la Sierra (3320 masl), Antofagasta de la Sierra department, Catamarca, Argentina. Anthropometric measurements, including weight (W), height (H), waist circumference, mid-upper arm circumference, and tricipital (T) and subscapular (S) skinfolds. Various indices and indicators, such as body mass index (BMI), waist-to-height ratio (WHtR), subscapular tricipital index (STI), and upper arm fat (UFA) and muscle area (UMA), were calculated. Additionally, the ratios of W/H, H/A (H for age), and BMI/A (BMI for age) were determined. Abdominal obesity was assessed using WHtR, and fat distribution was analyzed using STI. Protein and caloric reserves were estimated based on UMA and UFA, respectively.

The study revealed a low prevalence of low weight (3.7%) but a high prevalence of overweight (20.3%) and obesity (3.4%) among the evaluated preschool children. Notably, 30.0% of overweight children and 16.0% of normal weight children exhibited centralized fat distribution. Abdominal obesity was observed in 90.0% of overweight children and 42.2% of normal weight children. Stunting was also observed in 8.5% of the individuals. Additionally, a considerable prevalence of low caloric and protein reserves was identified.

These findings confirm the coexistence of deficit and excess malnutrition states, indicating a double burden of malnutrition, among the preschoolers of Antofagasta de la Sierra. Moreover, the study highlights the accumulation and distribution of abdominal and centralized fat as significant concerns in this population.

Keywords: Pediatric age, Body composition, Stunting, Malnutrition, South America.

INTRODUCTION

Nutrition, as a vital need and cultural fact, is conditioned by multiple factors (*e.g.*, geography, natural environment, energy resources, socioeconomic situation, and cultural patterns of the population to achieve a good nutritional status), represented by the balance between the needs of the organism and the expenditure of energy and nutrients [1]. Eating habits and lifestyles begin to be consolidated in one of the fundamental periods of ontogeny, the preschool age (between 4 and 5 years old) [2].

Several studies reported differences (morphological, physiological, environmental, and socioeconomic status) that human populations living at high altitude regions present, compared to those near sea level as a result of adaptation to extreme environmental conditions, in which the low pressure of dissolved oxygen in the air or hypoxia is permanent and cannot be modified by human action [3]. Additionally, there are other stressors such as low relative humidity, low nutritional intake, high solar radiation, and large thermal amplitude [4, 5]. These characteristics condition the growth and development of children, specifically in the most vulnerable stages of ontogeny [4, 6].

High altitude populations of Argentina are generally associated with low-income levels and high degree of geographic isolation, which, in turn, limits their genetic variability [7, 8]. They are settled in the Puna region, a large plateau with an average altitude of 3800 meters above sea level, which includes parts of Jujuy, Salta and Catamarca provinces.

Antofagasta de la Sierra is in the Puna region, northwest of Catamarca province, at 3320 meters above sea level, with a population of Atacameño Kolla

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E-ISSN: 2311-8687/23

indigenous descendants [9]. It is worth mentioning that these areas are scarcely populated (1436 total inhabitants in 28,097 km^2) and show very low population density (0.05 inhabitant/km^2) remained practically isolated from the province capital and urban centers until the opening of roads in the 1970s [10]. Since then, the inhabitants began to have greater access to foods different from those traditionally consumed. Currently, although their eating habits are mainly based on the consumption of animal proteins, the amount of processed and ultra-processed foods, carbohydrates and sugary drinks has increased [11]. These dietary changes, in addition to technological innovation, reduced physical activity, and the influence of the media, led to an increase in overweight and obesity in children, adolescents and adults [10]. The trend shows that this population is going through a process of food and nutrition transition [11]. Therefore, there are three components of interest to the research: a) populated areas with the highest geographic altitude, b) areas that have remained isolated for the longest time, and c) areas where the percentage of households that have acknowledged belonging to (or descending from) indigenous peoples exceed 20%. Despite this, the populations of the Puna region of Catamarca have been scarcely explored, with very few studies on the population under 5 years of age in Argentina in general, and in high altitude regions in particular.

For this reason, it is relevant to monitor nutritional status in early ontogeny, particularly in high altitude areas where part of their traditions and original population are preserved. This study aims to describe the nutritional status of preschoolers residing in a high-altitude region (>3000 masl) in the province of Catamarca, Argentina. The aim is to analyze growth, mesobrachial body composition and fat distribution.

MATERIALS AND METHODS

A cross-sectional, descriptive, anthropometric study was carried out in preschoolers from El Peñón and Antofagasta de la Sierra village (Antofagasta de la Sierra). These small towns totalize 993 inhabitants. The sample included a total of 59 students between 4 and 5 years old (45.8% girls), representing 91% of the total population in that age group [12]. Prior to the anthropometric survey, informed consent was obtained from parents/guardians and assent from the minors. Between 2013 and 2015, measurements of weight (W), height (H), waist circumference (WC), mid-upper arm circumference (MUAC), tricipital (T), and subscapular (S) skinfolds were collected following the standards of the International Society for the advancement of Kinanthropometry [13]. Prior to the beginning of the measurements, the intra and interobserver error was calculated, resulting in an error of less than 5% [13].

Data collected was processed to calculate body mass index (BMI: Kg/m^2), waist-to-height ratio (WHtR: WC/H), subscapular tricipital index (STI: S/T), and upper arm muscle area (UMA) and upper arm fat area (UFA) according to the equations proposed by Frisancho [14].

Indicators from weight and height include: Weight for height (W/H) for low weight-for-height; height for age (H/A) for stunting; body mass index for age (BMI/A) to estimate overweight and obesity. The values were compared with the WHO 2006 standards [15] using the WHO Anthro software. Values were obtained considering the median Z scores: <-2SD, indicative of deficit, >1SD and >2SD, indicative of excess.

Body composition from upper mid-arm measurements: From the upper arm fat and upper arm muscle areas, caloric and protein reserves were estimated as indicators of nutritional risk. The 10^{th} and 90^{th} percentile of the references for the Argentine population proposed by Oyhenart *et al*. [16] were used as criteria. Values <P10 were considered low reserve, between ≥P10 and ≤P90 normal reserve, and >P90 high reserve.

Indicators of abdominal obesity and adipose distribution: Abdominal obesity was estimated from the WHtR (≥0.5 indicated abdominal obesity), and fat distribution from the STI (≥1 centralized fat distribution).

Descriptive statistics and prevalences were obtained and the Shapiro Wilk test was applied to check the normality of the distributions. Sex comparisons were analyzed following the Mann Whitney U test for continuous variables, and Chi^2 test for categorical variables, all with confidence level of 95%.

Data collection followed the norms established in the Declaration of Human Rights [17], the Nuremberg Code [18], the Helsinki Declaration [19], and the Personal Data Protection Law of Argentina [20]. The Ethics Committee of the Hospital Interzonal San Juan Bautista, Catamarca, Argentina, approved the data collection.

RESULTS

Measurements of central tendency and dispersion of the direct and derived variables are shown in Table **1**.

Table 1: Sample Composition and Direct and Derived Measures

Variables	Males (n=32)		Females (n=27)		*p*
	Media	SD	Media	SD	
Weight (Kg)	19.28	2.81	17.79	2.77	0.027*
Height (cm)	109.89	4.88	107.25	5.54	0.155
Mid upper-arm circumference (cm)	16.85	1.43	16.36	1.86	0.196
Waist circumference (cm)	55.31	3.09	52.69	3.75	0.002**
Tricipital skinfold (mm)	8.65	2.10	8.62	2.77	0.710
Subscapular skinfold (mm)	6.74	2.54	6.27	2.57	0.343
BMI(Kg/m^2)	15.91	1.48	15.43	1.78	0.162
WHhR(cm/cm)	0.50	0.02	0.49	0.03	0.154
STI(mm/mm)	0.77	0.20	0.73	0.19	0.464
UMA(cm^2)	16.05	3.08	15.17	3.32	0.262
UFA(cm^2)	6.72	1.80	6.59	2.56	0.501

BMI=body mass index; WHhR=waist-to-height ratio; STI= subscapular tricipital index; UMA=upper arm muscle area; UFA=upper arm fat area; *p<0,05; **p<0,01.

All variables resulted with higher values in males, but only weight and waist circumference presented significant differences.

Median Z-scores of nutritional indicators compared to WHO 2006 standards are shown in Figure **1**.

Boys were mostly above the median, with the exception of the tricipital skinfold, and girls were below.

There were significant differences between males and females ($p<0.05$) in the nutritional indicators corresponding to weight, mid-upper arm circumference, tricipital skinfold, and subscapular skinfold.

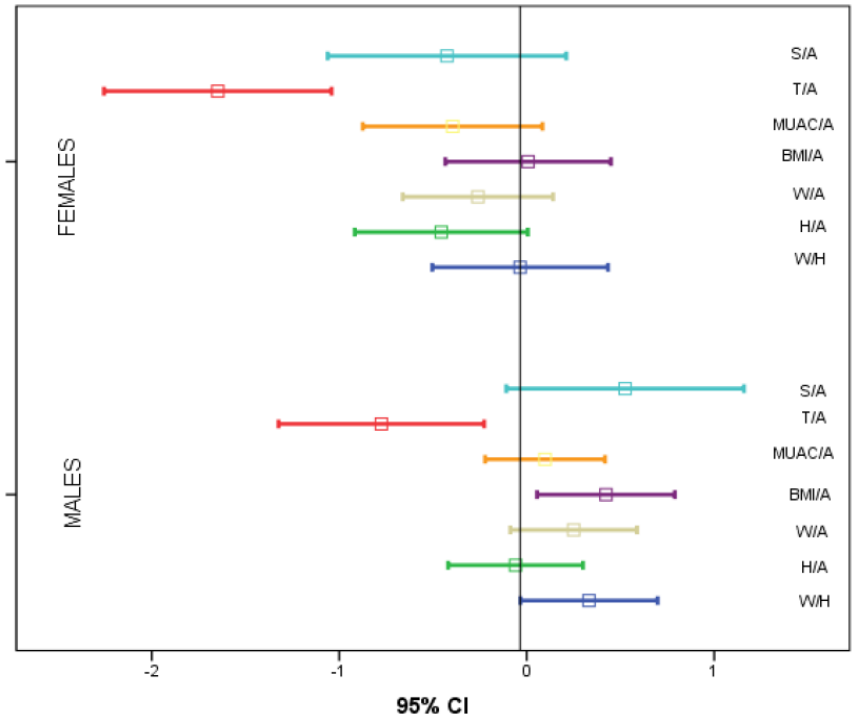

Figure 1: Median Z-scores of nutritional indicators (95%CI) compared to WHO 2006 standards.

S/A=subscapular/age; T/A=tricipital/age; MUAC/A=mid upper- arm circumference/age; BMI/A=body mass index/age; W/A=weight/age; H/A=height/age; W/H=weight/height.

Table **2** shows the prevalence of anthropometric indicators based on weight and height, adipose distribution, abdominal obesity, and mid-upper arm body composition.

Compared to WHO standards, underweight, stunting and obesity were more prevalent in girls than in boys, whereas overweight was more prevalent in boys.

Centralized fat distribution and abdominal obesity were more prevalent in boys.

Most preschoolers had protein and caloric reserves within normal values (≈ 60.0%) and only 15.0% to 20.0% had high protein reserves. None of the preschoolers had high caloric reserves. In turn, girls had twice the prevalence of boys with low protein and caloric reserves.

The differences observed in all the calculated indicators did not show significant differences between boys and girls. Centralized fat distribution was observed in 30.0% of overweight boys and girls and in 16% of normal weight. Abdominal obesity, on the other hand, was associated with 90% of overweight boys/girls and 42.2% with normal weight (Chi^2=8.489; *p*=0.037).

Forty percent of children with stunting were overweight. The occurrence of stunting and overweight was observed in 2 individuals (3.4%).

DISCUSSION

This study evaluated the nutritional status of children between 4 and 5 years old, permanent residents of the Puna region in Catamarca province, Argentina. Most preschoolers presented a normal weight condition, low prevalence of low-weight (3.7%), and high prevalence of overweight (20.3%) and obesity (3.4%). One third of children with overweight and three thirds with normal weight had centralized fat distribution and abdominal obesity. Stunting was also observed in 8.5% of individuals. At the same time, high prevalence of low caloric and protein reserves was registered.

The results obtained in the present study confirm the coexistence of deficit and excess malnutrition states, such as stunting and overweight in children of early age in a high-altitude area of northwestern Argentina. Similar results to those obtained here were reported in several articles conducted in different regions of Latin America [21-24] including Argentina [25]. These studies indicated the coexistence of stunting and excess weight (double burden of malnutrition) present in high altitude areas in recent years, regardless of the percentages obtained by the authors mentioned. Specifically, related to the area considered for this work, a study conducted in native populations of the Andes effectively reported an increase in the body mass index in recent years, concluding that these populations are going through a process of nutritional transition [26]. Indeed, the nutritional transition characterized by the substitution of traditional foods for industrialized ones (processed and

Table 2: Nutritional Status and Adipose Distribution of Preschoolers from Peñón and Antofagasta de la Sierra

		Males (n=32) (%)	Females (n=27) (%)	All (n=59) (%)
Deficit	Wasting	0.0	3.7	3.7
	Stunting	3.1	14.8	8.5
Excess	Overweight	21.9	18.5	20.3
	Obesity	3.1	3.7	3.4
	Overweight+Obesity	25.0	22.2	23.7
STI	Centralized distribution	258	7.7	16.7
WHhR	Abdominal obesity	61.3	37.0	49.1
UFA	Low caloric reserve	29.0	46.2	37.6
	High caloric reserve	0.0	0.0	0.0
UMA	Low protein reserve	6.5	11.5	9.0
	High protein reserve	22.6	15.4	19.0

STI=subscapular tricipital index; WHhR=waist-to-height ratio; UFA=upper arm fat area; UMA=upper arm muscle area.

ultra-processed), and the progressive sedentary lifestyle, is a phenomenon that has been observed in practically all societies. In Argentina, this phenomenon shows heterogeneities throughout the territory [27,28], giving rise to three nutritional profiles, according to Tumas *et al*. [29]:1) "Socionutritional lag"; 2) "Double burden of malnutrition"; 3) "Incipient socionutritional improvement". The province of Catamarca falls within the group of provinces corresponding to the second profile. It has been suggested that the nutritional transition appears to be more rapid in populations with indigenous ancestry compared to other societies [30], particularly regarding changes in lifestyles and sedentary behaviors. These changes, coupled with modifications in diet and eating habits, may contribute to an increased risk of obesity among populations [31]. In this sense, previous studies carried out in the provinces of Jujuy and Catamarca show the advanced nutrition transition process in northwestern Argentina [32] including the Puna of Catamarca, generating changes in the lifestyles and dietary patterns of this population [33, 10]. These processes are reflected in the high percentages of overweight and obesity [11, 34].

Our results are also similar to those reported at the national level in the latest nutrition and health survey [27]. In this survey, a coexistence of both nutritional deficits and excesses was observed. There were low prevalences of acute, moderate, or severe undernutrition and linear growth retardation, while high prevalences of overweight were observed. Furthermore, the study revealed that stunting and low weight have remained relatively stable since the first survey conducted in 2005 [35], and these conditions were found to be inversely related to the socioeconomic status of the families. Conversely, overweight and obesity were the most prevalent forms of malnutrition, which were associated with dietary changes, particularly among young children.

The evaluated preschoolers exhibited low protein and caloric reserves, as indicated by their upper arm body composition. There was a predominant accumulation of truncal fat, which was evident from the low values of the tricipital subcutaneous skinfold in contrast to the high values of the subscapular subcutaneous skinfold when compared to WHO 2006 standards. Furthermore, high percentages of abdominal obesity were observed.

Although high-altitude populations are biologically and culturally adapted to the natural and socioeconomic conditions characterized by decreased oxygen in the air, not all of them follow the same adaptive pattern [36]. Factors such as genetic ancestry and the duration of time spent at high altitude are related to this variability. The Andean regions of South America are among the most recently inhabited high-altitude areas. However, similar results regarding the phenotypic profile of abdominal fat accumulation have been observed, indicating a possible genetic adaptation associated with other adaptive traits. This has been observed in Asian populations [37] and in Argentina [38, 39]. While no association between this condition and chronic diseases was observed in these investigations, high prevalences of blood pressure in school-age children were reported in other studies conducted among indigenous populations at moderate and high altitudes in Argentina [40, 41]. Additionally, a study by Hirschler *et al.* [42] revealed low prevalences of HDL-C in these altitude zones. These findings indicate that the risk of chronic diseases in these areas could manifest in the early stages of life and could persist into adulthood.

The results obtained in the present study report a high prevalence of excess fat, both in terms of truncal distribution and accumulation at the abdominal level. This is particularly concerning in young children, as it poses a risk for chronic noncommunicable diseases not only in adulthood but also during childhood and adolescence. Consequently, it represents a significant community health issue [43]. Therefore, regular assessment of nutritional status is crucial. While the body mass index (BMI) is a cost-effective and widely used tool that shows a strong correlation with body fat, it is not the most appropriate method for analyzing fat distribution. Thus, we recommend the use of multiple criteria in combination during periodic evaluations of nutritional status to effectively prevent the development of chronic pathologies.

LIMITATIONS AND STRENGTHS

To describe for the first time the nutritional status of preschool children in a high altitude region of the Puna of Catamarca, Argentina, represents the strength of this work. A limitation of this study is that no information on other health and quality of life indicators is available.

In summary, in preschoolers from the Puna of Catamarca, Argentina, there is a coexistence of both deficit and excess malnutrition alongside abdominal and centralized fat accumulation and distribution. These conditions are likely associated with dietary changes and the subsequent nutritional transition to overweight and fat accumulation. However, it cannot be

disregarded that genetic predisposition and/or physiological adaptation may contribute to the development of obesity, particularly at the trunk and abdominal levels, as a protective mechanism against hypobaric hypoxia at high altitudes. Regardless, there is ample evidence indicating that excessive weight and abdominal obesity pose a risk for chronic noncommunicable diseases, such as type II diabetes, hypertension, and dyslipidemia, not only in adulthood but also during childhood. These pathologies present significant challenges and complexities for public health. Conducting new research during the early stages of ontogeny, where dietary habits, physical activity, and other lifestyle and health indicators are established, will facilitate a deeper understanding of high-altitude populations in Argentina.

ACKNOWLEDGMENTS

The authors would like to thank the educational, administrative, and support staff of the schools in El Peñón and Antofagasta de la Sierra, and Professor Norma Dip for their collaboration in the field data collection campaigns. They also extend their appreciation to the parents/guardians of the children who participated in this research, as without their consent and support, this study would not have been possible.

This work was carried out within the framework of the project PICTO 32451 funded by the National Agency for the Promotion of Scientific and Technological Research, Argentina, and the research project 02/P232 of the Research and Postgraduate Office of the National University of Catamarca, as well as the doctoral scholarship from National Council for Scientific and Technical Research (CONICET).

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Received on 13-06-2023 Accepted on 11-07-2023 Published on 14-07-2023

DOI: https://doi.org/10.12974/2311-8687.2023.11.10