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DIETARY PATTERNS AND SOCIAL DEFICIENCIES PUT PRESCHOOLERS IN RURAL AREAS AT RISK OF MALNUTRITION

María Elena **Calderón-Martínez**, Oswaldo Rey **Taboada-Gaytán***

[1]Colegio de Postgraduados, Campus Puebla. Boulevard Forjadores de Puebla 205, Santiago Momoxpan, San Pedro Cholula, Puebla, México. 72760.
*Corresponding author: toswaldo@colpos.mx

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ABSTRACT

Infant malnutrition is an ongoing multi-causal problem with serious consequences for individual and public health worldwide. Preschool children in rural areas represent the most vulnerable group; however, there is no research focused on micro-regions to provide accurate information about their nutritional status and underlying causes. The objective of this study was to determine the prevalence of infant malnutrition in Tochimilco, Puebla, and to specify the factors that influence nutritional status, both internal and external. A nutritional evaluation based on anthropometry and clinical and dietary history was carried out on 61 preschoolers; a semi-structured questionnaire was applied to 38 children from this population to analyze social and environmental variables that referred to descriptive and multivariate statistics. It was found that 51% are at risk of malnutrition, 48% manifest height/age deficit and 35% are underweight. Furthermore, the type of rural/urban locality influenced nutritional status; government support also related to weight/height and weight/age, with particular reference to the scholarship program. Eating patterns provide sufficient energy and macronutrients, but of very poor quality. In conclusion, the infant population of Tochimilco is at greater risk of malnutrition than reported and the most efficient strategy to eradicate this is not only to improve living conditions and social deficiencies, but to include the component of nutritional education.

Keywords: anthropometry, determinants of infant malnutrition, nutritional evaluation, rural sector**.**

INTRODUCTION

Malnutrition is a serious public health problem globally, due to its prevalence and the damage to the health and life of those who suffer from it. Although rates have decreased in recent years, it remains a problem that has not been eradicated (Solomons and Soto-Méndez, 2017). It can be classified in different ways, and depending on its manifestation, there may be 1) chronic malnutrition or inadequate linear growth, 2) low weight and 3) severe acute malnutrition (wasting) (Solomons and Soto-Méndez, 2017). In 2016, 155 million girls and boys suffered from some aspect of malnutrition, especially in Africa and Asia (United Nations Children's Fund UNICEF, 2018); worldwide, 1 in 4 children under 5 years of age show deficiency in terms of linear growth (Solomons and Soto-Méndez, 2017). Furthermore, it is estimated that 5.8 million in the Latin American and the Caribbean region suffer from chronic malnutrition (Galicia *et al*., 2016) and in Mexico this reaches 14.2% of the infant population; regarding low weight, 4.8% prevalence and 1.4% for wasting were reported (Shamah-Levy *et al*., 2020).

In the case of Mexico for the year 2018, rural localities had a prevalence of 17.5% of chronic malnutrition, 6.3% of underweight, and 2.3% of wasting (Shamah-Levy *et al*.,

2020). Given this, various strategies and programs have been shown to contribute to the eradication of this public order problem, by addressing the indirect factors, which in theory will improve the quality of life of vulnerable populations; some examples include monetary transfer programs (Galicia *et al.*, 2016), provision of food pantries, school breakfasts, community kitchens and improvement of rural housing with cement floors, ecological stoves, efficient drainage system, etc.

Another strategy used to diagnose malnutrition in the country is that of health censuses, particularly the National Health and Nutrition Survey (ENSANUT). Malnutrition is a public order problem analyzed in these surveys at the national and state level; however, the applied methodology does not lead to accurate results for the rural population within the municipalities of each state. Few Mexican regions have their own censuses and results; this creates a problem when implementing local strategies for nutritional improvement; as a completely reliable diagnosis is not provided and nor is there access to the most relevant results concerning this situation (Calderón-Martínez *et al.*, 2017).

In the state of Puebla, there is no public data on the prevalence of this pathology; there are some studies by researchers that provide data from specific localities, schools or groups (Acosta-Salinas *et al.*, 2017; Castro *et al.*, 2017). These diagnoses help to improve the planning of programs and policies directed towards child malnutrition, further defining targets that include characteristics of the region and the population, etiology, factors of influence and perceived requirements. The objective of this study was to determine the prevalence of child malnutrition in Tochimilco, Puebla, in its three manifestations: low weight, wasting and chronic malnutrition and to specify the determinants that influence nutritional status, both internal and external, such as diet, clinical history, economics, social, environmental and political aspects.

THEORETICAL FRAMEWORK

The data presented above are of impact because malnutrition in the infant population is a serious multifactorial problem that triggers dangerous consequences for individual and collective health, which may not only affect the moment it is suffered, but also in later years. The severity and, therefore, the consequences, are related to the type of malnutrition that is diagnosed and the length of time it has been suffered. Thus, there are various ways to classify and determine type of malnutrition; however, in this study, classification was defined according to manifestation, revealing three types: 1) low weight for height or wasting, 2) low height for age or stunting and 3) low weight for age (World Health Organization WHO, 2021).

Wasting is indicated by a z score below -2 for the anthropometric indicator weight for height (WHO, 2008). This manifestation occurs due to acute malnutrition, for which the girl or boy experiences a lack of nutrients or a pathology that results in weight loss for a short period of time, however, height is not affected. A young child with a moderate or severe level of wasting has a very high risk of dying, but can still be treated (WHO, 2021).

Wasting is the most serious manifestation, as it indicates chronic or recurrent malnutrition; in this case, the girl or boy has suffered from nutritional deficiencies over a long period,

which becomes evident in their delayed growth, preventing full physical and cognitive development. This is generally associated with poor conditions for the mother from a socioeconomic and nutritional point of view, recurrence of diseases, and inadequate care and diet. The anthropometric measurement taken into account is the height of children (WHO, 2021).

Low weight or insufficient weight for age is diagnosed when the boy or girl is below the z score by -2 in the weight for age indicator (WHO, 2008) indicating acute malnutrition. Underweight girls and boys may also experience wasting and stunted growth (WHO, 2021).

In both moderate and severe cases, malnutrition can be fatal and in mild cases it has consequences for physical, cognitive, psychological and social development (Cueva *et al*., 2021). Longitudinal growth, weight gain, physiological development, muscle and fatty tissue are affected, and the risk of serious infections increases (Fernández *et al*., 2017), anemia, cardiovascular, endocrine, metabolic and mental morbidities (Cueva *et a*l., 2021) Likewise, they experience a decline in their learning and attention capacity, which negatively influences their academic development, increasing the probability of late school entry, repeated years, falling behind, and dropping out, as well as low educational level (Fernández *et al*., 2017; Rojas-Guerrero *et al*., 2015). For example, in Mexico in 2014, an analysis was carried out that combined information from adults diagnosed with malnutrition at an early age in their lives. It was found that 540,000 people had repeated the school year, for which 16% was the result of malnutrition; furthermore, these people had 2.4 years less education than the average. It also revealed that it is 15 times more difficult to complete secondary school for those who suffered from malnutrition compared to those who did not. In this same study, they reported that an extra 151 million dollars was invested in the educational system due to the population that repeated a school year (Fernández *et al*., 2017).

Personal consequences go beyond the family orbit, as limitation in terms of capabilities of the malnourished infant impacts academic potential, job opportunities, productivity and the economy, at present and even in the long term, thus increasing the social and financial burden at all levels and in all sectors: municipal, state, national, health, academic, industrial, economic, etc. (Fernández *et al*., 2017). This instigates a cycle in which the intergenerational transmission of malnutrition occurs (Mönckeberg, 2014, consolidating inequality and the persistence of poverty (Beltrán and Seinfeld, 2011), thus negating or reducing the acquisition of good quality food and ultimately resulting in malnutrition among the younger generation.

Regarding causal factors, malnutrition is a multifactorial problem for which both individual and external components (social, cultural, economic and political) are interrelated. The most common associated factors include: 1) low birth weight; 2) sex, according to statistics, a woman is more prone to this than a man; 3) hereditary factors, if the mother or father were malnourished as children, it is more likely that their children will also suffer; 4) indigenous descent; due to their extreme vulnerability, reports indicate that the indigenous population suffering from malnutrition exceeds that of other sectors of society;

5) absence of exclusive breastfeeding, the use of formula from a bottle can cause nutrient deficiency; 6) poor complementary feeding practices, the lack of balance of nutrients in the meals of older infants and the consumption of foods high in sugars and saturated fats cause micronutrient deficiencies and excess body fat; 7) contemporary pathologies such as HIV and certain incapacities when combined with malnutrition can increase risk of death; 8) limited physical activity can stop the development of boys and girls, 9) unsuitable diet: consumption of foods with high caloric density, insufficient vegetable and fruit consumption and iodine, iron and zinc intake etc. (UNICEF *et al.*, 2020; Kuper, 2017; Beltrán and Seinfeld, 2011).

These components are mostly established during the first thousand days of life (from conception to two years), therefore, health care and nutrition at this stage is essential for girls and boys to grow and develop adequately, which will impact their future life (UNICEF *et al.*, 2020). However, other causes are derived from social, economic and political factors, such as food insecurity, deficiencies in health, water, hygiene and sanitation services, poor working conditions or unemployment, low educational level, insufficient economic income, inadequate policies and regulations related to the food industry, among others (UNICEF *et al.*, 2020; Beltrán and Seinfeld, 2011).

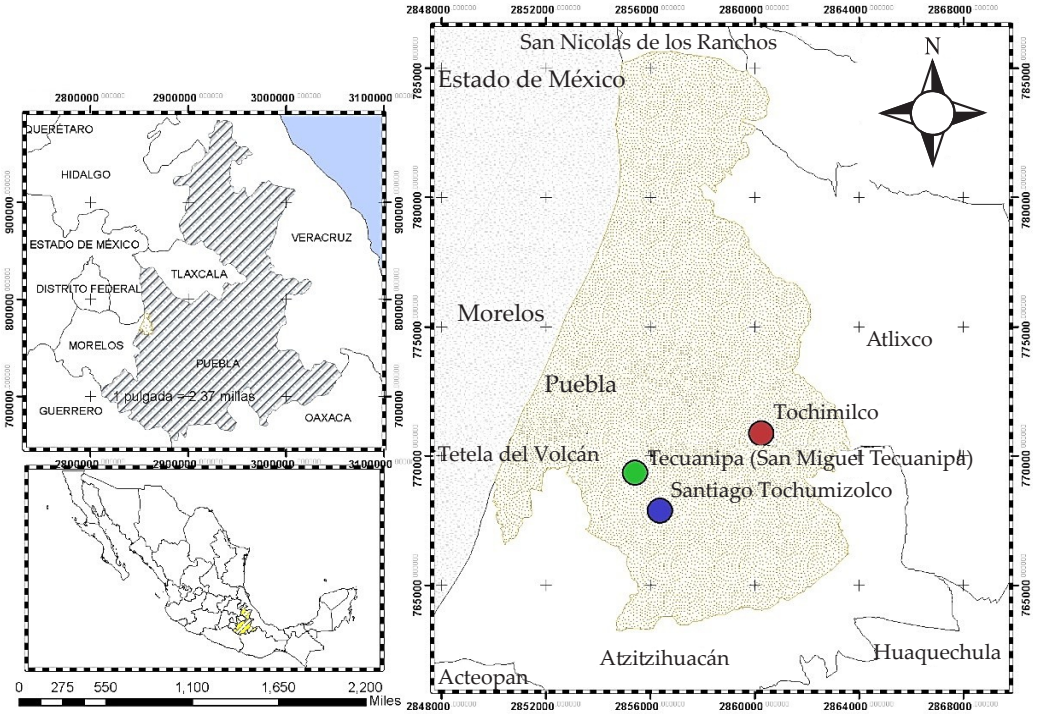
Thus, we find that malnutrition is more serious in rural areas, as social deprivation is greater than in cities (Ávila-Curiel *et al.*, 1998). The conditions of marginalization, lack of resources, lack of care provision and availability of health services are determining factors; this, added to poor diet, an unhealthy lifestyle, and in some cases, diseases (UNICEF *et al.*, 2020; Solomons and Soto-Méndez, 2017), makes girls and boys from the rural sector more vulnerable (UNICEF *et al.*, 2020; Sánchez and Gómez, 2015).

METHODOLOGY

The study was carried out in the municipality of Tochimilco, Puebla, located in the central region of the Mexican Republic. Three localities were selected for inclusion in the study: the municipal capital (urban), San Miguel Tecuanipa (rural) and Santiago Tochimizolco (rural). The criteria for their inclusion were that the localities are large producers of amaranth and that there was already contact between the corresponding authorities and participating families, due to previous projects. This was carried out during the period from August 2018 to January 2020.

Location and characteristics of the study area

Tochimilco is located in the central-west of the state of Puebla, Mexico, between the parallels 18° 50' and 19° 02' LN and the meridians 97° 18' and 97° 27' WL (Figure 1). The municipality consists of 24 localities, of which three are urban and 21 rural. The main economic activity consists of irrigated agriculture. 44% of the overall area is used for this activity and only 3% is urban (National Institute of Statistics and Geography INEGI, 2017). Another important source of income is remittances; in the second quarter of 2023, US$3.63 million reached the families in the municipality (Government of Mexico, 2023). The study area has a high proportion of rural and indigenous population (21.1%);



País	Estado	Sistema de Coordenadas		Falso Este	Paralelo Estándar	Latitud de origen	Unidad Lineal	Meridiano central	Escala
México	Puebla	Proyección	Lambert Conformal Conic	2500000	17.5000000	12.0000000	Metros	-102	1-250000
		Zona Centro	14						
		Coordenadas	WGS 1984						

Elaborated: Juan Velázquez, 2021 with data from the US Geological Survey (USGS) and the National Oceanic and Atmospheric Administration (NOAA).
Figure 1. Geographical location of Tochimilco within the State of Puebla, Mexico.

specifically in the municipal capital, 21% speak an indigenous language, 23% in San Miguel Tecuanipa and 1% in Santiago, Tochimizolco (Gobierno de Tochimilco, 2021). Evaluation of the municipality revealed moderate social backwardness and high marginalization: 30.4% of the population lives in extreme poverty, 56.6% in moderate poverty, 14.7% do not have access to water and 13.5% do not have drainage (Secretaría de Bienestar, 2022).

Research was undertaken among girls and boys enrolled in four official nursery schools. Two are located in the municipal capital, considered an urban locality; these are the kindergartens, "Vasco de Gama" and the Centro de Asistencia Infantil Comunitario, CAIC (Community Child Assistance Center); the other two schools are located in rural towns: one in San Miguel Tecuanipa, called the "Yanguik Xochikoskatl" Kindergarten, and the other in Santiago Tochimizolco, called the "Cuauhtémoc" Kindergarten.

The study population was assembled in these educational centers with help and authorization from the municipal authorities, local councils and school authorities of each kindergarten. Initially, an information meeting was organized with mothers, fathers

and guardians of girls and boys under 5 years of age, enrolled in one of the selected kindergartens.

To select the study population, non-probabilistic convenience sampling was carried out (Hernández-Sampieri *et al.*, 2014), with the following inclusion criteria:

1. That the girls and boys attended one of the kindergartens selected in the study.
2. That they were of the age established for the study.
3. That the mothers, fathers or guardians agreed to the anthropometric evaluation of the girls and boys, and signed the informed consent.

Dietary assessment

Dietary assessment was carried out to diagnose the nutritional status of the population sample (23 girls and 38 boys). It was obtained by the anthropometric evaluation of weight, height and upper arm circumference, according to the Lohman protocol (Lohman *et al.*, 1988). The instruments used were Tanita brand HA-621WH Dial Weight Scale and Seca brand 201 ergonomic tape to measure circumferences.

The indicators to determine nutritional status were: weight for age, height for age, weight for height, upper arm circumference for age and Body Mass Index (BMI) for age (Burgos *et al.*, 2017). Individual results were analyzed using z scores and reference parameters established by the World Health Organization (WHO, 2008) (Table 1), and through comparative analysis, a diagnosis was integrated for each child. Priority was given to those whose interpretation of any indicator was below adequate and their parents or guardians were the first to be notified.

We decided to use our own criteria for data analysis, based on the z scores derived from the WHO growth curves, in order to observe trends with more precise limits, particularly to perceive risk of malnutrition. For this, it was determined that z-scores from -1 to 1 represented an "adequate" diagnosis; from -1 to -2, "low"; below -3, "very low"; from 1 to 2, "high"; and from 2 to 3, "very high."

Table 1. Interpretations to diagnose nutritional status according to growth indicators.

z scores	Growth indicators			
	Size for age	Weight for age	Weight for size	BMI for age
Above 3	Very tall	Assess by weight for height or BMI for age	Obese	Obese
Above 2	Adequate		Overweight	Overweight
Above 1			Possible risk of overweight	Possible risk of overweight
0 (median)		Adequate	Adequate	Adequate
Below -1				
Below -2	Stunted	Underweight	Wasted	Wasted
Below -3	Severely stunted	Severely Underweight	Severely wasted	Severely wasted

BMI: Body Mass Index.
Source: OMS, 2008, page 14.

A semi-structured questionnaire was also applied with questions related to the clinical-nutritional history of the girls and boys, including a 24-hour recall. After amassing data, they were analyzed and compared to regular benchmarks, and then the degree of deficiency or excess of energy and macronutrients ingested (carbohydrates, proteins and lipids) was determined, in terms of percentage adequacy.

External indicators of infant malnutrition and the study population

The first meeting with the mothers and fathers made possible the application of a semi-structured questionnaire to the study population, in order to obtain information on probable indirect risk factors for infant malnutrition. This questionnaire was designed with questions based on international research, similar to the present study, which reported family, economic, social, political and environmental factors (UNICEF *et al*., 2020; Beltrán and Seinfeld, 2011). Analysis of the questionnaire helped explore the relationship that exists between the girls' and boys' environment and their nutritional status. Notably, the statistical tests were only applied to the information from those girls and boys participating in the anthropometric evaluation scheme using the answers to the questionnaire, so a total of 38 complete files were obtained.

For the statistical analysis of these indicators, it was decided to group the variables into the following categories: a) family context, b) infrastructure of the family unit, c) access and stability of food, d) government services and e) nutritional status.

Bioethical considerations

This study was undertaken in compliance with the Declaration of Helsinki, regarding research on human beings (World Medical Association, 2013); carried out with deference to the principles of bioethics: dignity, respect, protection, autonomy, distributive justice, equity, confidentiality, respect for traditions, informed consent, optimization of positive results and minimization of negative ones (Correal-Muñoz and Arango-Restrepo, 2014).

Data analysis

The information obtained was analyzed with descriptive and multivariate statistics, using the SPSS v.21 software (IBM, 2012). For tests of associations, Chi-square, Mann-Whitney U, Student's T and Fisher's Test were applied, with a confidence level of 95%. The dependent variables selected were: z scores and interpretation of anthropometric indicators. Independent variables included those assigned to the five categories described above.

RESULTS

Due to the importance of children's environment, some home attributes were identified. 79% have cement floors, one example has dirt floors and seven homes have both floor types. Likewise, evidently only 63% of homes have drainage. Overcrowding occurred in more than 50% of cases and in one case, six people occupy a room. Almost all of the people surveyed (97%) answered that they have drinking water service and only one case

mentioned that they do not have this service and three families consider that the water they receive is insufficient.

Regarding access to food, 24% responded that the roads around their house make it difficult to access food, due to the distance from the center of the town and grocery stores, and rain also affects negatively. Similarly, it appears that the majority of families (66%) are enrolled in a government program providing some type of support: 29% receive scholarships and 34% receive food supplies. Additionally, 79% mentioned that medical care is not available in their area every day of the year.

Dietary assessment

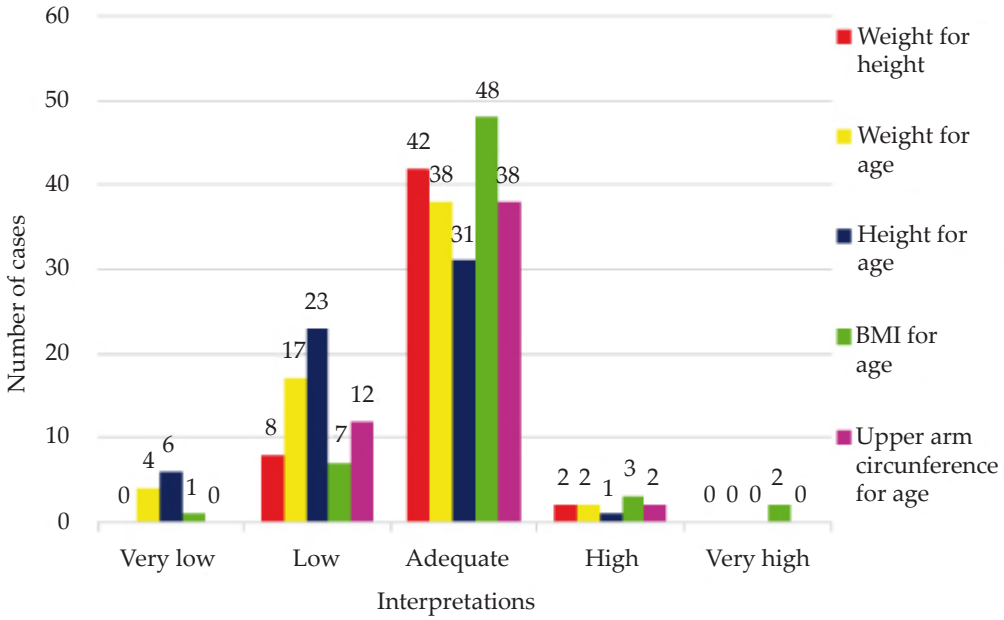
According to the WHO criteria, 93% of preschoolers were diagnosed as "adequate" in terms of all their indicators; furthermore, one case is overweight and another is obese. It was found that eight girls and boys have at least one diagnosis that indicates mild malnutrition, according to the z score for indicators (Table 2); these would signify greater risk, if a combined diagnosis exists, in the sense that, everyone has a "low" diagnosis for a certain indicator, but to this another equally severe diagnosis or another that poses a risk is added (z <-1). What stands out is the diversity of diagnoses, the complexity of cases and the difficulty in terms of addressing their treatment.

When examining the z scores in more detail so as to assess the prognosis for the children evaluated, the researcher's criteria do not "indicate" malnutrition at present; however they indicate a high future risk. Following this criterion, most preschoolers are clustered together in the "adequate" category for diagnosis of the five indicators (Figure 2); however there is a notable tendency towards "low" and "very low" diagnoses and minimally for "high" and "very high"; which means that, one in two preschoolers has one or more of their anthropometric indicators below what is appropriate, either for their age or their height. It is necessary to highlight the case of the height-for-age indicator, which has high percentages of girls and boys with "low height" (38%) and "extremely low height" (10%)

Table 2. Anthropometric indicators of preschoolers diagnosed as suffering from malnutrition in Tochimilco, Puebla.

No. of cases	Weight for height	Weight for age	Height for age	BMI for age	Upper arm circumference for age
1	At risk	At risk	Adequate	Wasted	Adequate
2	At risk	Underweight	At risk	At risk	Adequate
3	At risk	Underweight	Stunted	Adequate	Adequate
4	At risk	Underweight	Stunted	Adequate	At risk
5	Adequate	At risk	Stunted	Adequate	At risk
6	Adequate	Underweight	Stunted	Adequate	At risk
7	Adequate	At risk	Stunted	Adequate	Adequate
8	Adequate	At risk	Stunted	Adequate	At risk

BMI: Body Mass Index.
Source: own elaboration using data from the interview, 2018.



Source: own elaboration using data from the interview, 2018.
Figure 2. Initial anthropometric evaluation among preschoolers in Tochimilco, Puebla.

and a lower percentage (51%) in the "adequate" category; contrastingly, there is only one case that exceeds this indicator.

Characterization of the study population

Variables were obtained from the semi-structured survey, indicating the family context (Table 3) with some factors that had influence on nutritional status. It was found that mothers usually have secondary or high school education (76%); only 18% have ever received a course or talk on nutrition. More than 50% of those surveyed perceive their family as indigenous and from a middle socioeconomic stratum, although weekly spending on food does not exceed $1,000.00 for an average of five people, including girls and boys. It is important to mention that in a family, up to ten people eat from the same budget. In many cases, two people contribute to family expenses, 39% stated that sometimes income is insufficient; more serious is the case of 24% of families, whose income is not enough to purchase food, so certain foods (fruit, meat, milk and eggs) were not purchased due to insufficient funds.

Of the mothers 89% responded that they did take vitamin supplements during pregnancy, 76% of them did not present serious illness or malnutrition at this stage and 71% of the infant population was born at term, without complications during delivery and with a healthy weight, except for one case, born weighing 900 g due to being extremely premature. Regarding the feeding of newborns, 66% were breastfed during the first hour of life and 89% during the first day of life. More than half (60%) consumed formula milk at some time. In their pathological history, it was found that 8% presented malnutrition and

Table 3. Characterization of the family context of preschoolers in three localities in Tochimilco, Puebla.

	%	Variable	%
Number of children		Weekly food bill	
First child	74	Under $500	34
Second child	10	$500 to $1000	47
Third child or more	16	Over $1000	18
PCF		Person covering bills	
Mother	58	Mother and Father	34
Other relative	24	Father	34
Mother and Father	18	Mother	18
		Other relative	13
Occupation of PCF		Occupation of person paying bills	
Housewife (exclusively)	47	Diverse employment	39
Paid work	29	Farmwork	29
Combined	24	Salesperson	26
		Professional	5
Education		Way of acquiring food	
Just primary	13	Purchased	84
High school	76	Produced	13
Undergraduate education	5	Produced and purchased	3

PCF: person caring for family.
Source: own elaboration using data from the interview, 2018.

(5%) anemia, at some point during their lives; 18% have suffered some serious illness, such as bronchitis, severe stomach infection, dehydration, ear infection, dermatitis, etc. All PCFs perceived that their children are healthy and active. However, in the last three months, nine infants suffered from diarrhea and one case presented diarrhea on four occasions. Likewise, 50% have not presented acute respiratory infection in the last three months. Notably, more than half of the population has recently been treated for parasites (previous 6 months maximum).

Factors related to child malnutrition in Tochimilco

When performing statistical tests for association, no significant relationship ($p<0.05$) was found between z scores and interpretation of anthropometric indicators for many independent variables. The following paragraphs describe any perceived relationships.

A relationship was demonstrated between the variables of location type and nutritional status. We observed a high prevalence of risk of malnutrition or mild malnutrition in rural localities, and multivariate statistics corroborated the statistically significant relationship showing a moderately strong association ($x^2(2)=13.402$, $p<0.01$; $v=0.508$, $p<0.01$). This was confirmed when the presence/absence of risk due to malnutrition was assessed in terms of type of location; Fisher's exact test revealed significant differences between location types ($p=0.002$); specifically, significant differences were found for both weight/age ($t=2.99$, $p<0.01$) and weight/height ($t=2.11$, $p<0.05$).

Apparently, height for age in relation to the education level of PCF groups indicated significant differences ($p=0.01$); the Tukey test revealed significant differences between

higher education and upper secondary education group (p=0.05). The mean for higher education and higher degrees was z=0.40 ("adequate" percentile); in contrast, the average for mothers who only finished secondary or high school was z=-1.13 ("risk of being stunted"). This result should be taken with reservation, as the sample number in each group very different, and only two mentioned having higher education.

The government support variable influenced the presence/absence of risk of malnutrition (p=0.04); specifically, differences were found in the weight/height indicators (t=-2.148, p<0.05) and weight/age indicators (t=-2.147, p<0.05). Support from the scholarship program shows a diagnostic difference between girls and boys who receive scholarships and those who do not ($x^2(4)=10.357$, p<0.05). Furthermore, evidently 30% do benefit from this program, whereas 35% do not; however, in both instances they suffer from a risk or diagnosis of malnutrition.

Continuing with the exploration, the personal history of the girls and boys, documented in their medical records was analyzed, only revealing the following relationships. Apparently, the consumption of milk formula improves anthropometric measurements in contrast to exclusive breastfeeding; as more appropriate parameters were observed when there was formula consumption, especially in terms of height (t=-2.365, p<0.05), although weight and upper arm circumference also had significant p values. Evidently, not consuming milk formula results in a lower percentile; however, a larger study is needed to confirm this trend.

Although few external determinants were found that influenced the nutritional status of the infant population, evidently, internal factors, such as their diet, may be affecting the health and nutrition of the girls and boys from Tochimilco. By analyzing the 24-hour reminder, an average for adequacy percentages was observed confirming that nutritional requirements are being met; however, there are cases that fall outside the healthy ranges concerning all macronutrients (Table 4).

A more detailed analysis highlighted deficiencies in the quality of nutrients ingested and the presence of certain foods and commercial products that "provide" poor quality

Table 4. Statistical measurements of the daily intake of calories and macronutrients found in the dietary evaluation of preschoolers from Tochimilco, Puebla.

Variable	Average	Max.	Min.	SD
Energy (kilocalories)	1,495.0	1,947.0	916.0	351.0
Proteins (grams)	54.1	92.1	31.4	17.9
Lipids (grams)	49.5	73.8	27.1	16.8
Carbohydrates (grams)	213.8	264.9	133.6	47.2
% kilocalorie adequacy	99.1	134.6	64.3	27.2
% protein adequacy	97.6	169.7	58.8	33.1
% lipid adequacy	99.6	150.2	48.5	38.7
% carbohydrate adequacy	102.4	137.7	68.3	24.3

SD: standard deviation.
Source: own elaboration using data from the interview, 2018.

macronutrients and calories. Elevated consumption of products with high calorie density, added sugars, saturated fats, trans fats, additives and preservatives was found in products such as fruit yogurt, poor quality chocolates, cookies, soft drinks, fruits in syrup, cereals and commercial juices - products preferred by 45% for snacks and school lunches - and other foods such as sweet pastries and excess table sugar.

An excess of simple carbohydrates (34% of total carbohydrates) and saturated fats (20% of total caloric value), deficiency of polyunsaturated and monounsaturated fats (7% of total caloric value), lack of essential amino acids, minerals and some vitamins, especially B12 were detected; this is reflected in insufficient consumption of vegetables, chicken, fish, eggs, milk, red meat and green leafy vegetables. Apparently, all the children ate breakfast at home before school; they also all had at least two to three full meals a day and mostly ate food prepared at home.

DISCUSSION

The severity of nutritional deterioration affecting the majority of the evaluated child population is important to emphasize. Although it is true that few cases manifested below a score of -2 for any of the nutritional indicators (recommended by the WHO, 2008), risk of deficiency stood out in this municipality, predominantly in terms of weight and height. The results obtained in the baseline anthropometric evaluation were compared with national and state information, products of ENSANUT 2018 (Shamah-Levy *et al.*, 2020). In the comparison, it was apparent that the percentage of girls and boys with "low height for age" in Tochimilco is double that of the state average; also, disturbing data were found related to the weight for age indicator, as "low weight" is almost ten times more prevalent in the municipality evaluated than in the state; the same was evident for the diagnosis of "wasting" that is fifteen times more prevalent in Tochimilco than at the state level.

The national average for the rural sector was taken for comparison, as Tochimilco is a municipality where most of its localities are rural (INEGI, 2017) and there is a vulnerable population (indigenous, socially backward, marginalized) (Secretaría de Bienestar, 2022). Even so, according to the Nutrition Survey (Shamah-Levy *et al.*, 2020), malnutrition at the national level is lower than that shown in our results, as the percentage of underweight girls and boys here is four times higher than the national average; and infant stunting is twenty percentage points higher in the municipality and seven times higher for the wasting diagnosis.

Analysis of this information requires focusing on the height-for-age indicator, as height was often shown to be below the height considered ideal for the age of each boy and girl; similarly a diagnosis of low height for age was very common. This concurs with the results from various evaluations at the national and international level, which report that stunting is the most common manifestation of malnutrition, evident among children under five years of age (National Institute of Public Health INSP, 2020; Shamah-Levy *et al.*, 2020; UNICEF, 2018). Likewise, this represents quite a dangerous condition as it indicates chronic malnutrition; a state of nutrient deficiency suffered over a considerable time period, resulting in growth deterioration, preventing the boy or girl from reaching their potential height (Burgos *et al.*, 2017; Solomons and Soto-Méndez , 2017).

This research concurs with Bernabeu and Sánchez-Ramírez (2019), who reported a fairly similar prevalence of chronic malnutrition (31.1%) in preschool girls and boys in rural areas of Colima, Mexico; although apparently the data on acute malnutrition differ by a large number of percentage points, as these researchers found only 2.2% of low weight among their population. The observed low weight of the study population may be an alarm signal that needs to be addressed urgently, to avoid chronic malnutrition and greater future damage to the health of the infant population.

The above data corroborate the economic and social inequality of families in a context of deprivation, while also highlighting the vulnerability suffered in this environment, as hunger and food insecurity prevail among the majority of the population, in addition to being a latent danger (Sánchez and Gómez, 2015). This occurs, above all, due to the social deficiencies that family units deal with, such as lack of drinking water, drainage system, poor quality housing, health care availability, etc. promoting social backwardness, vulnerability and malnutrition (UNICEF *et al*., 2020; Ávila-Curiel *et al*., 1998). The negative consequences on nutritional status are observed mostly in rural girls and boys (Ávila-Curiel *et al*., 1998), which entails serious risks to their health, education and economy, both now and in future life stages (Solomons and Soto-Méndez, 2017). Although for now no harmful consequences of malnutrition were found in the majority of diagnosed children, this may already exist at an organic level and if nutrient deficiency continues, it may cause serious damage to health (Burgos *et al*., 2017; Solomons and Soto-Méndez, 2017) and in social aspects (UNICEF *et al*., 2020; Fernández *et al*., 2017). For this reason, it is necessary to take appropriate measures to prevent future harm and improve the quality of life of girls and boys at this moment. The younger the age at which nutritional intervention is carried out, the more growth potential will be achieved, as the WHO (2006) considers that all girls and boys under five years of age have the same opportunities for growth and development, provided they live in a context where conditions are similar and of course, appropriate. This is also the case among indigenous populations, who can reach their growth potential, as long as they have an adequate and complete diet (Ávila-Curiel *et al*., 1998).

Regarding overweight and obesity, this only occurred for half of the cases that exist in Puebla (INSP, 2020), in a study in Colima (Bernabeu and Sánchez-Ramírez, 2019) and at the national level (Shamah-Levy *et al*., 2020). However, overweight/obesity type malnutrition is not prevalent in the population studied; no case was found where chronic malnutrition and obesity coexist, as in the study by Apaza-Romero *et al*. (2014) carried out in Peru, where they confirmed the existence of this double burden of malnutrition. The groups most at risk are male children (Bermúdez *et al*., 2020) and also inhabitants of the rural sector (Apaza-Romero *et al*., 2014); however in Tochimilco, this complication has not yet been identified, as the positive correlation between height and weight, similar to that found by Bermúdez *et al*. (2020), provides guidelines for implementing prevention strategies to prevent overweight and obesity, whilst also helping propose other strategies to combat low weight, in order to reduce the danger of low height in the future.

Malnutrition is known to represent a multifactorial public health problem (UNICEF *et al*., 2020; Solomons and Soto-Méndez, 2017; Beltrán and Seinfeld, 2011); however in this research, nutritional diagnoses were apparently not influenced by sex or age, although they were influenced by the type of location: rural or urban (INEGI, 2017). This differs from studies that report that sex influences nutritional status, showing those with the worst nutritional status are women (Bernabeu and Sánchez-Ramírez, 2019; Beltrán and Seinfeld, 2011); although contrarily, Bermúdez *et al*. (2020) reported delayed growth occurring more often in males than in females; they also mentioned that the months of life influence the weight-for-height and height-for-age indicators, whereas in the research by Akimul Islam *et al*. (2018) its influence on the average upper arm circumference was found. It is advisable to take the results of the present study with reservation, because the sample size is small, probably explaining why similar associations to other investigations were not found.

Regarding the determinants of infant malnutrition, there were also few relationships between the variables related to nutrition and the social, economic and environmental factors of the family units. However, in the description of the environment where the girls and boys of Tochimilco grow up, similarities were found with Bermúdez *et al*. (2020), regarding level of education and socioeconomic stratum, both were low, presence of indigenous ancestry, communal availability of drinking water, lack of drainage and sewage disposal. Likewise, it was observed that the number of inhabitants per home is higher in rural localities and per capita spending on food is lower, which can increase the economic vulnerability of families and result in malnutrition among minors (UNICEF *et al*., 2020; Beltrán and Seinfeld, 2011). Although it is difficult for salaries to increase and with them the family investment in food, the goal may be to expand the production and diversification of backyard food. In this research it was reported that the majority of the population buys their own food, however backyard family gardens would increase the quantity and quality of food consumed, without the need to increase expenses per capita.

In the case of the influence of type of location on nutritional status, it is a highly studied relationship due to the implications this has on the quality of life and well-being of families. In the current research, a relationship was found with the weight of girls and boys, which coincides with some reports on the greater risk that these rural communities present, unlike urban ones, concerning the issue of child malnutrition (Bermúdez *et al*., 2020; Shamah-Levy *et al*., 2020; UNICEF, 2015). To further specify this point, Bermúdez *et al*. (2020) affirm that inequalities between sectors (urban and rural) "strongly limit human, social, structural and economic development", and they also propose education and the guarantee of access to food to permanently impact the diet of the population.

The study area has similar generalized conditions, which occur mostly in the rural sector and it is likely that these similarities will help make further investigations more profound and implement a strategy focused on rural deficiencies. Only actions which increase equality can help contribute to the eradication of rural malnutrition (Keats *et al*., 2020), as well as many policies and actions that focus on this environment, as this is where there is most vulnerability, 2015; Fernández *et al*., 2017).

In this study, no relationships were obtained between the family context, the infrastructure of the family unit or the availability, access and stability of food with nutritional status, although in other investigations (Bermúdez *et al*., 2020; Bernabeu and Sánchez -Ramírez, 2019; Akimul Islam *et al*., 2018) it has been shown that living conditions, family, community and social context are inherent to the nutritional status of girls and boys (Sánchez and Gómez, 2015; UNICEF *et al*., 2020). However, it is necessary to highlight some factors that were important concerning the nutritional status of girls and boys. It was found that secondary education is associated with height; in fact, it is one of the most important determinants of infant malnutrition (UNICEF *et al*., 2020; Akimul Islam *et al*., 2018; Beltrán and Seinfeld, 2011).

Likewise, it was confirmed that government support, whether in the form of cash transfers, food supplies or other types of programs, is important to reduce the risk of the population suffering from malnutrition and to maintain normal weight (Keats *et al*., 2020; Grellety *et al*., 2017; Galicia *et al*., 2016). The personal and hereditary history of girls and boys also represent factors affecting childhood malnutrition, for example birth weight, type of delivery, history and current status of the mother, etc. (Ber-nabeu and Sánchez-Ramírez, 2019; Akimul Islam *et al*., 2018; Beltrán and Seinfeld, 2011); however, in this investigation, no direct relationship between these variables and current nutritional status was found.

Questions related to nutrition in the stages of younger and older infants provide surprising answers; it was found that the consumption of milk formula leads to better nutritional health in girls and boys, in contrast to research that highlights the protective role of breastfeeding on nutritional status, immune system, future pathologies, mortality, etc. (Keats *et al*., 2020; UNICEF *et al*., 2020; WHO, 2014). Consumption of milk formula in the first months of life is already customary among the rural and indigenous population (Regalado-Vázquez *et al*., 2021) and throughout a large part of the world and national population (Shamah-Levy *et al*. , 2020; Vásquez-Ruiz *et al*., 2020), due to the unlimited marketing launched decades ago, whose effects continue to affect maternal and child health; however thanks to recent research and current public policies, it is known that exclusive breastfeeding brings greater benefits at an anthropometric, biochemical, immunological, intestinal, social, ecological, political, etc. level. (UNICEF *et al*., 2020; Vásquez-Ruiz *et al*., 2020; WHO, 2014); even though in this analysis, opposite results were found for this variable.

The probable explanations for this phenomenon are in the use of a bottle, the main vehicle for the milk formula, as those who used a bottle also have better anthropometric measurements and because the milk formula contains macronutrients that cause weight gain in infants, it modifies the number and architecture of adipocytes and provides the requirements to maintain adequate longitudinal growth. However, it is necessary to clarify that there comes a point where this does not contain the sufficient amount of minerals, vitamins and trace elements or the necessary immunoglobulins, in addition to the social, economic, emotional and cognitive implications that are curtailed or diminished (Regalado-Vázquez *et al*. , 2021; Vásquez-Ruiz *et al*., 2020; WHO, 2014). Likewise, the explanation that emerges is that ideal

practices for exclusive breastfeeding and maternal food may be lacking, thus indicating the need to improve the mother's diet in order to provide the micronutrients, immunoglobulins and trace elements that can only come from breast milk (Regalado-Vazquez *et al*., 2021; UNICEF *et al*., 2020; Vásquez-Ruiz *et al*., 2020).

Another element that contributes to the explanation of the phenomenon seen in this research is the process of introducing new foods, called complementary feeding, an activity whose initiation is recommended at around six months of age (Vásquez-Ruiz *et al*., 2020; WHO, 2014); this variable was not recorded in this study, thus limiting analysis. However, from the questions applied, it can be inferred that the PCFs are not trained in nutrition and complementary feeding, which can negatively affect their offspring; Vásquez-Ruiz *et al*. (2020) report that the introduction of complementary feeding must also have adequate mandatory practices to avoid the risk of nutritional deficiency during this period, so it is necessary to evaluate the time of introduction of new foods, as delaying this process runs the risk of causing malnutrition.

This research confirmed that dietary education offers a great tool for improving the nutritional condition of preschoolers in the locations studied, as eating habits are not healthy and the quality of the food consumed does not cover the recommendations for the population age-group. Unfortunately, that found in the present study shows that does not reflect the traditional healthy diet, typical of rural areas some years ago, as described by García-Chávez *et al*. (2017). In their study they found a dietary pattern in rural areas based on corn, tortillas, legumes and whole grain cereals, which provides high fiber consumption and low energy and fat consumption, contrary to the eating pattern that includes processed and ultra-processed foods (García -Chávez *et al*., 2017); contrarily, our research found a high consumption of processed and ultra-processed products; which seems to be an inevitable transition from the traditional diet to an industrialized one (García-Chávez *et al*., 2017).

This implies that they allocate a certain part of their spending to buying "cheap" products, which being of poor quality, their price is affordable and they are available close to home; furthermore, these products do not require preparation and children do not need help to eat them (García-Chávez *et al*., 2017). These factors are strong enough to influence the purchase of products instead of harvesting the crops in their gardens and preparing a dish. The research did not include questions about the impact of marketing on food selection; however, García-Chávez *et al*. (2017) affirm that the context of minors, such as the products offered at school or nearby, have an impact on the selection of foods and products. Therefore, education for a healthy diet and lifestyle is essential to improve the nutritional status of the children of Tochimilco. Finally, these findings contribute to the planning of regional strategies, programs and actions that improve the nutritional status of girls and boys in predominantly rural conditions, with social and nutritional deficiencies and poor nutritional knowledge.

CONCLUSIONS

The child population of Tochimilco is at high risk of suffering from the negative effects of malnutrition, entailing serious present and future consequences on their health, as

well as on community and social life. Although there are multiple determinants of this condition, in the municipality studied, personal history in terms of physical health does not predominate, so it becomes even more important to evaluate their personal and family diet, as well as their life style habits in detail, so as to create a plan that follows an individual approach, without avoiding the cultural aspect. It is extremely urgent to implement a strategy to combat the low weight of the preschool population, as the high rates found can lead to chronic malnutrition, malnutrition with negative implications for the family and the region.

Likewise, the characteristics of the context, identified as external determinants of the social level, are not, for the most part, definitive factors in child nutrition, but they can form part of a line of action to promote decent living conditions among families and thus improve their quality of life and health-nutrition; it is necessary to improve housing infrastructure, as well as services, increase government support, reinforce gender equality, improve medical care in localities, increase family food production, improve education levels and provide quality training to those in charge of family care in matters of breastfeeding, complementary feeding, family nutrition and reproductive health.

Promoting a state of equality between urban and rural localities, will improve the living conditions, habits, food and nutrition of families and, especially, of girls and boys at risk. To collect more relevant information about the context and nutritional status of girls and boys, it is necessary to include a larger population in the study with different geographical locations; as the sample size was small when compared with the preschool population that lives in the municipality, and with the state and national population that live in similar living conditions. The study is limited in terms of area and could not be applied in regions with very different characteristics; on the contrary, the information presented here is the basis for the implementation of very local strategies, focused on the deficiencies and problematic situations found in this municipality; most of the surrounding municipalities are in a comparable situation; meaning this could also be applied to other similar regions.

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