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| RESEARCH ARTICLE

The Incidence of Micronutrient Intake on Cognitive Development in Children Under 5 Years of Age: A Cross-sectional Study for the Ecuadorian Case

Zoila Moreira-Moreira[1] ✉ Ana Quimbiulco-Martínez[2] and Christie Troya-Pintado[3]
[1]Medical Doctor, Ministerio de Salud Pública, Hospital General Miguel Hilario Alcivar, Manabí, Ecuador
[2]Medical Doctor, Ministerio de Salud Pública, Coordinación Zonal2, Centro de Salud Pano, Tena, Ecuador
[3]Medical Doctor, Kursk State Medical University, Kursk, Rusia
Corresponding Author: Zoila Moreira-Moreira, **E-mail**: scienceacrev@gmail.com

| ABSTRACT
Analyzing the relationship between micronutrient powder intake from 6 months of age and cognitive development in children contributes significantly to the literature since nutritional status is one of the determinants of health and cognitive and psychosocial development in early childhood. Malnutrition at these stages may cause imbalances between nutritional needs that could lead to malnutrition and influence cognitive development. We used a representative sample of 3877 children aged 3-5 years from the 2018 National Health and Nutrition Survey (ENSANUT). We used a linear regression and binary logistic regression model where we estimated the Odds Ratio (OR) and marginal impacts with their 95% confidence intervals (95% CI) for each of the independent variables. Our results show that the odds ratio (OR) associated with the micronutrient intake variable is significant and greater than 1. This demonstrates that a child who consumes micronutrient powder between 6 months and 2 years of age is approximately 1.56 times more likely (CI=1.35- 1.85) to have high cognitive development. In addition, boys are more likely to have higher cognitive development, with an OR of 1.592 (CI=1.341- 1.978). Another important finding is that a greater number of siblings at home reduces 1.032 times the probability of having high cognitive development. Our data also reveal that the mother's age (very young) may decrease the risk of high cognitive development, while the number of hours of play causes an opposite effect, as the OR reveals that children with a higher number of hours of play are 1.68 times more likely to have high cognitive development. Based on our findings, we can determine that it is important to explore the neurodevelopmental processes that may be involved in malnutrition. Thus, in this article, we recommend the importance of micronutrient intake and a balanced diet as key factors for proper cognitive development.

| KEYWORDS
Micronutrients, deficiency, cognitive impairment, psychomotor development, nutritional status

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1. Introduction

Childhood is considered a transcendental stage in the evolutionary process of the human being, characterized mainly by two phenomena: growth and development. In order for these phenomena to occur normally, adequate nutrition is essential.(Ugarte and Cordova, 2021).. The World Health Organization (WHO) defines malnutrition as the lack of nutrients that delays the normal development of children under 5 years of age (Bedoya & Avila, 2014). Child malnutrition is considered one of the main public health and social welfare problems in Latin America; because it is one of the main causes of preventable death and morbidity among children in Latin America; it is also related to the lack of social, economic, political health determinants (Kac & García Alvear, 2010).

According to WHO, in 2016 worldwide, it was estimated that 52 million children under 5 years of age presented a state of wasting, 17 million suffered from severe wasting, and 155 million suffered from stunting, about 45% of deaths of children under 5 years of age are related to malnutrition, mostly recorded in low and middle-income countries (Alvarado, 2019). In Latin America, it has been recognized that about 25% of children under 5 years of age are undernourished.. Nowadays, there is greater awareness regarding the importance of nutrition in Ecuador, as child nutrition has an impact on children's developmental outcomes(Francke et al., 2020a).. In this regard, Ecuador, as a middle-income country, has a high level of malnutrition, with an estimated 25% of the population of children under 5 years of age suffering from malnutrition. Although a decrease in the figures can be identified, however, its level of malnutrition is close to double the average in Latin America. (Rivera, 2019)..

Nutrition is a process that begins at conception, and it depends on the survival of the human species and the development of its potential; it is closely related to the cerebral and cognitive development of the human being (Ocaña and Sagñay, 2020). Childhood is the stage of life where most changes occur, both physical and intellectual, and therein lies the importance of infant nutrition. Proper nutrition during the first years of life is an important factor in achieving proper child growth and development. If, at this age, children are provided with all the nutrients they need with proper eating routines and a healthy lifestyle, they will grow up healthy reducing the possibility that children may suffer certain pathologies such as nutritional disorders, anemia, overweight or obesity. (Verdezoto, 2019).

Poor nutrition over long periods is mainly reflected in growth retardation and is associated with poor socioeconomic conditions, poor maternal nutrition and health, and inappropriate infant and young child feeding or care. In addition, it is believed that nutrient deficiency experienced over the long term can manifest itself in short stature and can cause irreversible damage to brain development, preventing children from fully developing their physical and cognitive potential(Cuevas-Nasu et al., 2021)..

Insufficient intake of vitamins and minerals (micronutrients) does not allow the body to produce sufficient enzymes, hormones and other substances essential for growth and growth.(Francke et al., 2020a).. Micronutrients, which are necessary vitamins and minerals in small amounts, are essential for a good start in life and optimal growth and development. In particular, iron and vitamin "A" play a key role in maintaining healthy and productive populations. With them, children under 5 years of age have the opportunity for normal, healthy growth and to become productive adults. Without these micronutrients, human beings can lose the potential for life, becoming ill and dying (MSP, 2011). With micronutrient supplementation, it was observed that children from three months to five years of age had small gains in weight (0.24 kg per year) and height (0.54 cm per year) and moderate increases in hemoglobin(Aid, 2019). The percentage of households consuming micronutrient Chispaz in 2014 was 24%. This percentage has been increasing to between 41% and 43% in the 2015-2017 period. (MSP, 2018) .

Children who are malnourished and who present vitamin and mineral deficiencies in the first years of life are exposed to greater risks of death during childhood and of morbidity and malnutrition throughout the life cycle, limiting their potential physical and intellectual development and restricting their capacity to learn and work in adulthood, thus limiting opportunities for professional and economic development, which contributes to perpetuating the cycle of poverty.(Jara Navarro, 2008). Hunger and malnutrition hinder the achievement of all the Millennium Development Goals, not only because of their impact on poverty but also because they have repercussions, among many other aspects, on health, education and mortality. Countless studies and research show important evidence of the causal and associative relationships and interrelationships between hunger and undernutrition, on the one hand, and poverty, on the other, as well as revealing how hunger and undernutrition undermine school attendance and learning and hinder access to markets and resources, maternal and child health, the immune system, education and employment for women and girls (Riumalló et al. (Riumalló et al., 2004)..

This background shows the importance of nutrition in the health of the population, a responsibility that falls on the health sector, which, due to its relevance, is responsible for implementing programs aimed at reversing these problems. (MSP, 2011.)In this context, the country has a historical debt translated into the challenge of chronic malnutrition, which has been linked to the deep social inequality and economic problems that generally affect the population with greater poverty and adverse living conditions(Manosalvas & Manosalvas, 2019).. For this reason, the elaboration of the Intersectoral Plan for Food and Nutrition Ecuador, 2018-2025, was proposed in order to analyze the main nutritional problems and their respective solutions. The delivery of micronutrient supplementation to children aged 6 to 24 months was established. The administration of sixty sachets of Chis Paz optimally, in sixty days, one sachet per day, is sufficient to rapidly improve hemoglobin concentrations and iron stores in a large proportion of infants and young children. After ingestion of 60 sachets, hematological benefits are maintained for a period of six months (MSP, 2018).

Micronutrient interventions have received much attention internationally, as it is considered a cost-effective strategy in terms of cost-benefit. Based on these considerations, the Ecuadorian state, through the Ministry of Public Health, has implemented, during the last few years, some supplementation programs for children through the "Chis Paz" of micronutrients. Therefore, the present

research seeks to answer the following question: Does the delivery of micronutrient sachets have an impact on the reduction of chronic child malnutrition?

2. Methodology

2.1 Survey and Population

A cross-sectional study was conducted with data obtained from the 2018 National Health and Nutrition Survey of Ecuador (ENSANUT), whose data were obtained and presented by the National Institute of Statistics and Census (INEC). After cleaning the database, a total of 3877 Ecuadorian children under 5 years of age were obtained.

2.2 Source of Information

The ENSANUT 2018 is a survey included in the National Statistical Program that employs probability sampling applied every 5 years and whose target population is all household members in the 24 provinces of Ecuador. The ENSANUT 2018 includes the form Household in section 7: Anthropometry for all persons in the household.

2.3 Study Variables

Our dependent variable of interest is the cognitive development of the children. The information for this variable was obtained through 11 questions detailed in Table 1: Did you ever attend a CIBV/ CDI Child Development Center or day care center, Did you ever receive assistance from CNH educators in your home, With whom do you spend most of your time Monday through Friday, Can you identify or name at least ten letters of the alphabet, Can you read at least four simple, common words, Can you recognize the symbol for numbers from 1 to 10 and know their names, Can you pick up a simple, common object, and can you read at least four simple, common words, Can he/she read at least four simple, common words, Does he/she recognize the number symbols 1-10 and know their names, Can he/she pick up a small object with two fingers, such as a stick or a stone from the floor, Does he/she sometimes feel tired/discouraged with no desire to play, Can he/she follow simple instructions on how to do something correctly, When given something to do, can he/she do it on his/her own, Is he/she easily distracted, Does he/she get distracted easily

Our independent variable of interest is the consumption of micronutrients. For this variable, we use the question: In the last 12 months, (...) Did you receive from the health personnel iron powder as micronutrients (sparks) to prevent anemia? This question reveals whether or not a mother consumed micronutrients during pregnancy.

2.4 Inclusion and Exclusion Criteria

The working universe was considered to be children under 5 years of age, whose anthropometric measurements were reported in the Home form of the 2018 ENSANUT survey. All children with normal and high weight were excluded, i.e. all children above the 5th percentile.

2.5 Statistical Analysis

The ENSANUT 2018 survey database was analyzed with the statistical package Stata v15 (Stata Corporation, College Station, Texas, USA). A value of $p<0.05$ was considered to determine statistical significance between variables. The Chi-square test was used to determine the overall correlation between the variables of interest. The association was evaluated using prevalence ratios with their respective 95% confidence intervals with an analysis for each of the variables included in the study, with the independent variable being

In this context, taking into account the models used in previous works, this study uses a logit model to define how micronutrient intake impacts the cognitive development of Ecuadorian children. Thus, the model would have the following general form:

$$\Pr(Y = 1|X) = F(\alpha + X_i + e_i) \quad (1).$$

$$\Pr(Y = 0|X) = 1 - F(\alpha + X_i + e_i) \quad (2).$$

Where we study the probability that a child is malnourished or not (Y = 1 if malnourished and Y = 0 otherwise) according to a series of determinant variables (X: explanatory variables), which are specified in Table 2, the logit model assumes that the cumulative distribution function for the error term is normally distributed in the form Φ(-), this means that the probability of high cognitive development (in our case) can be defined as: $\Pr[\text{high cognitive development}_{kj} = 1] = \Phi[\text{high cognitive development}]$. This model estimates the parameters by maximizing the value of the log likelihood function, which is defined as:

$$\text{LogL}(\theta) = \sum_{k=1}^{k} LogP_{kj}(\theta) \quad (3).$$

Where $\theta = (\beta, \delta, \gamma, \sigma)$ and $P_{kj}(\theta) = \Pr(\text{high cognitive development}_{kj} = 1)^{\text{high cognitive development}_{kj}} * [1 - \Pr(\text{high cognitive development}_{kj} = 1)]^{1-\text{alto } desarrollo\ cognitivo_{kj}}$. The parameters are estimated using the maximum likelihood (ML) procedure. Therefore, in order to estimate a discrete choice model that estimates the probability of high cognitive development:

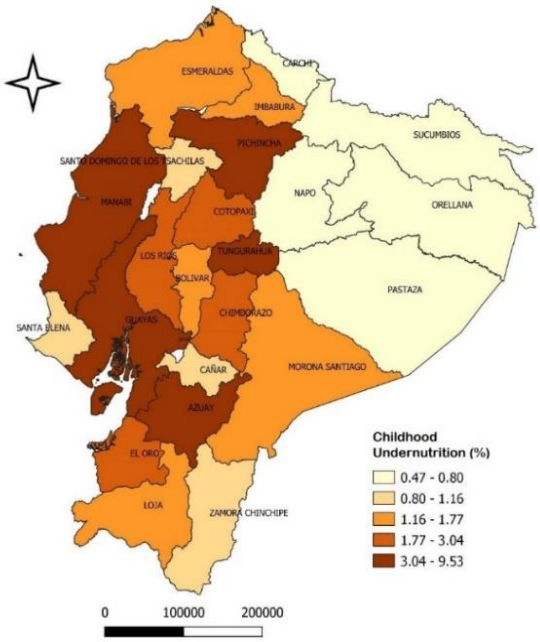
$$CD_i = \beta_0 + \beta_1 X_i + \sum_{j=2}^{12} \beta_j Z_i + \varepsilon_i \quad (4).$$

Where CD_i represents whether a child has high cognitive development (measured through the question of whether a child has high or low cognitive development), X_i represents the micronutrient intake variable, and Z_i represents a set of control variables of the linear regression model. Finally, ε_i represents the stochastic error term.

3. Results

First, to give importance to the case study, **Figure 1** shows the spatial distribution of child malnutrition. This is because the problem of malnutrition is more evident in some regions than others. In general, the provinces with a more intense color are those with a higher percentage of child malnutrition. This fact shows that child malnutrition mainly affects the provinces of the Ecuadorian Coast and Highlands. Therefore, micronutrient nutrition policies should focus on those regions with the highest prevalence of malnutrition.

Figure 1. Spatial distribution of child malnutrition in Ecuador.



To meet our research objective, we specifically used 11 items from the questionnaires and considered that cognitive development is a multidimensional concept, and used principal component factor analysis (PCA) to ensure that the items can be grouped into one factor dimension. Through PCA with a varimax rotation, we obtained 1 eigenvalue greater than 1. Therefore, we confirmed that we could explain the index of cognitive development through a one-dimensional index, where the factor loadings of each variable have the greatest weight in their respective dimension, and these explain 78% of the variance. The questionnaire questions and their initial coding in the questionnaires are presented in **Table 1.** Our index of cognitive development was standardized in such a way that we obtained a number between 0-1, where a number closer to 1 means greater cognitive development. To standardize our index to a number between 0-1, we followed the following procedure:

$$Standarized\ index = \frac{(X_i - X_i min^{sample})}{(X_i max^{sample} - X_i min^{sample})}$$

Where X_i is the factor value for individual i, $X_i min^{sample}$ is the minimum factor value for individual i in the entire sample and $X_i max^{sample}$ is the maximum factor value for individual i in the entire sample.

Subsequently, following the traditional literature, we dichotomize our index of cognitive development in such a way that we can simplify our analyses. All children with a cognitive development index of ≤ 0.79 (median index) were considered as children with low cognitive development, while children with an index >0.79 were considered as children with high cognitive development. We coded all children with high cognitive development as 1 and all children with low cognitive development as 0.

Table N°1: ENSANUT questions and coding

ENSANUT question	**Codification**
(...) Did you ever attend a CIBV/ CDI Child Development Center or daycare center?	0=No/1=Yes
(...) DID YOU EVER RECEIVE assistance from CNH educators in your home?	0=No/1=Yes
WITH WHOM do you stay (...) most of the time from Monday to Friday?	0=No/1=Yes
Can (...) identify or name at least ten letters of the alphabet?	0=No/1=Yes
Can you (...) read at least four simple, common words?	0=No/1=Yes
Do you recognize (...) the symbol for the numbers 1 to 10 and know their names?	0=No/1=Yes
Can (...) pick up a small object with two fingers, such as a stick or a stone from the floor?	0=No/1=Yes
Do you sometimes (...) feel tired/ discouraged and don't feel like playing?	0=No/1=Yes
Can (...) follow simple instructions on how to do something correctly?	0=No/1=Yes
When given something to do, can he/she (...) do it by him/herself?	0=No/1=Yes
Are you easily distracted (...)?	0=No/1=Yes

Table 2 shows the results of the validity and reliability tests. Here we observe that the total number of items is 11; moreover, the average inter-item correlation is 0.621. That is, we observe that there is a high correlation between the 11 items, so we can see that the items are highly correlated and explain our index in a good way. Crombach's alpha also shows an acceptable level since it presents a value of 0.712. The Kayser Meyer Olin (KMO) statistic shows a high level. The KMO takes values between 0 and 1, and small values indicate that, in general, the variables have too little in common to justify a PCA analysis. In our case, we observed that our 11 items considered for analysis have a lot in common. We also note that Barlet's test is significant, indicating that the items are good measures for constructing the index of cognitive development.

Table N°2: Results of the sample reliability and validity test.

Test				**Cognitive development index**
Number of items				11
Average interitem correlation				0.621
Cronbach's alpha				0.714
Kayser Meyer Olin measure (KMO)				0.801
Bartlett's test		Chi square		3.47e+05
		df		20
		Sig.		0.000

Table 3 shows the results of the factor loadings from the principal component analysis. Here we can observe each of the items used to construct our index of cognitive development. We observe that the factor loadings are high, meaning that each item contributes significantly to the constructed index. Furthermore, we observe that all our 11 items explain 81% of the variance, suggesting that our index has a large variance explained through each item used to construct it.

Table N°3: Results of the principal component analysis.

KMO= 0.801 **Variable**		**Cognitive Development Index**
(...) Did you ever attend a CIBV/ CDI Child Development Center or day care center?		0.723
(...) DID YOU EVER RECEIVE assistance from CNH educators in your home?		0.899
WITH WHOM do you stay (...) most of the time from Monday to Friday?		0.850
Can (...) identify or name at least ten letters of the alphabet?		0.825
Can you (...) read at least four simple, common words?		0.723
Do you recognize (...) the symbol for the numbers 1 to 10 and know their names?		0.899
Can (...) pick up a small object with two fingers, such as a stick or a stone from the floor?		0.850
Do you sometimes (...) feel tired/ discouraged and don't feel like playing?		0.825
Can (...) follow simple instructions on how to do something correctly?		0.745
When given something to do, can he/she (...) do it by him/herself?		0.882
Are you easily distracted (...)?		0.695
Variance explained		*81%*

Table 4 presents the descriptive statistics of the variables used in this study. Here we observe that the average index of cognitive development is 0.79 on a scale of 0 to 1. Regarding micronutrient intake, 82% (CI=79.52%-84.52%) of the mothers reported that their child consumed micronutrients up to two years of age. We also observed that 28.55% (CI=25.55%-30.55%) of the children in our sample reported suffering from obesity. This is a significant percentage. Our data also reveal that 53.33% (CI=50.33%-55.33%) of children are male. The number of siblings at home is 4, and our data show that the number of hours the child is exposed to TV is 4, and the average number of hours playing is 3. This would indicate that, on average, an Ecuadorian child spends more time exposed to TV than playing. On the other hand, 75.61% of the mothers are of mestizo ethnicity, while the average number of prenatal controls is 7 and 55.61% (CI=52.51%-57.51%) of the mothers reported having had a normal delivery.

Table N°4: Descriptive statistics of the variables used in this study

Variable	N	Mean-Percent	SD	Min	Max	95% CI		
Cognitive development								
Low cognitive development	616	15..89%	0.44	0	1	15.02%	-	16.77%
High cognitive development	3261	84.11%	0.89	0	1	83.17%	-	85.43%
Did you consume micronutrients until the age of two?								
No	677.70	17.48	0.89	0	1	14,48%	-	19,48%
Yes	3199.30	82.52%	0.67	0	1	79,52%	-	84,52%
Obesity								
No	2770.11	71.45%	0.12	0	1	68,45%	-	73,45%
Yes	1106.89	28.55%	0.43	0	1	25,55%	-	30,55%
Child's age								
Age	3877	3.8	0.12	3	5	3.13	-	4.22
Sex of child								
Woman	1809.39	46.67%	0.14	0	1	43,67%	-	48,67%
Man	2067.61	53.33%	0.33	0	1	50,33%	-	55,33%
Siblings at home								
Number of siblings at home	3877	4.12	0.25	0	8	4.01	-	4.98
Hours of TV watched by the child								
Number of hours watching TV	3877	4.01	0.67	0	5	3.68	-	4.49
Child's hours of play								
Number of hours of play	3877	3.08	0.54	1	6	2.97	-	3.96
Do you think a child should be punished?								
No	2692.57	69.45%	0.66	0	1	66,45%	-	71,45%
Yes	1184.43	30.55%	0.26	0	1	27,55%	-	32,55%
Mother's age								
Age	3877	34.78	0.55			31.54	-	36.86
Mother's ethnicity								
Indigenous	571.08	14.73%	0.35	0	1	14.26%	-	15.20%
Afro-Ecuadorian	156.24	4.03%	0.20	0	1	3.77%	-	4.29%
Mongrel	2931.39	75.61%	0.43	0	1	75.04%	-	76.18%
White	51.17	1.32%	0.11	0	1	1.17%	-	1.47%
Montubio	167.09	4.31%	0.20	0	1	4.04%	-	4.58%
Prenatal checkups								
Number of prenatal checkups	3877	7.01	0.25	1	28	4,01%	-	9,01%
Type of delivery								
Normal delivery	2152.12	55.51%	0.54	0	1	52,51%	-	57,51%
Cesaria	1724.88	44.49%	0.36	0	1	41,49%	-	46,49%

Subsequently, we performed a correlation matrix to perform a detailed analysis of the correlation between the variables and to highlight possible multicollinearity problems. **Table 5** shows significant correlations between cognitive development and the independent variables: Obesity, child's sex, number of siblings at home, number of hours watching TV, number of hours playing, should a child be punished, mother's age, micronutrient intake, and number of prenatal controls. All these variables have an expected sign which is correct. In addition, we note that no correlation between the independent variables is greater than 50%. This shows that there are probably no serious multicollinearity problems among the variables. Below we perform a formal test to test for multicollinearity among the variables.

Table N°5: Correlation matrix of the variables

	Var 1	Var 2	Var 3	Var 4	Var 5	Var 6	Var 7	Var 8	Var 9	Var 10	Var 11	Var 12	Var 13
Var 1	1												
Var 2	-0.2041*	2											
Var 3	0.1089	0.0091	2										
Var 4	-0.0826*	0.0739*	-0.0023	2									
Var 1	-0.2102*	0.0481*	-0.0041	-0.0226	2								
Var 6	-0.0840*	0.0307*	0.0046	-0.0229	0.6226*	2							
Var 7	0.0223	0.0394*	-0.0014	0.0024	0.0220*	0.0212*	2						
Var 8	-0.0276*	0.3322*	0.0062	0.0227*	0.0689*	0.0787*	0.0489*	2					
Var 9	-0.0468*	0.0018	0.0073	0.0000	0.0224	0.0248*	0.0147*	-0.0697*	2				
Var 10	0.0726*	0.4734*	0.0022	0.0129*	-0.0681*	-0.0444*	-0.0472*	0.2700*	-0.2847*	2			
Var 11	-0.0393	-0.0979*	0.0080	0.0074	-0.0207*	-0.0267*	-0.0782*	-0.0228*	-0.2026*	0.2239*	2		
Var 12	0.0198*	0.0132*	0.0099	-0.0440*	0.0229*	0.0287*	0.2291*	0.2234*	0.2420*	-0.3042*	-0.2964*	2	
Var 13	0.0087	0.0148*	-0.0007	0.0021	-0.0223	-0.0022	0.0129*	0.0061	0.2222*	-0.2198*	-0.2992*	0.3082*	2

Note: Var 1: Cognitive development index. Var 2: Obesity. Var 3: Child's age. Var 4: Sex of child. Var 5: Number of siblings at home. Var 6: No. of hours watching TV. Var 7: N. hours of play. Var 8: Should a child be punished? Var 9: Age of mother. Var 10: Micronutrients intake. Var 11: Mother's ethnicity. Var 12: Number of prenatal checkups. Var 13: Type of delivery. Asterisks mean: *p < 0.05.

As mentioned above, we performed a formal test to rule out the presence of multicollinearity among our independent variables. In **Table 6,** we present a multicollinearity analysis. We use the Variance Inflator Factor (VIF) to perform this test. Previous literature indicates that a VIF greater than 5 can demonstrate that there is multicollinearity in our data. As we can see, no variable presents a VIF greater than 5; therefore, we discard multicollinearity problems in our independent variables. This analysis is important since multicollinearity problems cause instability of the parameters of a regression, incorrect signs and higher standard errors, which translates into statistical insignificance of the parameters.

Table N° 6: Multicollinearity test for the variables

Variable	**VIF**	**SQRT VIF**	**Tolerance**	**R-Squared**
Micronutrient intake	1.25	1.55	0.9433	0.3305
Obesity	132	1.11	0.9966	0.0004
Child's age	1.01	1.54	0.9918	0.0082
Sex of child	1.77	1.28	0.6101	0.3899
N. of siblings at home	1.88	1.28	0.6145	0.3855
N. of hours watching TV	1.97	1.01	0.9764	0.0236
N. hours of play	1.45	1.06	0.8821	0.1179
Should a child be punished?	1.66	1.05	0.8812	0.1188
Mother's age	1.58	1.45	0.6310	0.3690
Mother's ethnicity	1.29	1.14	0.7746	0.2254
N. of prenatal checkups	1.17	1.08	0.8583	0.1417
Type of delivery	1.05	1.05	0.9537	0.0463
Mean VIF	1.49			

Table 7 below shows a multivariate logistic regression analysis to analyze the factors that influence cognitive development. Our logistic regression involves 3877 children aged 3 to 5 years. Here we observe that the dependent variable is the index of cognitive

development constructed weighted across 11 variables described above. Our results show that the consumption of micronutrients up to two years of age increases the probability of having high cognitive development by 1.57 times (OR= 1.57, CI= 1.354-1.853). We also show that the odd ratio (OR) associated with the obesity variable is significant and greater than 1 (with a negative sign). This shows that a child with obesity is approximately 2.01 times less (CI=-1.986- -2.321) likely to have high cognitive development. Another significant OR is associated with the child's sex variables with an OR of 1.592 (CI=1.341- 1.978), showing that males are more likely to have high cognitive development. Likewise, a greater number of siblings at home reduces the probability of having high cognitive development by 1.032 times. Our data also reveal that a greater number of hours in front of the TV could reduce the risk of high cognitive development, while the number of hours of play causes an opposite effect, as the OR reveals that children with a greater number of hours of play are 1.68 times more likely to have high cognitive development. We also evidenced that parents who answered that they believe children should be punished show that they are 1.45 times less likely to have high cognitive development. These results are in line with the results showing that a higher number of prenatal checkups increases 1.654 times the probability of having high cognitive development.

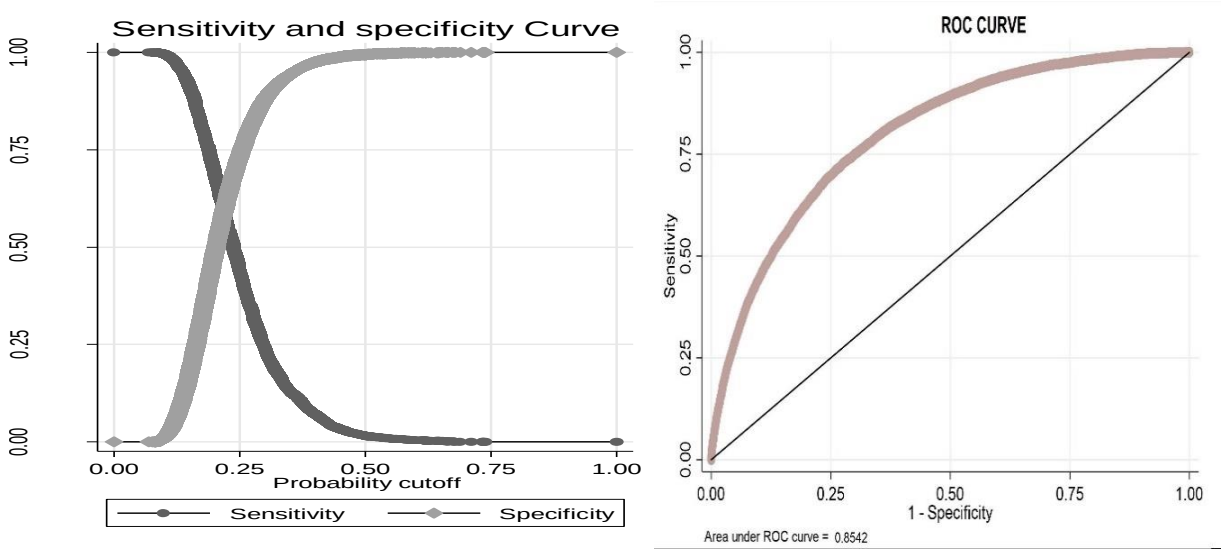
In **Table 7,** we observe that the chi-square (X^2) and log-likelihood statistics are stable and statistically correct. The chi-square statistic is significant, suggesting that, taken together, the independent variables jointly explain the variability of the dependent variable. On the other hand, the log-likelihood statistic is negative, and it is observed that it collects as much information as possible.

Table N° 7: Logistic regression analysis between cognitive development index and micronutrient intake

Variable		**OR**		**Std. Err.**		**P>z**		**95% CI**		
Did you consume micronutrients?										
No		Ref.								
Yes		1.567*		0.535		0.045		1.354	-	1.853
Obesity										
No		Ref.								
Yes		-2.011**		0.982		0.002		-1.986	-	-2.321
Child's age										
Age		-1.001		0.863		0.057		-0.872	-	-1.321
Sex of child										
Woman		Ref.								
Man		1.592**		0.765		0.003		1.341	-	1.978
Siblings at home										
Number of siblings at home		-1.032**		0.054		0.004		-1.012	-	-1.453
Hours of TV watched by the child										
Number of hours watching TV		-1.034		0.987		0.872		-1.001	-	-1.321
Child's hours of play										
Number of hours of play		1.686***		0.542		0.001		1.543	-	1.754
Do you think a child should be punished?										
No		Ref.								
Yes		-1.455*		0.216		0.032		-1.321	-	-1.765
Mother's age										
Age		-1.653		0.654		0.035		-1.345	-	-1.897
Mother's ethnicity										
Indigenous		Ref.								
Afro-Ecuadorian		-1.043		0.312		0.067		-1.012	-	-1.231
Mongrel		1.065		0.432		0.655		1.001	-	1.198
White		-1.986		0.563		0.192		-1.452	-	-2.004
Montubio		1.654		0.643		0.431		1.594	-	1.865

Prenatal checkups										
Number of prenatal checkups		1.654**		0.543		0.031		1.493	-	1.985
Type of delivery										
Normal delivery		Ref.								
Cesaria		-1.456		0.753		0.912		-1.321	-	-1.764
Observations		3877								
AIC		23975.03								
BIC		23138.09								
R^2		0.025								
X^2		3.956***								
Log-likehood		-31461.5								

Finally, the ROC curve was applied with the estimated probabilities when applying the logistic regression under the method of introducing its confidence intervals and its statistical significance $p < 0.05$. This is in order to know the explanatory power of our independent variables. The ROC Curve coincides with the probability of correctly distinguishing a case of high cognitive development from one that is not, through the significant predictor variables, being the worst scenario when the area is equal to 0.50. In our case, the significant variables: consuming micronutrients, obesity, sex of the child, number of siblings at home, number of hours of play, punishing the child and the number of prenatal controls, represented an area under the curve of 0.8542 (95% CI: 0.801-0.905), considering that they adequately predict cases of high cognitive development ($p < 0.001$). On the other hand, the sensitivity and specificity curve shows an adequate shape, given that it is observed to have normal behavior. Specifically, we observed that the curves cross at an approximate value of 0.25, given a good formation of the curves.



ROC curve and sensitivity and specificity curve for the determination of the sensitivity of the model of cognitive development and micronutrient intake.

4. Discussion

Child malnutrition is a public health problem that has short-, medium- and long-term repercussions, especially in children under 5 years of age. Not only does it affect the individual in this situation, but it also harms society in general since childhood is the most important stage in human life since it is a determining factor for physical and mental development. Malnutrition, in its different manifestations, has important consequences that include health, the development of cognitive abilities and educational outcomes, and social and labor inclusion, translating directly or indirectly into low productivity and health costs (Pizzol et al., 2021). It is important to emphasize that several studies have pointed out that the neurodevelopmental process is linked to nutrition, i.e., "cognitive development that is related to intelligence, attention, memory, thinking and perception will be negatively affected in the size and body functions" affecting the intellectual and behavioral abilities of children (Anjos et al., 2013).

That is why international health organizations set global objectives aimed at eradicating them. Ecuador is not far from the reality of other countries in the field of nutritional deficiencies, observing a figure of iron deficiency anaemia in children under 5 years of age above 50%. This background shows the importance of nutrition in the infant population of Ecuador. Therefore, the present work has examined the nutritional status of Ecuadorian children who have been considered as beneficiaries of a state micronutrient supplementation program. The results of this research showed that the consumption of micronutrients up to two years of age increases the probability of having high cognitive development by 1.57 times (OR= 1.57, CI= 1.354-1.853). On the other hand, an odd ratio (OR) associated with the obesity variable was also significant and greater than 1 (with a negative sign). This shows that a child with malnutrition is approximately 2.01 times less (CI=-1.986- -2.321) likely to have high cognitive development. Another significant OR is associated with the child's sex variables with an OR of 1.592 (CI=1.341- 1.978), showing that males are more likely to have high cognitive development. Likewise, a greater number of siblings at home reduces the probability of having high cognitive development by 1.032 times. This fact makes it evident that policies to mitigate child malnutrition should be a priority in a developing country like Ecuador. In addition, we observe that 71.45% (68.45% - 73.45%). Here we observe that the dependent variable is a dichotomous variable that takes the value of 1 if an infant suffers from child malnutrition. We found that, as expected, the odds ratio (OR) of having consumed micronutrients is significant and negatively greater than 1. Consuming micronutrients during pregnancy, obesity, sex of the child, number of siblings at home, number of hours of play, punishing the child and the number of prenatal checkups represented an area under the curve of 0.8542 (95% CI: 0.801-0.905), considering that they adequately predict cases of high cognitive development (p < 0.001).

Our results agree with A study conducted in Tena, in a population of children under 4 years of age, in a sample of 74 children, which demonstrated the positive influence of chispaz supplementation on the hemoglobin levels of the study participants, which contributed to evidence of better cognitive development in terms of neurodevelopment (Ewusie et al., 2014).. Another study conducted on a population of 337 children aged o to 59 months of age presented a better relationship with the environment with sparkle supplementation (p=0.022, CI: 95%:1.01-1.33)(Svarch, 2015). Similarly, Ocaña et al. (2020) were able to demonstrate that the impact of sparkle supplementation in infants showed a significant improvement in terms of verbal skills compared to children with low hemoglobin levels.(Ocaña Anzules, 2014).

However, our results differ from those of other studies, such as a study in which the supplementation of sparkle was evaluated in relation to the nutritional status of children in the Buen Vivir Children's Centers (CIVB) and Children's Centers Growing with our Children (CNH), where it was observed that there is no statistical significance between the use (87.5%) or not (93.1%) of micronutrients and the development of cognitive skills (OR 0.5; CI0.11-2.44; p=0.3989)(Petry et al., 2016). Similarly, similar results could be found in a meta-analysis which reveals that micronutrients had no effect on growth or psychomotor development but a positive effect in relation to child weight-for-age (p<0.05)(Warthon-Medina et al., 2015).. At the Latin American level, something similar could also be found in a Peruvian study in children aged 6 to 17 months in which micronutrient supplementation has no additional long-term effects on nutritional status(Francke et al., 2020b).. Another Japanese study found no evidence to quantitatively assess the efficacy of multiple micronutrient supplementation in improving infant health outcomes (Sarah K Abe et al., 2016).

Finally, it can be concluded that apart from cognitive factors, contextual factors such as socioeconomic status have a significant influence on malnutrition. It is necessary to point out that in homes with low income, malnutrition can be very marked because they do not have access to a basic food basket, and in homes with medium and high income, where parents do not have the time to give adequate attention because of their jobs, they use the marketing of processed products, which can lead to obesity at an early age. An analysis of studies on nutrition and its relationship with cognitive development has shown that children with malnutrition problems (obesity and malnutrition) do not reach a significant level of cognitive development in relation to children with an adequate nutritional status.

5. Conclusion

Nutrition is a process that occurs from gestation, and it depends on the brain and cognitive development of the human being. In adverse conditions, poverty and food shortages cause malnutrition problems, causing damage to brain development and, therefore, to cognitive development and learning, preventing equal opportunities in relation to children who are well nourished. On the other hand, obesity can lead to sedentary conditions with internalizing symptoms at an emotional level as a result of the negative evaluation they make of themselves regarding their body perception, reinforced by social feedback. However, these results are not conclusive since other studies have not found a direct relationship between nutritional status and psychomotor profile. Therefore, adequate nutrition and physical activity favor cognitive development and learning, which are necessary for the early childhood school process16; factors such as obesity, economic conditions and low academic expectations of parents constitute a health problem that has a negative impact on the self-concept or perception of each child, a situation that can influence behavior and dysfunctionality at the academic level and interpersonal relationships in the school stage. Malnutrition in

early childhood leads to negative effects on behavioural and cognitive development, with poor school performance limiting their ability to cope with life.

In the case of Ecuador, a country in the region still highly affected by its high rate of malnutrition, the "National Plan for Good Living" is being implemented, with undeniable successes and achievements in various areas, which currently has to face the threat posed by child malnutrition in children under five years of age and teenage pregnancy. Child malnutrition currently indicates that one in four children suffers from chronic malnutrition, which leads to a school population with limited performance, which implies undertaking food supplementation strategies to reduce this problem, in addition to training as a right to food sovereignty in rural families of the Sierra as the most affected child population. Our main limitations were evidenced by the fact that in order to obtain the BMI, children must be percentile-weighted in order to find the low, adequate and high weight. It is recommended that future research be conducted in more depth to study the causes of childhood obesity, especially in relation to the feeding of ultra-processed products, in order to obtain another point of view with respect to the other extreme of malnutrition, such as obesity.

A major challenge will be to translate the political commitment to reduce inequities into policies and programs that involve the poorest communities from the outset.

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