Clinical Epidemiology and Global Health 24 (2023) 101456

Contents lists available at ScienceDirect

Clinical Epidemiology and Global Health

journal homepage: www.elsevier.com/locate/cegh

Association between supplementation with vitamin A, iron and micronutrients with adequate psychomotor development in children from 9 to 36 months in Peru

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ARTICLE INFO

Keywords:
Vitamin A
Micronutrients

ABSTRACT

Background: Worldwide, it is estimated that 52.9 million children <5 years of age experience delayed psychomotor development, which is associated with multiple factors. Our primary objective is to evaluate whether there is an association between supplementation with Vitamin A, Iron, and Micronutrients and Adequate Psychomotor Development in children aged 9–36 months at the national level in Peru.
Methods: The study was an observational, analytical, cross-sectional study based on the secondary analysis of the Demographic and Family Health Survey databases from 2018 to 2020. The independent variables include the consumption of Vitamin A, Iron, and Micronutrients. The dependent variables encompass Motor Development in children aged 9–18 months, Psychological Development in children aged 9–18 months, and Psychological Development in children aged 19–36 months.
Results: The study included a total of 24 838 participants. In the adjusted regression model, the factors associated with adequate motor development between 9 and 18 months of age were: region of residence, overcrowding, and exclusive breastfeeding. For adequate cognitive development between 9 and 18 months of age, the associated factors were: vitamin A consumption, mother's education, child sex, delivery complications, and complete vaccinations. Regarding adequate psychological development in children aged 19–36 months, the associated factors were: mother's education, maternal employment, child sex, and birth weight.
Conclusions: There was no association found between nutritional supplementation and adequate development, except for the relationship between Vitamin A consumption and adequate psychological development in children aged 9–18 months. Therefore, further research, such as cohort studies and clinical trials, is suggested to corroborate this association.

1. Introduction

Psychomotor development (PD) is a dynamic process in which individuals acquire motor, cognitive, linguistic, and social skills as they progress through the years.[1] In Latin America, screening tests such as the Psychomotor Development Assessment Scale are used for children aged 0–24 months, while the Psychomotor Development Test is utilized for children over 2 years of age.[2] Since 2015, Peru has conducted the Demographic and Family Health Survey (ENDES) annually at the national level to assess the psychomotor development in children under 5 years of age based on maternal reports.[3]

Worldwide, it is estimated that 52.9 million children under 5 years of age experience delayed psychomotor development, with 95 % residing in low- and middle-income countries.[4] Consequently, numerous researchers have sought to identify risk and protective factors influencing adequate psychomotor development.

For example, Young et al. observed a significant enhancement in motor and mental development among Indian children aged 6–18 months who received 12 months of home fortification with micronutrient powders (Cohen's d: Motor = 0.12, 95 % CI 0.03–0.22; Mental = 0.15, 95 % CI 0.06–0.25).[5] Similarly, Sales et al. found that Brazilian children aged 0–35 months who received Vitamin A supplementation had a 67 % reduced risk of cognitive delay (adjusted PR = 0.33, 95 % CI 0.21–0.53).[6] In addition, Angulo-Barroso et al. (2016) conducted a study on iron supplementation in 1196 infants during pregnancy and childhood. They concluded that iron supplementation from week 6 to month

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https://doi.org/10.1016/j.cegh.2023.101456
Received 2 July 2023; Received in revised form 5 October 2023; Accepted 29 October 2023
Available online 3 November 2023

9 of infancy, even without iron supplementation during gestation, resulted in improved gross motor development at 9 months of age (RR 0.64, 95 % CI 0.52–0.80).[7]

Furthermore, several other crucial factors influence psychomotor development, including prematurity, breastfeeding, harmful habits during pregnancy, maternal or child violence, maternal mental health, socioeconomic factors, and the ongoing COVID-19 pandemic.[8]

In this context, the role of micronutrient, vitamin A, and iron supplementation in children's psychomotor development gains significance. However, there is a scarcity of studies evaluating the nutritional factors associated with good or poor psychomotor development. Hence, investigating this association at the national level using population data holds great relevance. Such research could not only raise awareness among prospective parents about the importance of maintaining proper supplementation for their children but also guide public health entities in investment, prioritization, and reporting on the benefits of such measures.

2. Materials and methods

2.1. Study design

An observational, analytical, cross-sectional study was conducted based on the secondary analysis of the Demographic and Family Health Survey (ENDES) databases for the years 2018–2020. ENDES is a national population survey in Peru. The study population consisted of children of both sexes aged between 9 and 36 months who participated in ENDES between 2018 and 2020.

The dependent variables included Motor Development for children aged 9–18 months, Psychological Development for children aged 9–18 months, and Psychological Development for children aged 19–36 months. Adequate development was defined as meeting all age-appropriate milestones, while inadequate development was defined as not meeting at least one milestone. It is important to note that milestone criteria varied for different age groups (9–12 months, 13–18 months, 19–23 months, and 24–36 months). ENDES established milestones for motor development only between 9 and 18 months but recorded psychological development milestones for the entire age range from 9 to 36 months. ENDES did not record milestones for children under 9 months, so they were excluded from the study.

The independent variables included Vitamin A Supplementation, Iron Supplementation, and Micronutrient Supplementation. Sociodemographic control variables were also incorporated.

Inclusion criteria encompassed children aged 9–36 months with parents who voluntarily participated in ENDES. Records lacking essential data such as sex, age, or geographic location were excluded. Additionally, records without data on any of the supplementation types (Vitamin A, Iron, and Micronutrients), those without data on Psychomotor Development, records corresponding to children with disabilities affecting psychomotor development (such as Cerebral Palsy or Down Syndrome), and children with extreme or very extreme prematurity (gestational age <28 weeks) were also excluded.

2.2. Sample design

The ENDES survey employs a two-stage, probabilistic, balanced, stratified, and independent design for each department, both in urban and rural areas. Given the fixed population for each of the ENDES surveys conducted in 2018, 2019, and 2020, a power calculation was performed. In this calculation, psychomotor development (PD) was the outcome of interest, while supplementation with Vitamin A, Iron, and Micronutrients served as the exposure variables.

Based on previous research findings, Sales et al.[6] reported a 67 % lower risk of cognitive delay among individuals who received vitamin A (adjusted PR: 0.33; 95 % CI 0.21–0.53), Angulo-Barroso et al.[7] found a 36 % reduced risk of being in the lowest quartile of Developmental Psychomotor Milestones (DPM) in children who received iron compared to those who received a placebo (RR: 0.64; 95 % CI 0.52–0.80), and Masuda et al.[9] observed a lower risk of psychomotor retardation associated with the use of micronutrients compared to spirulina (OR: 2.55; 95 % CI 1.26–5.14).

The total number of children under 5 years of age, combining data from the ENDES surveys conducted in 2018, 2019, and 2020, amounted to 31 400 children. Since the study analyzed data stratified into two groups: children aged 9–18 months (10 months) and those aged 19–36 months (18 months), the sample size for the first group was calculated as 5233 ($31\,400 \times 10/60$), and for the second group, it was calculated as 9420 ($31\,400 \times 18/60$). This calculation assumed a homogeneous distribution of children across each age in months.

Utilizing the Epidat 4.2 program for comparing proportions, a significance level of 0.05 was applied, followed by manual Bonferroni correction for three simultaneous exposures ($0.05/3 = 0.017$). Moreover, a correction for the two-stage structure of the original survey was considered, which involved dividing the population by the number of stages, in this case, 2. As a result, powers greater than 90 % were identified for each of the exposures within each population segment to be analyzed, as detailed in Table 1.

2.3. Statistical analysis

The databases required for this study were obtained from the Institute of Statistics website (http://iinei.inei.gob.pe/microdatos/) in dbf format for the necessary modules of the ENDES surveys conducted in 2018, 2019, and 2020. Subsequently, these files were exported to Stata 15.0 dat format for further analysis. The final database was processed and analyzed using the Stata statistical package.

Given the complex sampling design of the original study, all analyses were conducted using the 'Complex survey data' (svy) option. The strata defined by ENDES, the blocks, and dwellings served as conglomerates, while the expansion factors were applied as sample weights (pweights). Confidence intervals were set at 95 %, and statistical significance was determined at p values < 0.05. As all variables in the dataset were categorical, they were described in terms of absolute frequencies, relative frequencies (percentages), and weighted percentages, taking into account the sample weights.

Bivariate analysis was performed using the chi2 test corrected for clusters, using the Rao-Scott correction. Prevalence ratios (PRs) were obtained using Poisson regression (Generalized Linear Model, Poisson family, logarithmic linkage). Regressions were run in crude and adjusted form corrected for complex sampling using Taylor Linearization to estimate PRs. The variances were obtained in a robust way by conglomerates. The adjusted model (multivariate) included the exposure variables (vitamin A, iron, micronutrients), along with all variables that exhibited $p < 0.05$ values in the crude models (statistical criterion). Separate models were conducted for motor development at 9–18 months, psychological development at 9–18 months, and psychological development at 19–36 months.

3. Results

3.1. Descriptive analysis

A total of 24 838 participants within the age range of 9–36 months were included in the analysis using data from the Demographic and Family Health Survey (ENDES) conducted between 2018 and 2020. Among these participants, 23 997 (approximately 0.97 %) had available data on iron supplementation, 23 514 (about 0.95 %) had data on vitamin A supplementation, and 23 765 (approximately 0.96 %) had data on micronutrient supplementation.

Table 2 provides a description of the characteristics of children aged 9–36 months. It's worth noting that the proportion of male participants exceeded that of females. Most children had birth weight and height

Table 1
Statistical Analysis based on the ENDES 2018–2020 survey.

Main Exposure	Prevalence Exposure	Not Exposed/Exposed	Adequate PD in exposed	Adequate PD in not exposed	Population 2018–2020[a]	Potency
Vitamin A Supplementation[19]	76.5 %	23.5 %/76.5 % = 0.31	75.2 %	50.0 %	9–18 m: 2612 19–36 m: 4710	>99.9 % >99.9 %
Iron Supplementation[20]	51.4 %	48.6 %/51.4 % = 0.95	84.0 %	76.0 %	9–18 m: 2612 19–36 m: 4710	99.7 % >99.9 %
Micronutrients Supplementation (31)	49.8 %	50.2 %/49.8 % = 1.01	94.0 %	89.0 %	9–18 m: 2612 19–36 m: 4710	98.6 % >99.9 %

[a] Actual value divided by two, by two-stage sampling design.

within the normal range. Additionally, a significant portion of the population adhered to exclusive breastfeeding, attended Control of Growth and Development (CRED) sessions, and received complete vaccinations appropriate for their age.

3.2. Bivariate analysis

Examining the factors associated with adequate motor development in children aged 9–18 months reveals a complex interplay of environmental and physiological influences as region of residence, area of residence (urban-rural disparities), socioeconomic status (indicated by poverty level), overcrowding, exclusive breastfeeding and level of anemia emerge a significant effect for motor skill development (Table 3).

On the other hand, analyzing the factors linked to adequate psychological development in children aged 9–18 months reveals a multifaceted landscape of influences. Vitamin A supplementation stands out as a noteworthy factor, indicating the potential role of essential nutrients in supporting early cognitive development. Additionally, poverty level, overcrowding and education level of the mother may create stressors that influence a child's emotional well-being and cognitive development. Finally, the sex of the child, birth complications, control of growth and development and complete vaccinations have a significant effect for psychological development in early childhood (Table 3).

The factors associated with adequate psychological development in children aged 19–36 months sheds light on area of residence and poverty level, that emerges as a persistent factors, suggesting the enduring impact of socioeconomic disparities on early childhood development. Maternal education level and the maternal work status presents significance, raising questions about the balance between maternal employment and caregiving responsibilities. At last, gender differences (indicated by the sex of the child) and birth weight have a significant effect for psychological growth (Table 3).

3.3. Regression models

Crude and Adjusted models were developed for the exposure variables (Vitamin A, Iron, and Micronutrients) as well as for all variables that demonstrated statistical significance in the bivariate analysis.

The adjusted model will include the exposures variables and all variables that had an association with the outcome variable in the crude analysis with p values < 0.05, and that have not shown collinearity between them. Collinearity was previously evaluated using the variance inflation factor (VIF), and all selected variables had a value < 5, so none were excluded.

Table 4 shows the final model for adequate motor development from 9 to 18 months. It was found that those living in the Sierra Region had a 7 % lower probability of having adequate motor development (OR 0.93; 95 % CI 0.89–0.97) and living in overcrowded conditions had a 4 % lower probability (OR 0.96; 95 % CI 0.93–0.99). Children who received exclusive breastfeeding (EBF) also had a 3 % lower probability (OR 0.97; 95 % CI 0.95–0.99).

Furthermore, Table 4 presents the final model for adequate psychological development in children aged 9–18 months. Children who consumed Vitamin A had a 6 % higher likelihood of achieving adequate psychological development (OR 1.06; 95 % CI 1.01–1.13). Similarly, children whose mothers had completed secondary education had a 9 % higher probability of adequate psychological development (OR 1.09: 95 % CI 1.01–1.18). Female sex (OR 1.09; 95 % CI 1.01–1.18), experiencing complications during childbirth (OR 1.05; 95 % CI 1.01–1.11), and receiving full vaccinations appropriate for their age (OR 1.12; 95 % CI 1.03–1.22) were also associated with 9 %, 5 %, and 12 % higher probabilities, respectively.

Finally, Table 4 shows the final model for adequate psychological development from 19 to 36 months. A secondary educational level (OR 1.22; 95 % CI 1.11–1.34) or higher educational level of the mother (OR 1.28; 95 % CI 1.13–1.45), maternal employment (OR 1.08; 95 % CI 1.01–1.15), and female sex (OR 1.24; 95 % CI 1.17–1.32) had 22 %, 28 %, and 24 % higher probabilities of adequate development, respectively. Children with low birthweight (OR 0.81; 95 % CI 0.70–0.94) had a 19 % lower probability.

4. Discussion

4.1. Adequate psychomotor development

It was shown that most children between 9 and 18 months old reached an adequate motor development, however, psychological development declined at an older age. In this context, Quezada et al. found that 91.3 % achieve adequate motor development between 9 and 12 months of age.[10] Likewise, Veliz and Yanqui demonstrated that, of 100 children from 1 to 2 years of age, 42 % had deficient development in the sensory/motor area, while 55 % had deficient development in the cognitive area.[11]

4.2. Nutritional supplement coverage

Vitamin A, Iron and Micronutrient supplementation doses can vary widely depending on several factors, including individual's age, gestational age and/or birth weight. In our country, the Ministry of Health recommends supplementation with Vitamin A for children between 6 and 11 months at dose 100 000 UI once every 6 months and for children between 12 and 59 months at dose 200 000 UI once every 6 months. For Iron supplementation, the recommendation for children with low birth weight and/or preterm is 2 mg of elemental iron per kilogram per day from 2 months of age for 12 months. Children with adequate birth weight and/or born at term should receive 35–40 mg of elemental iron per week starting at 6 months of age for 6 months. Finally, for Micronutrients supplementation, all children should receive 1 sachet daily starting at 6 months of age and continuing for 12 months.

In our study, a coverage of 17.22 % for Vitamin A, 47.34 % for Iron and 54.19 % for Micronutrients was evidenced; The lower coverage of Vitamin A in our country stands out. Coincidentally, Morasso et al. found that vitamin A supplementation varies according to the poverty level of the household; poor households had 4 % vitamin A supplementation, compared with a prevalence of 20 % supplementation for lower-poverty households.[12]

Table 2
Sociodemographic characteristics and characteristics of the mothers and children between 9 and 36 months of age, with data on iron, vitamin A, or micronutrient supplementation, in the ENDES 2018–2020 surveys.

Variable	Absolut frequency	Relative frequency	Weighted[a]
	n	%	%
Sociodemographic characteristics and characteristics of the mothers of the children			
Interview year (n = 24 838)			
2018	9880	39.78	
2019	9427	37.95	
2020	5531	22.27	
Region (n = 24 838)			
Lima	2993	12.05	27.51
Coast	7418	29.87	27.09
Sierra	8221	33.10	27.38
Amazon	6206	24.99	18.01
Dwelling place (n = 24 838)			
Capital/Big city	2993	12.05	27.51
Small city	7435	29.93	21.51
Village	6966	28.05	25.09
Country	7444	29.97	25.89
Residency (n = 24 838)			
Urban	17 394	70.03	74.11
Rural	7444	29.97	25.89
Wealth quintile[b] (n = 24 838)			
1st quintile	7024	28.28	24.03
2nd quintile	6695	26.95	25.1
3rd quintile	4914	19.78	19.69
4th quintile	3639	14.65	17.07
5th quintile	2566	10.33	14.12
Level of poverty[b] (n = 24 838)			
3rd/4th/5th quintile	11 119	44.77	49.13
1st/2nd quintile	13 719	55.23	50.87
Overcrowding (n = 24 838)			
Not	16 188	65.17	67.18
Yes	8650	34.83	32.82
Literacy (n = 24 822)			
Read	995	4.01	0.37
Not read	23 827	95.99	96.3
Maternal educational level (n = 24 838)			
Without education/Primary school	4981	20.05	18.57
Secondary school	16 097	64.81	65.16
University/Master/Doctoral	3760	15.14	16.27
Mother job (n = 23 781)			
Not	10 808	45.45	45.00
Yes	12 973	54.55	55.00
Health insurance (n = 20 609)			
SIS	15 555	75.48	70.89
ESSALUD	4418	21.44	23.15
Others (FFAA, Private, EPS)	636	3.09	5.96
Violence towards the mother (n = 20 425)			
Not violence - 1	17 540	85.88	86.53
Violence - 0	2885	14.12	12.47
Mother with depression (n = 11 140)			
Not	8327	74.75	22.70
Yes	2813	25.25	77.30
Characteristics of the children			
Sex (n = 24 838)			
Male	12 591	50.69	50.57
Female	12 247	49.31	49.43
Age (n = 24 838)			
9 a 12 months	3382	13.62	14.33
13 a 18 months	5167	20.80	21.18
19 a 23 months	4397	17.70	17.73
24 a 36 months	11 892	47.88	46.75
Birth weight (n = 24 094)			
Underweight	1607	6.67	6.24
Normal weight	20 762	86.17	87.03
Macrosomia	1725	7.16	6.74
Height birth (n = 24 828)			
Very big height/Big height	6410	25.82	27.11
Normal	12 972	52.25	50.65
Very small height/Small height	5446	21.93	22.24
Cesarean birth (n = 24 838)			
Not	16 632	66.96	64.96
Yes	8206	33.04	35.04
Complications during birth[c] (n = 23 212)			
Not	17 899	77.11	77.39
Yes	5313	22.89	22.61
Exclusive breastfeeding (n = 14 148)			
Not	3701	26.16	31.10
Yes	10 447	73.84	68.90
Control of Growth and Development (CRED) (n = 24 830)			
No received	5800	23.36	20.54
Received	19 030	76.64	79.46
Full vaccine up to 6 months[d] (n = 24 437)			
Incomplete	4155	17.00	16.72
Complete	20 282	83.00	83.28
Full vaccine up to 12 months[e] (n = 24 464)			
Incomplete	7576	30.97	30.05
Complete	16 888	69.03	69.95
Vitamina A supplementation (n = 23 514)			
Not	18 221	77.49	82.78
Yes	5293	22.51	17.22
Iron supplementation (n = 23 997)			
Not	12 510	52.13	52.66
Yes	11 487	47.87	47.34
Micronutrients supplementation (n = 23 765)			
Not	11 026	46.40	45.81
Yes	12 739	53.60	54.19
Anemia level (n = 24 535)			
Mild	6802	14.04	11.69
Moderate/Severe	3445	14.04	25.89
Without Anemia	14 288	58.24	62.42
Motor development for children from 9 to 12 months (n = 3267)			
Inadequate	189	5.79	5.60
Adequate	3078	94.21	94.60
Psychological development for children from 9 to 12 months (n = 3274)			
Inadequate	757	23.12	22.29
Adequate	2517	76.88	77.71
Motor development for children from 13 to 18 months (n = 5001)			
Inadequate	300	6.00	5.87
Adequate	4701	94.00	94.13
Psychological development for children from 13 to 18 months (n = 5003)			
Inadequate	1359	27.16	27.85
Adequate	3644	72.84	72.15
Psychological development for children from 19 to 23 months (n = 4137)			
Inadequate	1454	35.15	35.42
Adequate	2683	64.85	64.58
Psychological development for children from 24 to 36 months (n = 11 209)			
Inadequate	5700	50.85	50.15
Adequate	5509	49.15	49.85

[a] Weighting considering complex sampling, strata determined according to the census population, blocks as conglomerates, and expansion factors as sample weights were used.
[b] Quintiles of wealth using the "Wealth Index".
[c] Includes prolonged labor, excessive bleeding, fever, seizures, and others.
[d] Complete Vaccines up to 6 months: BCG, and three doses of vaccines for Polio, Pertussis, Tetanus and Diphtheria.
[e] Complete Vaccines up to 12 months: BCG, three doses of vaccines for Polio, Pertussis, Tetanus and Diphtheria, plus one dose of Measles.

4.3. Nutritional supplementation and psychomotor development

An association was only found between Vitamin A supplementation and adequate psychological development between 9 and 18 months of age. Concordantly, Casamayor et al. demonstrated an association between the consumption of micronutrients (iron, zinc, folic acid, vitamin A and C) and normal psychomotor development (92.86 % vs 57.14 % with some disorder).[13] Likewise, Ali et al. demonstrated the association between antenatal or birth vitamin A supplementation and better school performance in the areas of reading, spelling, mathematics, and computing.[14]

No association was found between iron or micronutrient

Table 3
Sociodemographic, mother, and individual characteristics of children between 9 and 36 months of age, according to Age-Appropriate Motor and Psychological Development, in the ENDES 2018–2020 surveys.

	Inadequate		Adequate		P value
	n	(%)[a]	n	(%)[a]	chi2
Children between 9 and 18 months of age, according to Age-Adequate Motor Development					
MAIN					
Vitamin A supplementation					
Not	373	5.51	6207	94.49	0.294
Yes	108	6.89	1477	93.11	
Iron supplementation					
Not	174	5.86	2939	94.14	0.902
Yes	312	5.73	4811	94.27	
Micronutrientes supplementation					
Not	199	6.58	2760	93.42	0.346
Yes	289	5.28	5004	94.72	
SOCIOECONOMICS					
Region					
Lima	38	3.59	931	96.41	**0.026**
Coast	119	3.78	2324	96.22	
Sierra	218	9.46	2484	90.54	
Amazon	113	6.49	2026	93.51	
Residence					
Urban	299	4.85	5410	95.15	**0.008**
Rural	189	8.16	2355	91.84	
Poberty level[a]					
3rd/4th/5th quintile	167	4.27	3474	95.73	**0.036**
1st/2nd quintile	321	7.29	4291	92.71	
Overcrowding					
Not	283	4.91	4975	95.09	**0.039**
Yes	205	7.47	2790	92.53	
Maternal Education					
Without education/Primary school	142	9.66	1466	90.34	0.071
Secondary school	282	4.55	5115	95.45	
University/Master/Doctoral	64	6.17	1184	93.83	
Mother job					
Not	242	5.08	3933	94.92	0.244
Yes	246	6.46	3832	93.54	
Health insurance					
SIS	329	6.1	4898	93.9	0.132
ESSALUD	68	3.08	1291	96.92	
Others (FFAA, Private, EPS)	9	13.37	194	86.63	
Maternal violence					
Not	346	5.8	5542	94.2	0.821
Yes	59	6.17	788	93.83	
CHILDREN CHARACTERISTICS					
Sex					
Male	237	4.75	3945	95.25	0.071
Female	251	6.84	3820	93.16	
Birth weight					
Underweight	47	6.45	472	93.55	0.137
Normal weight	397	5.94	6572	94.06	
Macrosomia	22	2.17	520	97.83	
Cesarean birth					
Not	325	6.08	5165	93.92	0.389
Yes	163	5.2	2600	94.8	
Complications during birth[b]					
Not	381	5.33	5855	94.67	0.329
Yes	97	7.23	1794	92.77	
Exclusive breastfeeding					
Not	55	2.88	1145	97.12	**<0.001**
Yes	242	7.62	3290	92.38	
Control of Growth and Development					
Not	54	4.66	798	95.34	0.456
Yes	434	5.87	6966	94.14	
Full vaccine[c]					
Incomplete	129	6.25	1753	93.75	0.613
Complete	355	5.64	5937	94.26	
Anemia					
Mild	172	4.24	3244	95.76	**0.017**
Moderate/Severe	178	6.64	2605	93.36	
Without anemia	129	7.64	1838	92.36	
Children between 9 and 18 months of age, according to Age-Adequate Psychological Development					

Table 3 (*continued*)

	Inadequate		Adequate		P value
	n	(%)[a]	n	(%)[a]	chi2
MAIN					
Vitamin A supplementation					
Not	1710	26.31	4873	73.69	**0.031**
Yes	379	21.14	1212	78.86	
Iron supplementation					
Not	845	28.3	2270	71.7	0.061
Yes	1263	24.24	3867	75.76	
Micronutrients supplementation					
Not	818	27.64	2145	72.36	0.125
Yes	1296	24.44	4002	75.56	
SOCIOECONOMIC CHARACTERISTICS					
Region					
Lima	237	26.17	733	73.83	0.158
Coast	557	22.12	1888	77.88	
Sierra	776	27.52	1931	72.48	
Amazon	544	27.3	1596	72.7	
Residency					
Urban	1360	24.73	4355	75.27	0.118
Rural	754	28	1793	72	
Poberty level[a]					
3rd/4th/5th quintile	837	23.21	2808	76.79	**0.015**
1st/2nd quintile	1277	28.1	3340	71.9	
Overcrowding					
No	1280	24.05	3983	75.95	**0.021**
Si	834	28.79	2165	71.21	
Maternal Education					
Without education/Primary school	506	32.52	1104	67.48	**0.004**
Secondary school	1311	24.07	4094	75.93	
University/Master/Doctoral	297	24	950	76	
Mother job					
Not	1089	26.87	3092	73.13	0.204
Yes	1025	24.39	3056	75.61	
Health Insurance					
SIS	1352	24.56	3881	75.44	0.455
ESSALUD	339	27.15	1021	72.85	
Others (FFAA, Private, EPS)	57	30.42	147	69.58	
Maternal violence					
Not	1450	24.57	4442	75.43	0.227
Yes	243	28.22	606	71.78	
CHILDREN CHARACTERISTICS					
Sex					
Male	1204	29.11	2982	70.89	**<0.001**
Female	910	22	3166	78	
Weight birth					
Underweight	172	31.32	350	68.68	0.173
Normal weight	1713	25.14	5261	74.86	
Macrosomia	124	21.17	419	78.83	
Cesarean birth					
Not	1428	26.26	4069	73.74	0.408
Yes	686	24.48	2079	75.52	
Complications during birth[b]					
Not	1630	26.8	4609	73.2	**0.031**
Yes	448	22.03	1448	77.97	
Exclusive breastfeeding					
Not	295	23.29	905	76.71	0.298
Yes	941	26.36	2597	73.64	
Control of Growth and Development					
Not	218	32.19	635	67.81	**0.041**
Yes	1896	25.04	5512	74.96	
Full vaccine[c]					
Incomplete	582	33.57	1303	66.43	**<0.001**
Complete	1503	23.28	4794	76.72	
Anemia					
Mild	708	23.56	2075	76.44	0.226
Moderate/Severe	562	27.99	1404	72.01	
Without anemia	817	25.84	2608	74.16	
Children between 19 and 36 months of age, according to Age-Adequate Psychological Development					
MAIN					
Vitamin A supplementation					
Not	5373	45.49	6130	54.51	0.120
Yes	1693	48.5	1975	51.5	
Iron supplementation					

(*continued on next page*)

Table 3 (*continued*)

	Inadequate		Adequate		P value
	n	(%)[a]	n	(%)[a]	chi2
Not	4349	45.78	4965	54.22	0.637
Yes	2787	46.58	3207	53.42	
Micronutrients supplementation					
Not	3684	45.15	4292	54.85	0.265
Yes	3466	47.04	3897	52.96	
SOCIOECONOMIC CHARACTERISTICS					
Region					
Lima	841	43.11	1041	56.89	0.134
Coast	2126	47.65	2494	52.34	
Sierra	2350	46.05	2732	53.95	
Amazon	1837	48.48	1925	51.52	
Residency					
Urban	4901	44.64	5975	55.36	**0.001**
Rural	2253	50.51	2217	49.49	
Poverty level[a]					
3rd/4th/5th quintile	3016	43.84	3964	56.16	**0.006**
1st/2nd quintile	4138	48.46	4228	51.54	
Overcrowding					
Not	4.570	44.99	5563	55.01	0.054
Yes	2584	48.4	2629	51.6	
Maternal Education					
Without education/Primary school	1776	56.06	1347	43.94	**<0.001**
Secondary school	4461	44.67	5423	55.33	
University/Master/Doctoral	917	40.49	1422	59.51	
Mother job					
Not	3185	49.06	3365	50.94	**0.002**
Yes	3969	43.94	4827	56.06	
Health Insurance					
SIS	4575	47.85	4938	52.15	0.286
ESSALUD	1254	43.56	1604	56.44	
Others (FFAA, Private, EPS)	170	48.62	241	51.38	
Maternal violence					
Not	5045	45.92	5734	54.08	0.993
Yes	916	45.90	990	54.10	
CHILDREN CHARACTERISTICS					
Sex					
Male	4045	51.96	3722	48.04	**<0.001**
Female	3109	40.18	4470	59.83	
Weight birth					
Underweight	506	56.01	500	43.99	**0.005**
Normal weight	5850	45.09	6932	54.91	
Macrosomia	493	44.07	589	55.93	
Cesarean delovery					
Not	4881	46.44	5455	53.56	0.593
Yes	2273	45.46	2737	54.54	
Complications during birth[b]					
Not	5045	46.79	5705	53.21	0.139
Yes	1390	43.79	1777	56.21	
Exclusive breastfeeding					
Not	1069	43.14	1282	56.86	0.107
Yes	3057	46.94	3275	53.06	
Control of Growth and Development					
Not	2135	47.78	2338	52.22	0.232
Yes	5018	45.48	5849	54.52	
Full vaccine[d]					
Incomplete	1438	48.83	1540	51.17	0.066
Complete	5535	44.92	6509	55.08	
Anemia					
Mild	1783	46.38	1945	53.62	0.181
Moderate/Severe	670	51.04	686	48.96	
Without anemia	4642	45.52	4486	54.48	

Appropriate Motor and Psychological Development: Meets motor development milestones for children 9–12 months and for children 13–18 months as appropriate. Meets psychological development milestones for children 19–23 months and for children 24–36 months as appropriate.
Chi2 test with Rao-Scott correction by cluster sampling.
CRED: Control of Growth and Development.

[a] Quintiles of wealth using the "Wealth Index".

[b] Includes prolonged labor, excessive bleeding, fever, seizures, and others.

[c] Complete Immunizations as appropriate for children 9–12 months (BCG, and three doses of vaccines for Polio, Pertussis, Tetanus and Diphtheria), and for children 13–18 months (BCG, three doses of vaccines for Polio, Pertussis, Tetanus and Diphtheria, plus a dose of Measles).

[d] Complete Vaccines for children over one year of age (BCG, three doses of vaccines for Polio, Pertussis, Tetanus and Diphtheria, plus one dose of Measles).

supplementation and adequate psychomotor development. Corimaya et al. concluded that the consumption of iron and/or vitamin C in children between 6 and 59 months of age had no direct association with adequate psychomotor development (iron: $p = 0.938$; vitamin C: $p = 0.056$).[15] On the other hand, Rueda et al. suggest that nutritional supplementation with polyunsaturated fatty acids (DHA, AA, omega 3 and 6) and minerals (iron and zinc) provided benefits in cognitive development, preferably in infants and schoolchildren.[16]

4.4. Other factors associated with adequate motor development

A reduced likelihood of adequate motor development in children residing in the Sierra region has been attributed, possibly due to prenatal stressors. Ticona-Rendón M's research revealed a higher incidence of intrauterine growth retardation in the Sierra, at 14.6 %, in contrast to the coastal region, where it stood at 8.1 %.[17] Zambrano et al. determined that insufficient opportunities for effective learning are more prevalent in rural and low-income areas. This can be attributed to factors such as the low educational attainment of parents, overcrowded living conditions, and limited income.[18]

Furthermore, living in crowded environments has also been linked to a diminished likelihood of child development. In this regard, Alvarado Llatance's study uncovered a negative correlation between overcrowding and child development.[19]

Additionally, children exclusively breastfed exhibited a lower likelihood of achieving adequate motor development. Comparatively, Hye Jeong Choi et al. found that infants who received exclusive breastfeeding for up to 4 months demonstrated improved communication (OR = 4.12; CI: 1.11–15.28) and social interaction (OR = 6.04; CI: 1.05–34.66), and at 12 months, enhanced cognition (OR = 6.66; CI: 1.02–43.63), communication (OR = 3.93; CI: 1.07–14.40), and social interaction (OR = 8.17; CI: 1.59–42.05).[20] However, Tintaya-Peña's study in Villa el Salvador, Peru, did not find any significant association between psychomotor development and exclusive breastfeeding ($p = 0.90$), breastfeeding within the first hour ($p = 0.50$), or maternal breastfeeding technique ($p = 0.74$).[21] Finally, Michels et al. observed a trend indicating that introducing solid foods alongside breastfeeding at 4 months postpartum may potentially be associated with slightly faster achievement of standing (Acceleration Factor (AF): 0.93; 95 % CI: 0.87, 0.99) and walking milestones (AF: 0.93; 95 % CI: 0.88, 0.98) in term infants when compared with those exclusively breastfed.[22] These nuanced findings underscore the importance of continued investigation into the complex interplay between infant feeding practices and developmental outcomes.

4.5. Other factors associated with adequate psychological development

A mother's higher level of education (secondary or higher) was associated with a higher likelihood of adequate psychological development for both age groups, namely 9–18 months and 19–36 months. This finding aligns with the research of Nima Chistama C. A, which also established a direct relationship between mothers with higher educational levels and satisfactory psychomotor development ($p < 0.023$).[23] Similarly, Alvarado et al., in their study conducted in Peru, demonstrated that a greater degree of maternal education leads to improved psychomotor development ($p < 0.01$).[24]

Female gender was also associated with a higher likelihood of adequate psychological development in both age groups. Furthermore, Alvarado Llatance's nationwide study revealed that females exhibited superior child development in cognitive, communication, motor, and socio-emotional skills (OR: 2.35; $p = 0.002$).[19]

Table 4
Crude and adjusted regression models for Adequate Motor and Psychological Development for 9–36 months of age in children of that age according to the ENDES 2018–2020 surveys.

Variables	Crude Model[a]			Fitted Model[b]		
	RPc	IC 95 %	p value	RPa	IC 95 %	p value
Adequate Motor Development for 9–18 months of age						
Vitamin A supplementation						
Not	Ref.	-	-	-	-	-
Yes	0.99	0.96–1.01	0.316	0.99	0.95–1.02	0.499
Iron supplementation						
Not	Ref.	-	-	-	-	-
Yes	1.00	0.98–1.02	0.903	1.01	0.98–1.04	0.369
Micronutrients supplementation						
Not	Ref	-	-	-	-	-
Yes	1.01	0.98–1.05	0.382	1.01	0.98–1.03	0.671
Region						
Lima	Ref	-	-	-	-	-
Coast	0.998	0.96–1.04	0.923	0.99	0.96–1.02	0.637
Sierra	0.94	0.90–0.98	0.004	**0.93**	**0.89–0.97**	**<0.001**
Amazon	0.97	0.93–1.01	0.157	0.97	0.93–1.01	0.115
Residency						
Urban	Ref.	-	-	-	-	-
Rural	0.97	0.94–0.99	0.008	0.99	0.95–1.02	0.445
Poverty level[c]						
3rd/4th/5th quintile	Ref.	-	-	-	-	-
1st/2nd quintile	0.97	0.94–0.99	0.015	0.996	0.97–1.03	0.820
Overcrowding						
Not	Ref.	-	-	-	-	-
Yes	0.97	0.95–0.99	0.033	**0.96**	**0.93–0.99**	**0.006**
Exclusive breastfeeding						
Not	Ref.	-	-	-	-	-
Yes	0.95	0.93–0.97	<0.001	**0.97**	**0.95–0.99**	**0.013**
Anemia						
Mild	0.97	0.95–0.99	0.031	0.97	0.94–1.00	0.059
Moderate/Severe	0.96	0.94–0.99	0.010	1.01	0.98–1.04	0.640
Without anemia	Ref.	-	-	-	-	-
Adequate Psychological Development for 9–18 months of age						
Vitamin supplementation						
Not	Ref.	-	-	-	-	-
Yes	1.07	1–1.13	0.022	**1.06**	**1–1.13**	**0.034**
Iron supplementation						
Not	Ref.	-	-	-	-	-
Yes	1.05	0.99–1.12	0.070	1.03	0.9–1.1	0.222
Micronutrient supplementation						
Not	Ref	-	-	-	-	-
Yes	1.04	0.98–1.10	0.133	1.02	0.97–1.08	0.339
Poverty level[c]						
3rd/4th/5th quintile	Ref.	-	-	-	-	-
1st/2nd quintile	0.93	0.88–0.98	0.014	0.95	0.90–1.01	0.154
Overcrowding						
Not	Ref.	-	-	-	-	-
Yes	0.93	0.88–0.99	0.024	0.96	0.90–1.01	0.174
Maternal education						
Without education/Primary school	Ref.	-	-	-	-	-
Secondary school	1.12	1.04–1.21	0,002	**1.09**	**1.01–1.18**	**0.025**
University/Master/Doctora	1.12	1.02–1.23	0.015	1.08	0.97–1.20	0.131
Sex						
Male	Ref	-	-	-	-	-
Female	1.10	1.04–1.15	<0.001	**1.09**	**1.01–1.18**	**0.001**
Complications during birth[d]						
Not	Ref	-	-	-	-	-
Yes	1.06	1.01–1.25	0.024	**1.05**	**1.01–1.11**	**0.047**
Control of Growth and Development						
Not	Ref	-	-	-	-	-
Yes	1.10.	0.99–1.22	0.066	0.98	0.87–1.10	0.757
Full vaccine[e]						
Not	Ref.	-	-	-	-	-
Yes	1.15	1.06–1.24	<0.001	**1.12**	**1.03–1.22**	**0.006**
Adequate Psychological Development for 19–36 months of age						
Vitamin A supplementation						
Not	Ref.	-	-	-	-	-
Yes	0.94	0.88–1.02	0.127	0.96	0.89–1.03	0.249
Iron supplementation						
Not	Ref.	-	-	-	-	-
Yes	0.99	0.93–1.05	0.638	1.00	0.94–1.07	0.925
Micronutrient supplementation						
Not	Ref	-	-	-	-	-

(continued on next page)

Table 4 (*continued*)

Variables	Crude Model[a]			Fitted Model[b]		
	RPc	IC 95 %	p value	RPa	IC 95 %	p value
Yes	0.97	0.91–1.03	0.266	0.97	0.92–1.04	0.422
Residency						
Urban	Ref.	-	-	-	-	-
Rural	0.89	0.83–0.96	0.003	0.99	0.92–1.08	0.883
Poverty level[c]						
3rd/4th/5th quintile	Ref.	-	-	-	-	-
1st/2nd quintile	0.92	0.86–0.98	0.006	1.02	0.94–1.10	0.666
Overcrowding						
Not	Ref.	-	-	-	-	-
Yes	0.94	0.88–1.00	0.057	0.99	0.92–1.06	0.677
Maternal education						
Without education/Primary school	Ref.	-	-	-	-	-
Secondary school	1.25	1.15–1.37	<0.001	**1.22**	**1.11–1.34**	**<0.001**
University/Master/Doctora	1.35	1.21–1.51	<0.001	**1.28**	**1.13–1.45**	**<0.001**
Mother job						
No	Ref.	-	-	-	-	-
Yes	1.10	1.03–1.17	0.003	**1.08**	**1.01–1.15**	**0.014**
Children sex						
Male	Ref.	-	-	-	-	-
Female	1.24	1.17–1.32	<0.001	**1.24**	**1.17–1.32**	**<0.001**
Weight birth						
Underweight	0.80	0.69–0.92	0.003	**0.81**	**0.70–0.94**	**0.007**
Normal weight	Ref.	-	-	-	-	-
Macrosomia	1.01	0.90–1.14	0.762	1.07	0.95–1.20	0.248

RPc: Crude Prevalence Ratio. RPa: Adjusted Prevalence Ratio. IC95 %: Confidence Interval 95 %. Ref: Reference Category.
[a] Poisson regression corrected for complex sampling using clusters and sample weights.
[b] Poisson regression with correction for complex sampling using clusters and sample weights adjusted for all the variables in the Table.
[c] Quintiles of wealth using the “Wealth Index”.
[d] Includes prolonged labor, excessive bleeding, fever, seizures, and others.
[e] Complete Immunizations as appropriate for children from 9 to 12 months (BCG, and three doses of vaccines for Polio, Pertussis, Tetanus and Diphtheria), and for children from 13 to 18 months (same, plus one dose of Measles).

Conversely, maternal employment for mothers of children aged 19–36 months was linked to a higher probability of achieving adequate psychological development. Similarly, Nima Chistama’s research demonstrated that mothers engaged in employment had children with enhanced psychomotor development ($p = 0.017$), potentially due to improved economic resources or increased psychological stimulation.[23]

For children aged 9–18 months, a complete vaccination schedule was also associated with a greater likelihood of adequate psychological development. In line with this, Joe and Kumar’s findings indicated that fully vaccinated children at 12 months, in the 8 to 10-year-old age group, outperformed their peers who were either incompletely vaccinated or not vaccinated in math tests (OR: 1.87, 95 % CI: 1.48–2.35), writing (OR: 1.77, 95 % CI: 1.44–2.18), and reading (OR: 1.60, 95 % CI: 1.23–2.09).[25]

Lastly, low birth weight was associated with a reduced probability of adequate psychological development in children aged 19–36 months. Correspondingly, Rodriguez et al. found that low birth weight (weight <2500 g) led to developmental delays in psychomotor skills.[21] Similarly, Díaz-Granda, R. identified low birth weight (weight <2500 g) as a factor associated with psychomotor retardation (OR = 5.9; 95 % CI = 2.3–15.2; $p = 0.000$).[26]

5. Conclusions

No significant association was found between adequate psychomotor development with nutritional supplementation, except between Vitamin A and adequate psychological development in children aged 9–18 months (PR: 1.06; 95 % CI 1.01–1.13). Adequate motor development in children from 9 to 18 months was negatively associated with living in the Sierra region, overcrowding, and receiving exclusive breastfeeding. Adequate psychological development in children from 9 to 18 months was positively associated with the mother’s secondary educational level, female children, and having complete vaccinations. Adequate psychological development in children from 19 to 36 months was positively associated with secondary or higher educational level, working mother and female sex; instead, it was negatively associated with low birth weight. Further research is suggested, such as cohort studies and clinical trials, to assess with greater certainty whether there is an association between psychomotor development and nutritional supplementation.

Data availability

Data is available on request.

Ethic approval statement

This study relied on the Demographic and Family Health (ENDES), which obtained informed consent from all participants. The protocol for this research received approval from the ethics committee of the Faculty of Health Sciences at the Universidad Peruana de Ciencias Aplicadas under letter number FCS-CEI/659-07-21.

Funding information

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

Author contribution

Andres Chaponan-Lavalle: Conceptualization, Visualization, Investigation, Validation.: **Karla Hernandez Randich**: Data curation, Writing- Original draft preparation, Investigation, Validation.: **Roger Araujo Castillo**: Methodology, Software, Supervision, Writing- Reviewing and Editing.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Acknowledgments

The authors would like to thank Dr. Araujo, who provided support by reviewing this article. A previous version of this work is available in the thesis repository of the Universidad Peruana de Ciencias Aplicadas.

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