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RESEARCH ARTICLE

# Association between development level and nutritional status in children under 5 years of age in primary care

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## Abstract

**Background:** *Malnutrition is a risk factor for childhood development disorders. Although undernutrition is recognized as a public health problem, the impact of overweight/obesity on childhood development remains unknown. The objective is to determine the effects of undernutrition, overweight, and obesity on development in children aged between 1 and 59 months in rural/urban areas of Mexico.* **Methods:** *The Childhood Development Evaluation (EDI, for its acronym in Spanish) test was administered to children 1-59 months of age who visited primary care units in Guanajuato State, Mexico, between 2013 and 2015. The World Health Organization classification (weight/height ratio) was used for nutritional status. Logistic regression adjusted by sex, age, rural/urban, and level of marginalization, used to calculate odds ratios (OR) to stablish the association between nutritional status and developmental outcomes.* **Results:** *34,972 participants were included. 50.3% were male, 39.5% had a very low level of marginalization, 58.6% lived in urban areas, and 55.0% were beneficiaries of a conditional cash transfer program. Age distribution: 31.9% between 1 and 12 months old; 17.5% between 13 and 24 months old; 16.3% between 25 and 36 months old; and 34.3% between 37 and 59 months old. Overall 85.8% of participants had normal nutritional status, whereas 9.1% were identified as malnourished, and 5.0% were classified as overweight or obese. 79.1% had typical development. The OR for atypical development was 1.820 (95% confidence interval [95% CI], 1.671-1.981) for mild undernutrition; 2.796 (95% CI: 2.195-3.562) for moderate undernutrition; 14.903 (95% CI: 8.149-27.257) for severe undernutrition; and 1.160 (95% CI: 1.030-1.307) for overweight/obesity.* **Conclusion:** *Undernutrition and overweight/obesity are factors that increase the risk of developmental problems in children < 5 years of age.*

***Keywords:*** *Obesity. Overweight. Malnutrition. Infants. Child development. Mass screening.*

## *Asociación entre el nivel de desarrollo y el estado nutricional en niños menores de 5 años atendidos en el primer nivel de atención*

## Resumen

**Introducción:** *La malnutrición es un factor de riesgo para anormalidades del desarrollo infantil. A pesar de ser un problema de salud pública, aún no se conoce el impacto que tiene el sobrepeso u obesidad en este aspecto. El objetivo es dar a*

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*conocer el impacto de la desnutrición, sobrepeso y obesidad sobre las alteraciones en el desarrollo de niños de 1-59 meses en áreas rurales/urbanas en México.* **Métodos:** *Se aplicó la prueba Evaluación del Desarrollo Infantil (EDI) a niños de 1-59 meses que acudieron a unidades de primer nivel de atención del estado de Guanajuato, entre 2013 y 2015. Se utilizó la clasificación de la OMS para determinar el estado de nutrición, tomando en cuenta la relación peso/estatura. Para determinar la asociación entre estado nutricional y desarrollo se calculó con razón de momios de prevalencia (RMP) mediante regresión logística, ajustada por sexo, edad, localidad y nivel de marginación.* **Resultados:** *Se incluyeron 34,972 participantes: 50.3% de sexo masculino, 39.5% de muy bajo nivel de marginación, 58.6% en localidades urbanas y 55.0% beneficiarios Prospera. Por edad, 31.9% de 1-12 meses; 17.5% de 13-24 meses; 16.3% de 25-36 meses y 34.3% de 37-59 meses. El estado nutricional: normal en el 85.8%, desnutrición 9.1% sobrepeso/obesidad 5.0%. 79.1% con desarrollo normal. RMP para desarrollo anormal: desnutrición leve 1.820 (IC 95% 1.671-1.981); desnutrición moderada 2.796 (IC 95% 2.195-3.562); desnutrición severa 14.903 (IC 95% 8.149-27.257); y 1.160 (IC 95% 1.030-1.307) para sobrepeso/obesidad.* **Conclusión:** *La desnutrición y el sobrepeso/obesidad son factores que incrementan el riesgo de problemas en el desarrollo en niños menores de cinco años.*

***Palabras clave:*** *Obesidad. Sobrepeso. Desnutrición. Desarrollo infantil. Tamizaje masivo.*

## Introduction

Childhood development is a continuous process of change; developing children gradually master increasingly complex movements, thoughts, emotions, and social relationships[1]. The first 5 years of life entail a series of sensitive developments related to children's neurological circuits as they acquire specific learning skills[2]. During this critical period, brain functioning achieves optimal development; however, this process can be influenced by various factors, including the nutritional status of the child and the surrounding environment[2,3].

The brain amounts to 10% of a newborn's body weight; this proportion diminishes throughout life until it reaches 2% of adult body weight. However, this process is not linear: by the end of the 1st year of life, the brain has reached 70% of its adult size, representing 15% of the infant's body weight; by the 2nd year, the brain is at 77% of its final size, weighing 20% of the infant's total body weight[4].

The Childhood Development Assessment (EDI, as abbreviated in Spanish) screening test was developed and validated in Mexico to detect disorders in childhood development with 81% sensitivity and 61% specificity. The results of the test are ordinal, with color-coding in green for typical development, yellow for developmental lag, and red for risk of delay[5] This test is useful and reliable[6] and has been successfully implemented in diverse contexts[7-10] and is recommended as the national screening tool for Mexico[11].

Undernutrition is a pervasive problem in developing countries; although its prevalence has decreased in recent years[12-14], there has been a concurrent rise in overweight and obesity, which have posed a significant challenge to healthcare systems. This phenomenon is particularly pronounced in Mexico, where a progressive increase in obesity and overweight since the 1980s has led to its second-highest rate of adult obesity globally. Moreover, Mexico has the fourth-highest rate of child obesity and overweight worldwide, with a nearly 40% prevalence[13]. This has led to a significant increase in the risk of cardiovascular diseases, disability, and pre-mature death in adulthood[15,16].

A wide range of studies have found a close relationship between malnutrition and neurodevelopment; research has found that infants who are underweight for their age tend to have lower neurodevelopmental scores than those who have good nutritional status[17]. In particular, Alam et al. analyzed data from a cohort of 1,575 children from eight countries (Bangladesh, Brazil, India, Nepal, Pakistan, Perú, South Africa, and Tanzania), finding that neurodevelopmental deficits are greater when nutritional deficits (stunting) begin before 6 months of age[18]. However, research on the possible developmental effects of overweight and obesity in the 1st years of life has been limited.

This study investigates the effects of undernutrition, overweight, and obesity on developmental disorders (assessed using the EDI test) in infants and pre-schoolers who live in rural and urban areas in Mexico.

## Methods

A cross-sectional and prospective study was conducted. The study group constituted children between 1 and 59 months of age who had well-child visits at 318 primary care units in the state of Guanajuato, Mexico, between December 2013 and June 2015.

In the well-child visits, psychologists conducted the EDI test for all participants. These tests were standardized, as previously described[19,20]. Standardized weight

and height assessments were performed, with standard equipment used for these assessments (scales, a measuring rod, and a stadiometer). Nutritional status was classified into normal, undernutrition, overweight, and obesity following the World Health Organization standard[21,22], based on the weight/height ratio.

### Statistical analysis

The data were compiled in a Microsoft Excel spreadsheet and were analyzed using the Statistical Package for Social Sciences, version 25.0.

For the descriptive analysis, qualitative data are presented using absolute and relative frequencies. Ages are grouped into intervals, and weight and height are measured to assess nutritional status, categorized into the following groups: normal, undernutrition (mild, moderate, and severe levels), and overweight/obesity. For the inferential analysis, the prevalence odds ratio (POR) and 95% confidence intervals (95% CIs) are calculated with a logistic regression model, using the overall EDI test result as the dependent variable (normal: green; abnormal: yellow or red), stratified by age intervals. The independent variables were sex (reference: female), age group (reference: 1-12 months old), nutritional status (reference: normal), beneficiary of the Prospera program (reference: without); type of district (reference: urban), level of marginalization (reference: very low), and interaction of the type of district as a composite variable (reference: rural) × (level of marginalization, ≥ low).

### Ethical aspects

Parents were asked for verbal consent before measurements were taken. The study was approved by the Hospital Infantil de México Federico Gómez Ethics, Biosafety, and Research Commission, under registration number HIM/2013/063. The data were collected by personnel responsible for health jurisdiction registration during well-child visits at the primary care level. These data were encoded using anonymizing numbers; no personally identifying information was used.

## Results

The study group included 34,972 participants between 1 and 59 months of age. Table 1 presents the general characteristics of this population; 50.3% were male, 39.5% lived in areas with a very low level of marginalization, and 58.6% lived in urban districts. The age distribution was as follows: 31.9% were 1-12 months old; 17.5% 13-24 months old; 16.3% 25-36 months old, and 34.3% 37-59 months old. In addition, 55% (n = 19,243) were beneficiaries of the Prospera program, and 45% (n = 15,729) did not have access to this program.

Table 1 also shows participant's nutritional status; most participants had a normal nutritional status (85.8%), 9.1% were undernourished (of these, most had mild undernutrition), and 5.0% were overweight or obese. It is worth highlighting that these proportions were similar across the four age groups. In terms of development, EDI test results showed that 79.1% had normal development (green), 17.2% had a lag (yellow), and 3.7% had a risk of delay (red).

Figure 1 presents the distribution of EDI test results according to the nutritional status category, indicating that participants with undernutrition (n = 3,191) also had the highest proportion of yellow (24.5%) and red (8.8%) results compared with those with normal nutritional status (16.4% and 3.2%, respectively) or overweight/obese (17.5% and 3.8%, respectively). In addition, the greater the degree of undernutrition, the higher the proportion of yellow and red results; for 56.7% of the 60 participants with severe undernutrition (stunting), the EDI test result was red.

Finally, table 2 presents the logistic regression analysis results of the factors studied. It shows that a higher degree of undernutrition increased the risk of atypical development: prevalence odds ratio (POR) 1.820 (95% CI: 1.671-1.981) for mild undernutrition, POR 2.796 (95% CI: 2.195-3.562) for moderate undernutrition, and POR 14.903 (95% CI: 8.149-27.257) for severe undernutrition (stunting). In addition, overweight/obesity was also identified as a risk: POR 1.160 (95% CI: < 1.030-1.307). In this final group, we tried to identify the development area that was most affected; we determined that the gross motor area was affected to a significantly greater extent than other areas from a statistical perspective, but this was true only for certain age groups: POR 1.52 (95% CI: 1.16-1.99) for the 1-12 month age group and POR 1.86 (95% CI: 1.25-2.74) for the 37-59 month age group.

## Discussion

The findings of this study confirm that in a pediatric population under 5 years of age, undernutrition significantly affects neurodevelopment; in addition, the findings indicate that there is a greater risk of developmental disorders in children who are overweight or obese. Overall, our findings add to previous evidence identifying the coexistence of the public health problems of

**Table 1.** Distribution of sample characteristics by age group

| Characteristics of the study population | 1-59 months old | | Age group in months | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | 1-12 | | 13-24 | | 25-36 | | 37-59 | |
| | n = 34,972 | (%) | n = 11,160 | (%) | n = 6,121 | (%) | n = 5,690 | (%) | n = 12,001 | (%) |
| Sex | | | | | | | | | | |
| Female | 17,376 | (49.7) | 5,538 | (49.6) | 3,046 | (49.8) | 2,796 | (49.1) | 5,996 | (50.0) |
| Male | 17,596 | (50.3) | 5,622 | (50.4) | 3,075 | (50.2) | 2,894 | (50.9) | 6,005 | (50.0) |
| Nutritional status (weight/height) | | | | | | | | | | |
| Normal | 30,022 | (85.8) | 9,718 | (87.1) | 5,215 | (85.2) | 4,821 | (84.7) | 10,268 | (85.6) |
| Undernutrition mild | 2,844 | (8.1) | 672 | (6.0) | 505 | (8.3) | 547 | (9.6) | 1,120 | (9.3) |
| Moderate | 287 | (0.8) | 76 | (0.7) | 69 | (1.1) | 50 | (0.9) | 92 | (0.8) |
| Severe | 60 | (0.2) | 27 | (0.2) | 14 | (0.2) | 9 | (0.2) | 10 | (0.1) |
| Overweight/obesity | 1,759 | (5.0) | 667 | (6.0) | 318 | (5.2) | 263 | (4.6) | 511 | (4.3) |
| Degree of marginalization | | | | | | | | | | |
| Very low | 13,809 | (39.5) | 3,952 | (35.4) | 2,371 | (38.7) | 2,401 | (42.2) | 5,085 | (42.4) |
| ≥ Low | 21,163 | (60.5) | 7,208 | (64.6) | 3,750 | (61.3) | 3,289 | (57.8) | 6,916 | (57.6) |
| Beneficiary of Prospera | | | | | | | | | | |
| Yes | 19,243 | (55.0) | 3,564 | (31.9) | 3,286 | (53.7) | 3,729 | (65.5) | 8.664 | (72.2) |
| No | 15,729 | (45.0) | 7,596 | (68.1) | 2,835 | (46.3) | 1,961 | (34.5) | 3,337 | (27.8) |
| Type of district | | | | | | | | | | |
| Urban | 20,503 | (58.6) | 6,696 | (60.0) | 3,249 | (53.1) | 3,282 | (57.7) | 7,276 | (60.6) |
| Rural | 14,469 | (41.4) | 4,464 | (40.0) | 2,872 | (46.9) | 2,408 | (42.3) | 4,725 | (39.4) |
| Developmental level | | | | | | | | | | |
| Normal | 27,655 | (79.1) | 9,397 | (84.2) | 4,905 | (80.1) | 4,458 | (78.3) | 8,895 | (74.1) |
| Developmental lag | 6,019 | (17.2) | 1,532 | (13.7) | 982 | (16.0) | 911 | (16.0) | 2,594 | (21.6) |
| Risk of delay | 1,298 | (3.7) | 231 | (2.1) | 234 | (3.8) | 321 | (5.6) | 512 | (4.3) |

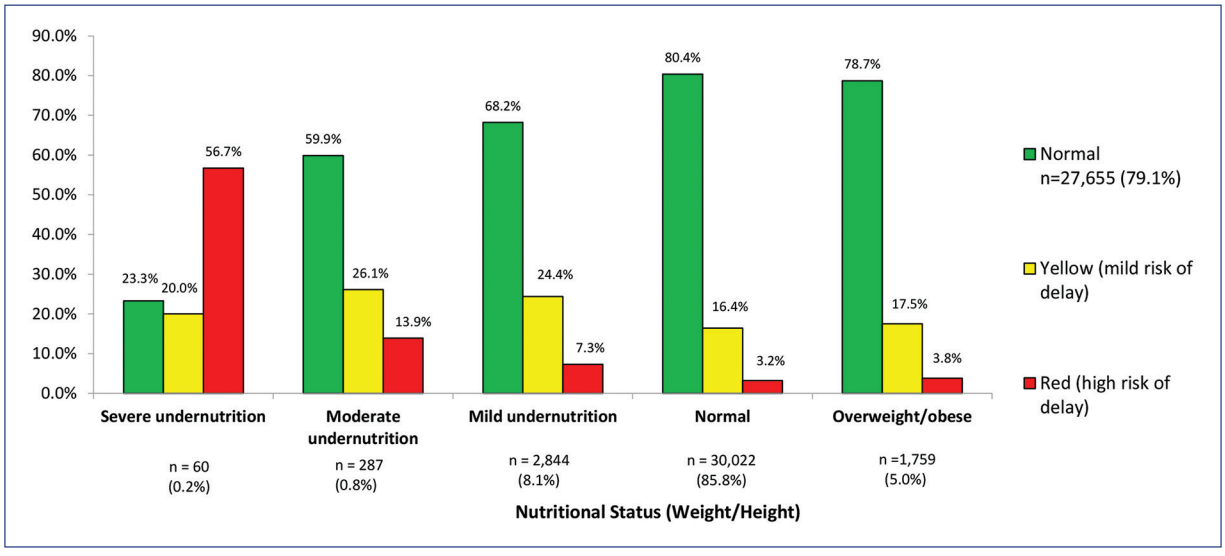


**Figure 1.** Differences in the distribution of child developmental assessment test results by nutritional status category (weight/height).

undernutrition and obesity, which represent a double burden, particularly in low- and middle-income countries[14].

Undernutrition has been significantly reduced in Mexico in recent decades; however, it shows a continued prevalence of 2.8%[13]. This problem still affects a

**Table 2.** Crude and adjusted prevalence odds ratio (POR) for disorder in child development (atypical EDI test result)

| Independent variable | POR (95% CI) | |
|---|---|---|
| | Crude | Adjusted |
| Sex | | |
| Female* | 1.000 | 1.000 |
| Male | 1.308 (1.242-1.377) | 1.318 (1.25-1.389) |
| Age group (months) | | |
| 1-12* | 1.000 | 1.000 |
| 13-24 | 1.321 (1.219-1.433) | 1.309 (1.205-1.423) |
| 25-36 | 1.473 (1.358-1.597) | 1.446 (1.329-1.574) |
| 37-59 | 1.861 (1.744-1.987) | 1.836 (1.712-1.969) |
| Nutritional status | | |
| Normal* | 1.000 | 1.000 |
| Undernutrition | 1.911 (1.757-2.078) | 1.820 (1.671-1.981) |
| Mild | 2.746 (2.165-3.483) | 2.796 (2.195-3.562) |
| Moderate | 13.493 (7.413-24.56) | 14.903 (8.149-27.257) |
| Severe | 1.109 (0.986-1.247) | 1.160 (1.030-1.307) |
| Overweight/Obesity | | |
| Beneficiary of Prospera | | |
| No* | 1.000 | 1.000 |
| Yes | 1.211 (1.149-1.276) | 1.050 (0.911-1.113) |
| Type of district | | |
| Urban* | 1.000 | 1.000 |
| Rural | 0.812 (0.770-0.856) | 0.425 (0.381-0.474) |
| Level of marginalization | | |
| Very low* | 1.000 | 1.000 |
| Low | 1.275 (1.208-1.345) | 1.057 (0.988-1.130) |
| (Type of district) × (marginalization level) | | |
| Urban district and very low level of marginalization*. | - | 1.000 |
| Rural district and≥Low level of marginalization. | - | 2.343 (2.062-2.662) |

*Reference category. 95% CI: 95% confidence interval. The shaded cells have non-significant confidence intervals. For the crude POR, we obtained the Exp (B) and 95% confidence interval (Wald) through a model with (a) binomial probability distribution; (b) logit function; (c) dependent variable: the overall result in the EDI test (reference category result: typical or green; atypical: yellow or red), and d) independent variable: each variable individually: (1). sex (reference: female); (2). age group (reference: 1-12 months); (3). nutritional status (reference: normal); (4). beneficiary of Prospera (reference: no); (5). type of district (reference: urban); (6). marginalization level (reference: very low); (7). interaction term: (type of district = rural) × (marginalization level ≥ low).

significant number of children, with long-lasting impacts including those on school performance, as described in multiple studies[17,18].

As well, in recent years childhood obesity in Mexico represents a critical public health concern as the nation exhibits one of the highest rates of the condition globally[23,24]. This issue is particularly concerning considering the potential health complications that overweight or obese children and adolescents might experience in adulthood. These complications include an increased risk of developing diabetes mellitus and cardiovascular diseases at younger ages. The results of this study indicate that overweight and obesity also affect neurodevelopment, leading to other potential problems in the long run, such as cognitive challenges. These findings indicate the need to reflect, reinforce, and expand the strategies implemented to improve nutrition at early stages of life by enhancing families' eating habits, particularly those of children and adolescents[25].

Notably, this is among the first studies in the world to show a deleterious effect of overweight/obesity on neurodevelopment in the 1st years of life, particularly in the motor areas. So far, most published studies on the possible effects of overweight on child neurodevelopment have been conducted in gestation; overall, these studies have found that children of mothers who gain more weight during their pregnancy or who are obese before pregnancy have an increased risk of developmental disorders[26]. Therefore, it is necessary to perform more studies to accurately identify the impact that overweight and obesity have on childhood development; this could help clarify the underlying mechanisms and long-term effects of these conditions on children's,

adolescents,' and young adults' cognitive, motor, and emotional capacities. This line of research was initiated by Black et al. in 2013[24].

Finally, intervention programs such as Prospera have been shown to be effective in mitigating the negative impacts of adverse socioeconomic factors on the population (in this case, on neurodevelopment). This indicates the relevance of formulating public policies that focus on early detection and attention to nutritional and childhood development problems in a multisectorial approach[27,28]. Furthermore, this study advocates for the utilization of the EDI test and analogous tools to identify developmental disorders in a timely manner in cases of malnutrition and obesity.

## Conclusion

The findings of this study confirm that neurodevelopment in children under 5 years old is influenced by both undernutrition and overweight/obesity.

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## Conflicts of interest

The authors declare no conflicts of interest.

## Ethical considerations

**Protection of humans and animals.** The authors declare that no experiments involving humans or animals were conducted for this research.

**Confidentiality, informed consent, and ethical approval.** The authors have obtained approval from the Ethics Committee for the analysis of routinely obtained and anonymized clinical data, so informed consent was not necessary. Relevant guidelines were followed.

**Declaration on the use of artificial intelligence.** The authors declare that no generative artificial intelligence was used in the writing of this manuscript.

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