Gross motor development and malnutrition in Ecuadorian children: A cross-sectional study

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Research Article

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Abstract

Objective: The objective of the present work was to study the relationship between malnutrition and gross motor development.

Methodology: Sample included 6087 infants under 24 months of age, participants of the ENSANUT-ECU study. To evaluate nutritional status we calculated z-scores by sex for body mass index/age (BAZ) and height/age (HAZ). Six gross motor milestones were evaluated: sitting without support, crawling, standing and walking with support, standing and walking without support. Data was analyzed using logistic regression models in R.

Results: Independently from age, sex and other socio-economic factors, the achievement of three gross motor milestones was significantly associated to nutritional status: sitting without support, crawling and walking without support. Compared to infants with normal HAZ, the odds of sitting without support was significantly lower among infants at risk of chronic undernutrition (OR, 0.688; 95% CI, 0.496–0.954) or with chronic undernutrition (OR, 0.601; 95% CI, 0.433–0.833). The odds of crawling (OR, 0.730; 95% CI, 0.635–0.860) and walking alone (OR, 0.741; 95% CI, 0.590–0.933) were also significantly lower among infants with chronic undernutrition in comparison to infants with normal HAZ. In general obesity/overweight were not associated with the achievement of gross motor milestones, except for sitting without support. Obese infants showed higher a odds of sitting without assistance in comparison with children with normal BAZ (OR, 1.650; 95% CI, 1.160–2.245).

Conclusions: Chronic undernutrition is related to delayed gross motor development. In Ecuador, public health measures are needed to be implemented in order to prevent malnutrition and its detrimental effects on infant development.

1. Introduction

Early-life years are important to physically and cognitively develop, so as to enter into adulthood as a healthy person (1). Psycho-motor learning, as part of a child’s developmental process, refers to the interaction and cooperation between cognitive function and physical movement. Through psycho-motor learning, infants learn to control and coordinate their movements, which is fundamental to be able to explore and learn (2, 3). Within the frame of psycho-motor learning, gross motor abilities are among the first abilities to be acquired during early infancy, and are involved in the coordinated motion of large body parts, such as arms and legs (4).

Six gross motor milestones are fundamental to self-sufficient erect locomotion and easily assessable in non-clinical settings: sitting without support, hands-and-knees crawling, standing with assistance, walking with assistance, standing alone and walking alone (5). Among healthy infants, time-windows of achievement of those six gross motor milestones vary widely, depending on the cultural setting and probably genetic makeup of the child (5). Nevertheless, in low/medium income countries like Ecuador,
acquisition of development milestones is highly sensitive to adverse socioeconomic circumstances, specially malnutrition (6–10).

In Ecuador the paradoxical coexistence of chronic undernutrition, overweight, obesity and diet-related noncommunicable diseases that is, the double burden of malnutrition is of increasing concern (11). Results of nation-wide health surveys during the last years show that while the prevalence of chronic undernutrition is decreasing, that of overweight/obesity is alarmingly increasing among infants (11). These trends are closely related to changing dietary patterns, which are increasingly rich in carbohydrates and saturated fats, and poor in nutrients such as proteins, iron, zinc and fiber (12). Malnutrition harms health throughout life, but its early emergence has particularly harmful consequences, specially if it strikes during early infancy (13).

Considering the impact of the double burden of malnutrition, and that few publications have addressed the impact of undernutrition and overweight/obesity on gross motor development, both worldwide and particularly in Ecuador, there is a need to deepen this analysis (8–10, 14–17). In this way, the objective of the present study is to study the relationship between the acquisition of gross motor milestones and nutritional status in Ecuadorian children under 24 months of age.

2. Methodology

2.1 Study design and setting

The present work is a cross-sectional study. Sample included children under 24 months old who participated in the study “Encuesta Nacional de Salud y Nutrición” (ENSANUT), which was carried out by the “Instituto Nacional de Estadísticas y Censos” (INEC) in Ecuador between 2018 and 2019. The objective of ENSANUT was to evaluate health and nutritional status and identify related problems among the Ecuadorian population (18). Data and operational manuals of ENSANUT are publicly available and can be downloaded from:

https://datosabiertos.planificacion.gob.ec/dataset/encuesta-salud-nutricion-2018

2.2 Participants form ENSANUT

Participants of ENSANUT came from urban and rural areas of whole country and included individuals from different age groups who were selected by stratified, double stage probabilistic sampling (18). During the first stage a stratified sample of primary sampling units (PSU) were randomly selected. During the second stage depending on the size of the PSU a variable number of dwellings were randomly selected for each PSU. All the dwellings were investigated and from them members of targeted age groups (18).

2.3 Eligibility criteria
Sample included all children younger than 24 months of age who participated in ENSANUT and underwent developmental evaluation, in total 6460 children. We excluded children who were two months of age or younger (n = 373) because milestones started to be acquired from three months of age. Thus, the final sample included 6087 girls and boys between three and 23 months of age.

2.4 Variables

2.4.1 Gross motor development

Six milestones that are fundamental to acquiring self-sufficient erect locomotion and are simple to evaluate according to the World Health Organization (WHO) were assessed (5). These milestones included: sitting without support, hands and knees crawling, standing with assistance, walking with assistance, standing alone, and walking without support. Assessment was performed by trained personnel. During the assessment, evaluators presented the mothers cards with figures that depicted each of the milestones and explained what they meant. Then, they were asked to select the cards with the activities that they consider their children could perform (18). Thus, for each of the six milestones two answers were possible: the child achieved or not a given milestone.

2.4.2 Nutritional status

Anthropometric data including weight and length were measured to assess the nutritional status of children. Length was measured using an infantometer, whose measuring range extends from 10 to 100 cm, with 1mm divisions. Weight was measured using an electronic scale SECA 874, with 200 kg of capacity with 50g divisions. The scale has a mother/baby function that allows to measure the weight of children while in their mother's arms. Length and weight were measured following international recommendations. Detailed information on how measurements were performed has been published before (18).

To assess infant nutritional status we calculated z-scores of height-for-age [HAZ] and body mass index (BMI)-for-age [BAZ] for males and females, using WHO Anthro Version 3.2.2, based on WHO standard growth charts for infants younger than 24 months. Risk of under-nutrition and chronic under-nutrition were defined as HAZ < 2, and HAZ ≥ -2 & < -1, respectively. Normal height/age was defined as HAZ ≥ 1. Overweight and obesity were defined as BAZ > 1 & ≤ 2, and BAZ > 2, respectively. Normal BMI/age and low BMI/age were defined as BAZ ≥ -1 and ≤ 1 and BAZ < -1, respectively (19).

2.4 Statistical analysis

We defined “acquiring or not” a given milestone as the outcome variable. We fitted six multiple logistic regression models, one for each of the milestones (see section Gross motor development). Two explanatory variables (HAZ and BAZ) were considered in the analysis, both were included in the models as categorical variables (see section Nutritional status). Models were adjusted by age [months], sex [males/female], mother's level of education [none/primary/secondary/university], ethnicity [indigenous/mestizo/Afro-descendant/white/other], residential zone [urban/rural], region [highlands,
coast, amazon, insular], mother’ job status [yes/no], income ($ per month). Age in months was modelled to allow no-linearity using restrictive cubic splines. Knot points were located at percentiles 5, 27.5, 50, 72.5, and 95, as recommended to avoid forcing curvature or inflections (20). All statistical analyses were performed using R, RStudio and related packages available in R, including rms (20–22). The function lrm from rms was used to fit the models.

3.5 Ethical considerations

The present study was performed using data that is publicly accessible and was approved by the Research Office – Escuela Superior Politécnica de Chimborazo.

3. Results

3.1 General characteristics of the sample

The sample included 6087 infants under 24 months of age. Median age for males and females was 13 months and there were no differences in age between both sexes (Table 1). Most of infants were identified by their caregivers as mestizo or indigenous, and distribution of ethnic groups between males and females was similar. Infants primarily came from urban areas of the Highlands and Coast region. The majority of caregivers reported having a job, but this percentage was slightly higher among caregivers of male infants. Median monthly income per family member of households was similar among males and females (Table 1).

Males had significantly higher weight and height than females, but the difference between both sexes was modest (Table 1). Both, chronic undernutrition and overweight/obesity were highly prevalent among infants (Table 1). In this way, between 40% and 50% of male and female infants were at risk of undernutrition, had chronic undernutrition or were overweight/obese (Table 1). Although the double burden of malnutrition was evident among infants of both sexes, males were the more affected. For instance, chronic undernutrition and obesity was more prevalent among male than female infants (Table 1).

Table 2 shows the percentage of infants who acquired a specific milestone by groups of age. As expected, we observed that the acquisition of gross motor milestones was significantly associated to age. By the age of 18 months near 98% of infants were able to sit without support (Table 2). A lower percentage (~ 72%) of infants were able to craw by the age of 18 months and this percentage did not increased much by the age of 24 months (Table 2). By the age of 18 months near 95% of infants were able to stand and walk with support, and this percentage increased further by the age of 24 months. By the age of 18 months ~ 80% of infants were able to stand without support and ~ 68% could walk without support (Table 2). In contrast, acquisition of gross motor milestones was not associated to sex (Supplementary table 1).

3.2 Sitting without support and nutritional status
Chronic undernutrition ($X^2 = 11.13$, df = 2, $p = 0.004$) and obesity ($X^2 = 14.12$, df = 3, $p = 0.003$) were significantly associated with sitting without support. The odds of sitting without support was significantly lower for children with risk of chronic undernutrition ($p = 0.025$) or with chronic undernutrition ($p = 0.002$) compared to children with normal height/age (Fig. 1 panel a, Supplementary table 2). Interestingly, the odds of sitting without support was significantly higher for children with obesity ($p = 0.005$) in contrast to children with normal BAZ. There were no significant differences between the odds of sitting without support of children with overweight ($p = 0.211$) or with low BAZ ($p = 0.382$) compared to children with normal BAZ (Fig. 1 panel b, Supplementary table 2).

### 3.3 Crawling and nutritional status

Chronic undernutrition ($X^2 = 15.47$, df = 2, $p = 0.000$) but not obesity ($X^2 = 1.72$, df = 3, $p = 0.633$) was significantly associated with crawling. The odds of crawling were significantly lower for children with chronic undernutrition ($p < 0.001$) in contrast to children with normal height/age (Fig. 2 panel a, Supplementary table 2). In contrast, the odds of crawling were similar between children with risk of chronic undernutrition and those with normal height/age ($p = 0.085$). There were no significant differences between the odds of crawling of children with obesity ($p = 0.300$), overweight ($p = 0.681$) or with low BAZ ($p = 0.615$) compared to children with normal BAZ (Fig. 1 panel b, Supplementary table 2).

### 3.4 Standing and walking with support and nutritional status

Neither chronic undernutrition ($X^2 = 1.91$, df = 2, $p = 0.385$), nor obesity ($X^2 = 3.21$, df = 3, $p = 0.360$) were associated with standing with support (Supplementary table 2). Neither chronic undernutrition ($X^2 = 1.66$, df = 2, $p = 0.437$), nor obesity ($X^2 = 1.38$, df = 3, $p = 0.711$) were associated with walking with support (Supplementary table 2).

### 3.7 Standing and walking without support and nutritional status

Neither chronic undernutrition ($X^2 = 5.68$, df = 2, $p = 0.058$), nor obesity ($X^2 = 2.82$, df = 3, $p = 0.420$) were associated with standing without support (Supplementary table 2). However, chronic undernutrition ($X^2 = 8.40$, df = 2, $p = 0.015$) but not obesity ($X^2 = 2.57$, df = 3, $p = 0.462$) was significantly associated with walking without support. The odds of walking without support were significantly lower for children with chronic undernutrition ($p < 0.010$) in contrast to children with normal height/age (Fig. 3 panel a, Supplementary table 2). In contrast, the odds of walking without support were similar between children with risk of chronic undernutrition and children with normal height/age ($p = 0.828$). There were no significant differences between the odds of walking without support of children with obesity ($p = 0.315$), overweight ($p = 0.692$) or with low BAZ ($p = 0.150$) compared to children with normal BAZ (Fig. 1 panel b, Supplementary table 2).

### 4. Discussion
The objective of the present work was to study the impact of the double burden of malnutrition on gross motor development among Ecuadorian infants. Our findings indicate that independently from age, sex and other socio-economic factors, chronic undernutrition, but not overweight/obesity is related to delayed acquisition of gross motor milestones. For instance, we found that among infants with chronic undernutrition, the odds of sitting without support, crawling and walking without support was lower than that among infants with normal HAZ. Surprisingly, we also observed that obese infants had higher odds of sitting without support in comparison to children with normal BAZ.

4.1 The double burden of malnutrition among infants in Ecuador

The Sustainable Development Goals adopted by the members of the United Nations, emphasize the need of ending hunger and all forms of malnutrition as well as achieving food security by 2030 (23). Although some progress has been made, the double burden of malnutrition is still a matter of concern in Ecuador (11, 24). In fact, our data indicate that in 2018, one fifth of Ecuadorian infants younger than 24 months suffered from chronic undernutrition and another 20% obesity. Strikingly, considering those who were at risk of chronic undernutrition or overweight, only half of Ecuadorian infants younger than 24 months achieved normal growing standards in 2018. These rates are not only alarmingly higher than those of other countries with similar income in the region, but also far away from achieving the second goal of the 2030 Agenda for Sustainable Development (25).

The emergence of obesity in a society where the problem of undernutrition has not yet been solved, is a stark indication of how a large majority of Ecuadoreans are poorly protected from the multiple factors driving malnutrition in all its forms (13). In the case of infants, their vulnerability might arise from intergenerational transmission of risk of malnutrition within a context of socio-economic disadvantage and gender inequalities (13, 26). For example, household food insecurity, a condition related to social inequalities that limits access to a nutrition and safe diet, has been consistently associated to both undernutrition and overweight/obesity (26). Moreover, there are challenges in Ecuador related to infant malnutrition that have been poorly addressed by policy makers including, poor promotion of exclusive breastfeeding and insufficient marketing regulation for infant formula (27).

4.2 Chronic undernutrition and gross motor development

Nutrition during critical phases of development has long-term effects on organ size, structure and function and thus, it is a key player in infant cognitive and physical development. It is not surprisingly then, that we and others have found that infants with chronic undernutrition are less likely to sit without support, crawl or walking alone compared to infants without undernutrition of the same age (8–10, 15–17). Moreover, since achievement of gross motor abilities requires integrity of the nervous system, the delay we observed in chronically under nourished infants might be the consequence of suboptimal brain development.
It is not well understood how nutrients contribute to brain development or behaviour; however, there are two possible mechanisms (28). On one hand, nutrients might support structural and functional development of the brain; on the other, they might enhance health and thus interaction with the environment, which stimulates brain development (28). Though all nutrients are important for brain development, there are some that are particularly important during early life, specially when their deficiency coincides with critical or sensitive periods (29). Macro and micronutrients critical for brain development and whose deficiency is highly prevalent among infants growing in low/middle income countries include, protein, long-chain polyunsaturated fatty acids, iron, zinc, and iodine (12).

Although severe delays in achievement of gross motor milestones in infancy are generally prodromal symptoms of intellectual disability, the importance of motor development is not limited to children with disabilities (30, 31). For example, among normally developing infants, achieving a gross motor milestone later than peers has unfavourable effects on adaptive skills and cognitive performance in childhood (31). Furthermore, the detrimental consequences of undernutrition on brain development might not only have an immediate effect on infant development, but cause global dysfunction on the person as a child and adult (29, 32). Along this line, undernourishment during infancy has been shown to negatively impact academic and work productivity as well as adult mental health (10).

4.3 Excess weight and gross motor development

Since we found that obese infants were more likely to sit without support in comparison to infants with normal BAZ of the same age, it seems that our results somehow contradict those of previous studies, which in general found excess of weight to be detrimental (14, 33, 34). Further, in contrast to what has been previously described we did not find evidence to support an association between delayed gross motor development and overweight/obesity (33, 34). However, it is noteworthy that besides sitting without support, obese/overweight infants were not more likely than their peers with normal weight to acquire earlier other gross motor milestones. Together these observations suggest that the effects of malnutrition related to excess of weight could be less evident during this stage of development, because it is not related to a massive deprivation of nutrients as in the case of chronic undernourishment (29, 35).

4.3 Implications, strengths and limitations

Our findings suggest a harmful influence of malnourishment on infant development. More specifically, we found that chronic undernourishment but not overweight/obesity is related to delayed gross motor development in Ecuadorian infants younger than 24 months of age. Considering the high prevalence of malnutrition among Ecuadorian infants and its deleterious consequences, a huge impact on the general health and productivity of the population is expected within few years. This last observation highlight the need of an immediate response from public health policy makers in order to resolve the problem of infant malnutrition in Ecuador and keep aligned with the 2030 Agenda for Sustainable Development.

Still our work has some limitations that should be considered. First, because of the nature of our study design we were unable to establish a causal association between malnutrition and delayed gross motor development. Second, despite we adjusted our statistical models by influential confounders including age...
and mother’s level of education, we were not able to take into account the impact of other important factors such as birth weight. Nevertheless, our models were able to explain a substantial part of the outcome variance and had a good level of classification accuracy. Third, although the exposure was objectively measured following international standards, the measure of achievement of gross motor milestones relayed on the information given by caregivers, probably introducing information bias.

Conclusions

The double burden of malnutrition is worrisome reality of Ecuadorian infants. Only half of Ecuadorian infants younger than 24 months of age achieved normal growing standards in 2018. Chronically undernourished infants are less likely to timely develop their motor abilities, which might prevent them for reaching their full potential as children and adults. It is very important that every infant grows up in an environment that favours her/his cognitive and physical development, which should include adequate nutrition. Public health interventions to overcome the double burden of malnutrition among infants are needed in Ecuador. More studies are needed to understand the dramatical failure of previous interventions and made aware the public administration of the harmful consequences of malnutrition for development of Ecuadorian society.

Declarations

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Conflict of 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.

Founding

None.

Author contributions
The corresponding author of this work declares that all authors have contributed and work on the development of it as follows. BC: Conception and design, analysis and interpretation of data, drafting of the article, final approval of the version to be published. DJGV: Conception and design, analysis and interpretation of data, drafting of the article, final approval of the version to be published. TVCA Conception and design, analysis and interpretation of data, drafting of the article, final approval of the version to be published. SD: Critical revision for important intellectual content, writing and final approval of the version to be published. ADVV: Critical revision for important intellectual content, writing and final approval of the version to be published. MPRV: Critical revision for important intellectual content, writing and final approval of the version to be published. YAMT: Critical revision for important intellectual content, writing and final approval of the version to be published. MFVV: Conception and design, analysis and interpretation of data, drafting of the article, critical revision for important intellectual content, final approval of the version to be published.

Data statement

Data and operational manuals of ENSANUT-ECU are publicly available and can be downloaded from INEC web page:

https://datosabiertos.planificacion.gob.ec/dataset/encuesta-salud-nutricion-2018

References


Tables

Tables 1-2 are available in the supplementary files section.

Figures
Figure 1

Odds of sitting without support by age for different nutritional status.
Figure 2

Odds of crawling by age for different nutritional status.
Figure 3

Odds of walking without support by age for different nutritional status.

Supplementary Files

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