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Neurodevelopment and timely early stimulation in children of indigenous migrant and non-migrant mothers in Chihuahua, Mexico

Marsela Alejandra Álvarez-Izazaga[1], Carlos Galindo-Gómez[2*], José Antonio Roldán-Amaro[2], Gabriel Saucedo-Arteaga[1], Margarita Díaz-Martínez[3], Adolfo Chávez-Villasana[1], and Mario Cuchillo-Hilario[3]

1 Departamento de Nutrición Aplicada y Educación Nutricional, Instituto Nacional de Ciencias Médicas y Nutrición Salvador Zubirán, Ciudad de México (México)
2 Dirección de Nutrición, Instituto Nacional de Ciencias Médicas y Nutrición Salvador Zubirán, Ciudad de México (México)
3 Departamento de Nutrición Animal, Instituto Nacional de Ciencias Médicas y Nutrición Salvador Zubirán, Ciudad de México (México)

Título: Neurodesarrollo y estimulación oportuna en niños de madres indígenas migrantes y no migrantes en Chihuahua, México
Resumen: El objetivo de este estudio fue comparar características generales y de atención en salud entre menores y sus madres migrantes y no migrantes en indígenas Tarahumaras, en Chihuahua, México. Así mismo, se evaluó la asociación entre el riesgo de retraso en neurodesarrollo en niños y las prácticas de estimulación oportuna. Niños y niñas de entre 12 a 48 meses de edad fueron estudiados en dos grupos: 1) menores de madres migrantes ubicados en asentamientos urbanos en la ciudad de Chihuahua y 2) menores de madres no migrantes residentes en sus localidades de origen. La prevalencia de riesgo de retraso del neurodesarrollo moderado y grave (RNMG) fue mayor en menores de madres migrantes versus no migrantes (75.6%, IC95% [69.5, 80.8] vs 59.8%, [51.4, 67.7], p = .003). La proporción de niños(as) que recibieron una estimulación oportuna favorable (EOF) en casa fue mayor en los menores de madres no migrantes (p < .001). La migración de las madres indígenas hacia asentamientos urbanos estuvo asociada al RNMG en sus hijos(as) (p = .03), así como las prácticas insuficientes de estimulación oportuna (p = .03). La asistencia consistente a sesiones de estimulación temprana del programa de Educación Inicial fue mayor en niños(as) de madres no migrantes (p = .01); y la no asistencia fue predictor del RNMG (p = .02).
Palabras clave: Tarahumaras. Migración indígena. Neurodesarrollo infantil. Estimulación infantil temprana. Estimulación oportuna.

Abstract: This study aimed to compare the general and health care characteristics of young children of migrant and non-migrant mothers from indigenous Tarahumara communities in Chihuahua, Mexico, and to evaluate the association between child risk for neurodevelopment delay with parental practices of early childhood stimulation. Male and female children aged 12 to 48 months were studied in two groups: 1) children of migrant mothers residing in urban settlements and 2) children of non-migrant mothers residing in their native rural localities. Prevalence of the risk of moderate to severe neurodevelopment delay (MSND) was greater in children of migrant mothers as compared to non-migrant mothers (75.6%, CI95% [69.5, 80.8] *vs.* 59.8%, [51.4, 67.7], p = .003). The proportion of children who received adequate and favorable early stimulation (FTES) at home was greater in children of non-migrant mothers (p < .001). The migration of indigenous mothers to urban settlements was associated with child MSND (p = .03), as well as to insufficient early stimulation practices (p = .03). Consistent attendance at early childhood stimulation sessions through the Initial Education program was greater in children of non-migrant mothers (p = .01), and non-attendance predicted child MSND (p = .02).
Keywords: Tarahumara. Indigenous migration. Childhood neurodevelopment. Early childhood stimulation. Timely stimulation.

Introduction

Approximately 80% of key milestones for childhood neurodevelopment are achieved during the first three years of life. During the following two years, around 90% of cognitive functions supporting the development of new abilities are perfected (Loor-Rivadeneira et al., 2018). Factors such as the lack of cognitive stimulation at home linked to poverty and isolation interfere in early childhood neurodevelopment (Martell et al., 2007). In Mexico, the assessment of childhood neurodevelopment is stipulated in the Official Mexican Standard (in Spanish, NOM) for child healthcare (NOM-031-SSA2, 1999). A screening tool for the developmental assessment of children (in Spanish, EDI) is available (Rizzoli-Córdoba, Campos-Maldonado, et al., 2015); nonetheless, it has not been applied at the national level.

Current estimates indicate the existence of 272 million international migrants worldwide: equivalent to 3.5% of the global population (IOM, 2019). During the migration process, children are the sociodemographic group most exposed to negative impacts in health and development. A 2002-2016 systematic review of the literature in developing countries looked at children from 0 to 18 years of age to compare children born to migrant or refugee mothers to children who were not. It concluded that children in the former group were at higher risk for neurological disorders such as autism, intellectual deficits and attention-deficit/hyperactivity disorder (Abdullahi et al., 2018). Psychological wellbeing is affected in migrant children and adolescents, particularly since they are likely targets of child abuse (Gao et al., 2017), spend less quality time with parents and experience limited early childhood stimulation. This in turn has negative effects on child cognitive development, academic performance and physical health (Powers, 2011). Evidence indicates that migration during childhood affects neurodevelopment. Schmengler et al. (2019) demonstrated the importance of the timely detection of signs of neurological abnormalities in immigrant children two years of age, given the potential repercussions for age-appropriate development.

Migration exposes children and adolescents to additional health risks, including malnutrition and communicable diseases (ISSOP-Migration Working Group, 2018). Even the shift from a rural to an urban environment may influence the likelihood of child mortality. This was demonstrated in a na-

*** Correspondence address [Dirección para correspondencia]:**
Carlos Galindo Gómez. Dirección de Nutrición, Instituto Nacional de Ciencias Médicas y Nutrición Salvador Zubirán. Av. Vasco de Quiroga 15, Col. Belisario Domínguez Sección XVI, Delegación Tlalpan, C.P. 14080, Ciudad de México (México). E-mail: carlos.galindog@incmnsz.mx
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tionally representative study in Nigeria where children below five years of age born to non-migrant rural mothers showed a lower risk of mortality than their migrant counterparts. Determinant factors for migrants included the rupture of familial and community ties, low socioeconomic status, social vulnerability, and difficulties adapting to urban settings and new environmental conditions (Antai et al., 2010). Further negative impacts on general health have also been demonstrated, particularly in children and adolescents displaced due to changes in the marital status of their mothers (Anglewicz et al., 2019).

Migrations occur in the optimistic context of seeking an improved quality of life, but often result in worse living conditions in the short term. For example, international literature points to increased poverty and reduced primary-level health care (Rice & Webster, 2017), as well as inadequate medical care provided to pregnant women during delivery and postpartum (Phillimore, 2016). One exemplary case is the Kichwa indigenous community of the Tunguruhua Province of Ecuador, where migration to large cities as a survival strategy has led to begging by women and children (Pinos Montenegro, 2016).

In Mexico, indigenous migrants – especially children and adolescents - face significant challenges in terms of language barriers (Colmenares-Roa et al., 2017) and unfamiliar cultural practices in the urban zones where they arrive (León-Pérez, 2019), and are subject to marginalization (Franco-García, 2016). Furthermore, they experience inequalities in general health outcomes (Juárez-Ramírez et al., 2014) and, in the case of children below five years of age, in nutritional status (Ortega et al., 2012). Existing evidence indicates significant contrasts between indigenous populations residing in their native territory and those who reside in urban areas (Roldán et al., 2017) which are not fully explained by the act of rural-urban migration. The Tarahumara ethnic group in the state of Chihuahua is one of 62 indigenous groups in Mexico who experience extreme poverty. In 2008, the Tarahumara region suffered a famine which spurred the emigration of many families (Roldan et al., 2012). In light of this, it is critical to study the migration of vulnerable ethnic groups from marginalized and overwhelmingly rural areas, to urban areas. This process may imply detrimental health effects for children of migrant mothers, especially in the early childhood stage.

Our study therefore has two objectives: 1) to compare the general and health care characteristics of mothers and their children from 12 to 48 months of age for both migrant mothers in urban settlements in Chihuahua City, Mexico and in non-migrant mothers residing in rural indigenous localities in the state of Chihuahua; and 2) to assess the association between a) the risk of neurodevelopment delays in these children and b) the migration condition of their indigenous Tarahumara mothers and the parental early stimulation practices provided to children at home.

Methods

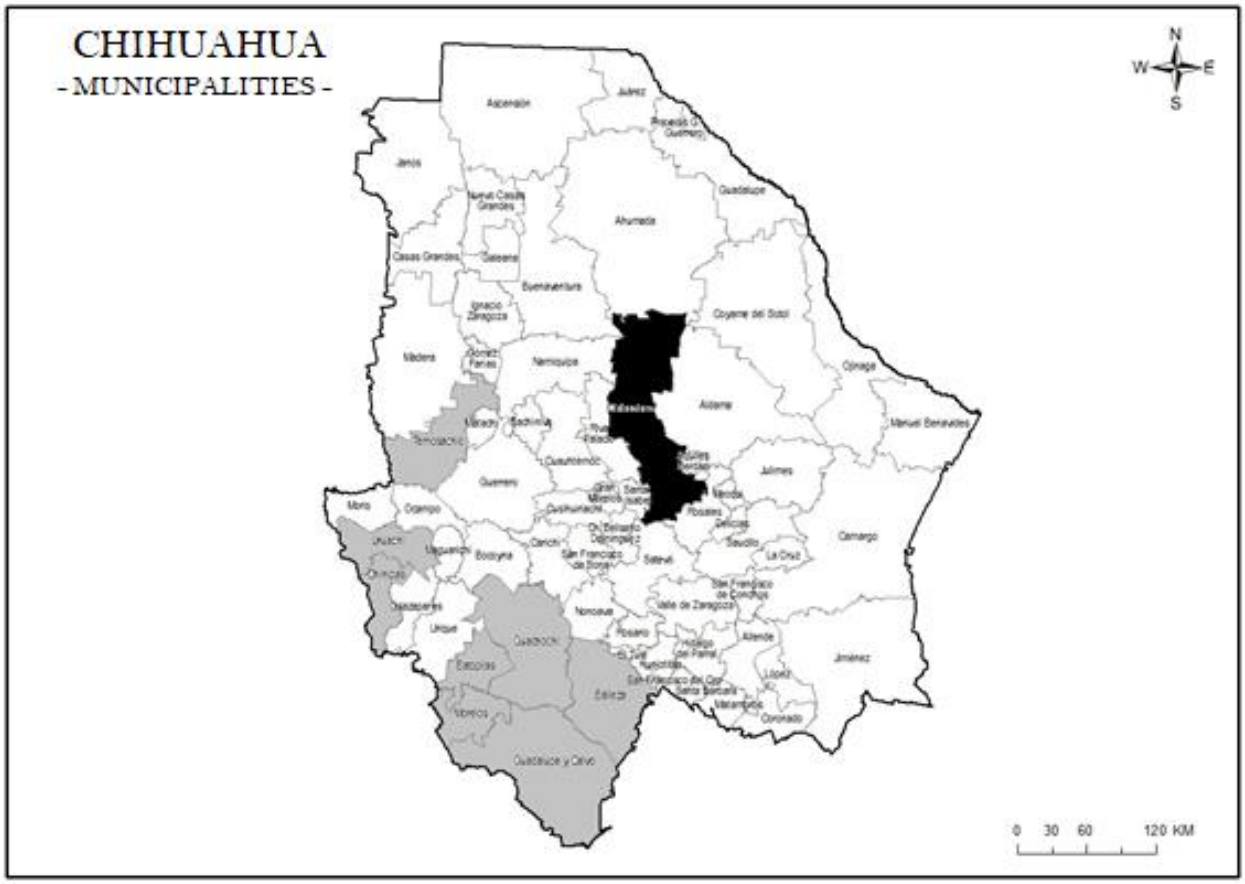
Study site

The Tarahumaras, or self-identified Rarámuris, are an indigenous community in the north of Mexico. They are native to a section of the Sierra Madre Occidental which passes through the state of Chihuahua as well as the southeast regions of Durango and Sonora. The Tarahumaras occupy one fourth of the territory of Chihuahua and are mainly concentrated within 17 municipalities spanning the similarly named Sierra Tarahumara. In general, the Tarahumara lack access to healthcare services and must travel multiple hours to seek medical attention, in addition to suffering from a poor diet (Roldan et al., 2012). Chihuahua City has over 100 unofficial settlements where the indigenous migrant population resides. While these settlements were originally built on the outskirts of the city, their continuous growth now places them within city boundaries. These settlements have some basic public services such as electricity, water, sewage, transportation, streetlights and primary education institutions. Indigenous families in these suburb areas have resided there an average of 20 years (Saucedo et al., 2012).

Study design

We conducted a transversal study from January to October of 2015 using information from the indigenous Tarahumara populations residing in both urban settlements of Chihuahua City and rural localities in eight municipalities of the state of Chihuahua, corresponding to the migrant and non-migrant population, respectively. We therefore defined two groups of interest: 1) migrant mothers residing in three urban settlements in Chihuahua City, selected by convenience sampling near a shelter maintained by the National Commission for the Development of Indigenous Communities (in Spanish, CDI) specifically created for families who migrate from the Sierra Tarahumara to Chihuahua City, and 2) non-migrant mothers native to and residing in 29 rural localities throughout eight predominantly indigenous (≥ 40% of the total population) municipalities in the Sierra Tarahumara, Chihuahua. Selection of localities was by convenience within the CDI sphere of influence, where shelter-schools were installed to serve the population living in the Sierra and which have less than 500 inhabitants. Urban settlements and rural localities were selected based on CDI guidance which determined the selected areas as reflective of the populations of interest (Figure 1).

Figure 1
Selected municipalities reflective of the indigenous population in the state of Chihuahua. Chihuahua City is marked in black.



Study population

Both study groups included children of both sexes aged 12 to 48 months and who were children of indigenous mothers. The indigenous mother-child pair was defined by the ability to speak an indigenous language and by the mother's ethnic self-identification as Tarahumara. Inclusion criteria were: children aged 12, 18, 24, 36 or 48 months at time of study (± 1 month) without visible signs of neurological damage, whether residing in the selected urban settlements in Chihuahua City or born in the selected rural localities. Selection was performed through house visits to a total of 518 families in 29 selected rural localities, and 250 families in the selected urban settlements, resulting in a final recruitment of 276 children and their respective mothers. Table 1 shows the representative municipalities selected, including the numbers of localities/settlements selected, families interviewed, and children who made up the total study sample.

Table 1
Municipalities and sites selected as reflective of the indigenous Tarahumara population.

Municipalities in the state of Chihuahua	Rural localities	Families interviewed	Children recruited
Balleza	4	73	15
Batopilas	3	52	13
Chinipas	1	22	3
Guachochi	6	78	16
Uruachi	1	29	3
Guadalupe y calvo	8	163	41
Morelos	1	34	4
Temósachi	5	67	17
Urban settlements			
Chihuahua City	3	250	164
TOTAL	32	768	276

Assessment of the risk of delayed childhood neurological development

To assess the risk for delayed neurological development in the children recruited, we applied the Screening Test for Early Childhood Neurodevelopment (in Spanish, PTNI), designed and validated by the Instituto Nacional de Ciencias Médicas y Nutrición Salvador Zubirán (INCMNSZ). This test is applicable to five pre-school age groups in critical de-

velopmental stages for evaluation: 12, 18, 24, 36 and 48 months (± 1 month). Timely detection of a developmental delay (before 24 months of age) can signal interventions to facilitate the development of new age-appropriate abilities, and may allow the child to still achieve the expected neurological maturity (Bolaños, 2002; Shaffer, 2000). After 24 months of age, when development is less rapid, annual assessment is recommended to ascertain whether or not the child has reached optimal development of the expected age-appropriate abilities. In this way, developmental stages prior to five years of age where cerebral plasticity is greater represent windows of opportunity which can be taken advantage of to ensure adequate development (Shaffer, 2000). The PTNI addresses six areas of childhood neurodevelopment: gross motor, fine motor, language, cognitive, social-affective and independence. The total test score is out of a maximum of 12 points, and conforms the following ranges: 1) 0-6 points - "serious risk of delay" equivalent to an evident risk of delay, 2) 6.5 - 8 points - "moderate risk of delay" indicating that the child has not achieved adequate and appropriate development for his or her age, 3) 8.5 - 10 points – "mild risk of delay" where child has failed to exhibit three of the 12 expected behaviors, indicating the need for timely early stimulation at home, and 4) 11 - 12 points – "normal neurodevelopment" if the child exhibits 11 - 12 of the 12 behaviors and therefore appears to have reached adequate cognitive development. Results falling under the first two categories (0 - 8 points) should be referred for diagnostic tests and specialized care for the child.

The creators of the PTNI applied expertise in childhood neurodevelopment to determine a set of ideal behaviors which represent different developmental milestones and serve to detect potential structural or functional damage due to underdevelopment of the central nervous system. The results of PTNI pilot studies such as the literature review of key evidence (WHO, 2006; Newborg, 2011), as well as the validation of the study context, may be found in Ávila et al. (2013). The test demonstrates a sensitivity of 0.88, specificity of 0.77, and reliability by internal consistency with a Kuder-Richardson 20 coefficient of 0.724. The PTNI is simple and easily applied by trained personnel. It is a screening tool designed for practical community-level use (Ávila et al., 2013), and has been applied in a variety of studies across all states of Mexico (Ávila et al. 2013, 2018).

Assessment of timely early stimulation practices

We used the Timely Early Stimulation Scale (in Spanish, EEO) to evaluate parental practices of early childhood stimulation, which consists of a set of questions querying activities the mother or child-caregiver performs to stimulate her child's neurodevelopment. Each question has three response options: daily = 1, sometimes = 0.5 and never = 0. Input by experts on timely/early stimulation, neurodevelopment and psychometry contributed to a list of timely stimulation practices which is divided into three categories: 1) "minimal stimulation" (0 - 16 points) indicating that the mother or child-caregiver interacts with the child to only a minimum extent, at the disadvantage of the child's neurodevelopment; 2) "moderate stimulation" (16.5 - 20 points) indicating that the mother or child-caregiver interacts with the child but not sufficiently to enable optimal neurodevelopment for his or her age; and 3) "favorable stimulation" (20.5 - 24 points) indicating that the mother or child-caregiver adequately stimulates the child according to age-appropriate needs, through playing and spending quality time with him or her (Ávila et al., 2013). The EEO scale has criterion validity and reliability for internal consistency with a Kuder-Richardson coefficient of 0.81.

Both instruments (the PTNI and EEO) were adapted to the indigenous Tarahumara population and tested prior to the study in order to minimize application errors. Adaptation and testing were performed by expert professionals in neurodevelopment assessment.

General and health care characteristics of the mother-child pair

We applied a questionnaire to collect general information on subjects, as well as pre- and peri-natal risks and childrearing and care context (Ávila et al., 2013). Questions were related to: 1) the child, such as age and gender; 2) the mother-child pair, such as complication during pregnancy and delivery, healthcare services received during delivery, breastfeeding during the first 30 minutes post-delivery, and amount of mother and child time spent together; and 3) the mother, such as her marital status. Additional questions related to the birth order of the child in relation to any other siblings, whether he or she lives with a father, who is his or her main caretaker, and whether he or she has participated in timely/early stimulation sessions through the Initial Education program. The questionnaire was adapted to the indigenous population and tested prior to the study.

Procedures

A group of 15 bilingual health professionals and indigenous Initial Education professors native to the selected localities were trained in the application of the PTNI, EEO and questionnaire on general and health care characteristics. They also received orientation for explaining to mothers the importance of their child's participation, the appropriate treatment of the children during assessment and the need for informed consent. Furthermore, personnel acted as indigenous translators (in their native language of Tarahumara) in order to facilitate the logistics of entrance to localities and settlements, and house visits to recruit children accompanied by their mother or caretaker who met the inclusion criteria. Application of the PTNI, EEO and questionnaire took place in an adequate space within the child's home, and took an average of 40 minutes. In cases where the child would not engage with the evaluator, the mother was asked to interact

with the child in order to observe and record his or her behaviors. This situation was documented in 8% of visits, and did not appear to interfere in successful data collection. The general and health care information questionnaire for the mother-child pair was applied to the mother. Prior to data gathering, a pilot study was performed for both assessment tools and questionnaire in order to minimize data collection errors. In addition to conducting training, study researchers supervised data collection to guarantee data quality.

Statistical analysis

We estimated prevalence for each category of neurodevelopment and timely early stimulation for each study group. Children were divided into two age groups: 1) 12 - 24 months (including children of 12, 18, and 24 months of life ± 1 month), and 2) 36 - 48 months (including children of 36 and 48 months of life ± 1 month). For each group, prevalence of the variables and categories of interest were obtained with their respective 95% confidence intervals (CI95%). For the PTNI variable "risk of neurodevelopment delay", we divided the original categories into two: 1) "moderate/severe risk of neurodevelopment delay (MSND)" indicating that the child must be referred to a specialist to confirm diagnosis and receive necessary care for potential central nervous system damage, and 2) "mild risk of neurodevelopment delay or normal neurodevelopment" (MND/N) indicating that the child would only require the initiation or continuation of timely stimulation to reach normal development. In the case of the EEO variable "timely early stimulation", we also established two categories: 1) "insufficient timely early stimulation" (ITES) (by combining the original "minimal stimulation" and "moderate stimulation" categories) indicating that the child has not received adequate stimulation to allow the development of age-appropriate abilities and capacities, and 2) "favorable timely early stimulation" (FTES) indicating that the child assessed received adequate stimulation for optimal brain development. For the general and health care characteristics of the indigenous mother-child pairs, we calculated prevalence with CI95% for comparison between both groups, and used the chi² test for homogeneity to evaluate the differences of proportion between different categories. In addition, we applied the Mann Whitney U-test and student *t*-test for the comparison of medians or means, as applicable. The normality of data points obtained from the total PTNI and EEO scores was evaluated through Skewness/Kurtosis and Shapiro-Wilk tests. To quantify the association between the condition of child MSND with the migrant condition of their mother and ITES, we generated two logistic regression models to estimate odds ratios (OR) with CI95%. The first model estimated raw ORs for each variable. The second model estimated adjusted ORs for each variable. In both models, the dependent variable was MSND and covariables were the various characteristics of interest. Standard errors were adjusted for variable dependence in the interior of the localities/settlements (Hosmer et al., 2013). Data were analyzed using the program STATA, 2015.

Ethical considerations

Evaluators explained to mothers or child-caregivers the importance of their child's participation in the study. Their authorization to participate was provided via signature or fingerprint on an informed consent form, which included details on the advantages and disadvantages of free and voluntary participation in the study. The form also specified that the decision not to participate would have no negative repercussions. These explanations were provided in the native language of the potential participant when he or she did not speak Spanish. The study was approved by the Research Ethics Committee of the INCMNSZ.

Results

Prevalence for the risk categories of developmental delay in migrant mothers and children was: mild – 18.3% CI95% [13.2, 24.8], moderate - 33.5% [27. 4, 40.3] and severe - 42.1% [31.0, 54.0]. These were statistically distinct from the non-migrant group, which showed: mild - 17.0% [10.2, 26.7], moderate - 24.1% [17.3, 32.5] and severe - 35.7% [27.1, 45.3] ($\chi^2 = 17.6878$, $p = .0013$). In terms of timely early stimulation, significant contrasts were also observed between different categories: minimal - (86.6% [81.7, 90.3] *vs.* 56.3% [45.6, 66.4]), moderate - (12.8% [9.3,17.5] *vs.* 33.9% [27.1, 41.5]) and sufficient - (0.6% [0.4, 0.8] *vs.* 9.8% [5.0, 18.4]) ($\chi^2 = 35.1253$, $p < .001$) for migrants and non-migrants, respectively (Figure 2).

Figure 2
Prevalence of risk categories for neurodevelopment delays and timely early stimulation, by children of migrant and non-migrant mothers.

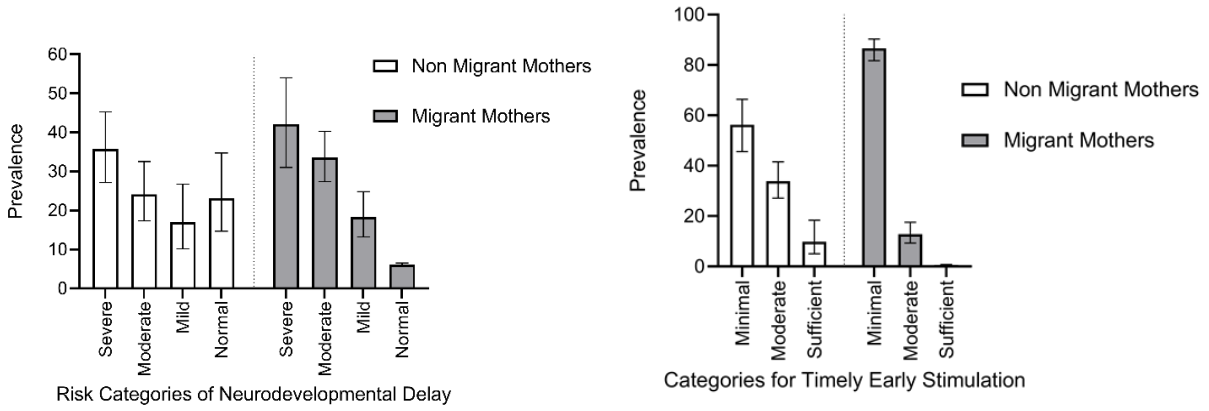


Table 2 describes the characteristics of indigenous mothers and children by their migratory condition. Among children, no statistically significant differences were observed by age in either group. As far as gender, the percentage of male children was greater in the non-migrant mother group (p = .018). The median and mean were statistically different for PTNI and EEO scores between the two study groups (p = .005 and p < .001, respectively). Significant differences were also noted between the two groups in terms of MSND (75.6% for migrant mothers *vs.* 59.8% in non-migrant mothers) (p = .003), as well as for ITES among the same groups (99.4% and 90.2%, respectively) (p < .001). Consistent attendance (daily or up to three times a week) at timely early stimulation sessions through the Initial Education program was greater in rural localities that in urban settlements (20.6% *vs.* 10.4%) (p = .003). Rates of pregnancy complications (p = .006) and delivery complications (p = .003) were greater in non-migrant mothers (22.3% and 25.4%, respectively) than in women who migrated to the city (12.4% and 13.0%, respectively). The majority of births for both groups of mothers were attended by physicians; however, this was more true in migrant mothers as compared with non-migrant mothers (80.5% *vs.* 60.4%, respectively) (p = .002). In contrast, women delivering in their native rural localities were more frequently attended by nurses or midwives, or in some cases, gave birth unattended (39.6%). As far as the best practice of initiating breastfeeding in the first 30 minutes post-delivery, a greater negative response was obtained from migrant mothers (20.1%) than non-migrants who remained in their native rural localities (12.7% (p = .038).

Table 2
General and health care characteristics of indigenous children and mothers by study group[a], Chihuahua, Mexico.

Characteristics	*Migrant mothers in urban settlements (n = 164)*	*Non-migrant mothers in rural localities (n = 112)*	*p-value*	*TOTAL (n = 276)*
General (child)				
Age in months % [CI95%][b]				
12 to 24	58.5 [57.4,59.7]	60.7 [52.2,68.6]	.600 [o]	59.4 [55.9,62.8]
36 to 48	41.5 [40.3,42.6]	39.3 [31.4,47.8]		40.6 [37.2,44.1]
Gender % [CI95%]				
Male	45.7 [42.6,48.9]	57.1 [48.4,65.4]	.018 [o]	50.4 [42.9,57.8]
Female	54.3 [51.1,57.4]	42.9 [34.6,51.6]		49.6 [42.2,57.1]
Total PTNI score[c]				
Median (P_{25}-P_{75})[d]	6.8 (4.0,8.0)	7.5 (5.5,10.0)	.005 [p]	7.0 (4.5,9.0)
Neurodevelopment category % [CI95%]				
MSND[e]	75.6 [69.5,80.8]	59.8 [51.4,67.7]	.003 [o]	69.2 [63.9,74.0]
MND/N[f]	24.4 [19.2,30.5]	40.2 [32.3,48.6]		30.8 [25.1,36.1]
Total EEO score[g]				
Mean (SE)[h]	12.1 (0.29)	15.1 (0.48)	< .001 [p]	13.3 (0.50)
Timely early stimulation category % [CI95%]				
Insufficient (ITES)	99.4 [99.2,99.6]	90.2 [81.6,95.0]	< .001 [o]	95.7 [87.9,98.5]
Favorable (FTES)	0.6 [.04,0.8]	9.8 [5.0,18.4]		4.3 [1.5,12.1]
Birth position in relation to siblings[XX] % [CI95%]				
First-born	29.9 [23.1,37.7]	33.9 [25.5,43.5]	.484 [o]	31.5 [27.1,36.3]
Second-born or later	70.1 [62.3,77.0]	66.1 [56.5,74.5]		68.5 [63.7,72.9]
Residing with father % [CI95%]				

Characteristics	*Migrant mothers in urban settlements (n = 164)*	*Non-migrant mothers in rural localities (n = 112)*	*p-value*	*TOTAL (n = 276)*
Yes	77.8 [72.9, 82.0]	79.5 [73.4, 84.4]	.634 [o]	78.5 [74.2, 82.2]
No	22.2 [18.0, 27.1]	20.5 [15.6, 26.6]		21.5 [17.8, 25.9]
Attends or has attended Initial Education[i] % [CI95%]				
Never	89.6 [88.3, 91.0]	79.4 [67.9, 87.6]	.011 [o]	85.5 [79.4, 90.0]
Daily or up to three times/week	10.4 [9.2, 11.7]	20.6 [12.4, 32.1]		14.5 [10.0, 20.6]
Child caretaker[j] % [CI95%]				
Mother	98.2 [75.3, 99.9]	90.2 [82.4, 94.7]	.184 [o]	94.9 [81.8, 98.7]
Father/Grandmother/Sister	1.9 [0.1, 24.7]	9.8 [5.3, 17.6]		5.1 [1.3, 18.2]
Pregnancy complications of mother % [CI95%]				
Yes	12.4 [9.9, 15.4]	22.3 [15.7, 30.7]	.006 [o]	16.4 [11.1, 23.6]
No	87.6 [84.6, 90.1]	77.7 [69.3, 84.3]		83.6 [76.4, 88.9]
Delivery complications of mother[k] % [CI95%]				
Yes	13.0 [11.1, 15.3]	25.4 [17.4, 35.7]	.003 [o]	18.1 [13.1, 24.4]
No	87.0 [84.7, 88.9]	74.6 [64.3, 82.6]		81.9 [75.6, 86.9]
Birth attendance for mother[l] % [CI95%]				
Physician in hospital/health center	80.5 [78.3, 82.5]	60.4 [45.6, 73.4]	.002 [o]	72.4 [62.1, 80.7]
Nurse/midwife at home or unattended birth	19.5 [17.5, 21.7]	39.6 [26.6, 54.4]		27.6 [19.3, 37.9]
Breastfeeding during the first 30 minutes post-delivery[m] % [CI95%]				
Yes	79.9 [78.7, 81.0]	87.3 [80.4, 91.9]	.038 [o]	82.9 [78.3, 86.6]
No	20.1 [18.9, 21.3]	12.7 [8.0, 19.6]		17.1 [13.4, 21.7]
Mother time spent with child[n] % [CI95%]				
All day	54.3 [51.6, 57.0]	58.0 [46.8, 68.5]	.506 [o]	55.8 [50.6, 60.9]
≥ 1 hour apart	45.7 [43.1, 48.4]	42.0 [31.5, 53.2]		44.2 [39.1, 49.4]
Marital status of mother % [CI95%]				
Married/domestic partnership	86.5 [85.7, 87.3]	81.2 [73.1, 87.4]	.101 [o]	84.4 [80.4, 87.6]
Single/divorced/widowed	13.5 [12.8, 14.3]	18.8 [12.6, 26.9]		15.6 [12.4, 19.6]

Note: Estimates are adjusted by study groups/strata and by localities/settlements. [a]Obtained from children aged 12, 18, 24, 36, 48 months (±1 month). [b]CI95% = 95% confidence interval. [c]Obtained through the PTNI test applied to children in each corresponding age group. [d]P_{25}-P_{75} = percentile 25, percentile 75. [e]MSND = moderate to severe risk of neurodevelopment delay. [f]MND/N = mild risk of neurodevelopment delay or normal neurodevelopment. [g]Obtained through the EEO test applied to children in each corresponding age group. [h]SE = standard error. [xx]Birth order of child according to their positioning among any living siblings of the same mother. [i]Initial Education = timely early stimulation sessions for children under four years of age coordinated by the National Council for Educational Advancement (in Spanish, CONAFE) in marginalized rural localities and urban settlements. [j]Family member charged with care of the child during the majority of each day. [k]Complications experienced by mother or child during labor or delivery. [l]Person or persons present and attending child delivery. [m]Immediately, during the first 30 minutes post-delivery. [n]Time which mother and child spend physically together. [o]Chi² test for different of proportions, for comparison among study groups. [p]Student t-test (means) or Mann-Whitney U-test (medians). Normality of data was assessed using Skewness/Kurtosis and Shapiro-Wilk tests.

Table 3 shows the second model, where adjusted odds ratios predict the risk for moderate to severe neurodevelopment delay (MSND) in children. The migrant condition of the mother in urban settlements determined greater MSND in children, as compared to non-migrant mothers who stayed in their native rural localities (OR = 1.92, p = .03). Children who were second-born or later (i.e., not first-born) among their siblings showed a greater likelihood of suffering MSND (OR = 1.61, p = .03). Children who received insufficient timely early stimulation (ITES) from their caretaker showed a greater probability for risk of neurodevelopment delay (OR = 12.7, p = .03). Not attending Initial Education sessions was also associated with child MSND (OR = 2.30, p = .02). Similarly, children with a person other than the mother as a caregiver during the day presented a considerable risk of MSND (OR = 14.9, p = .00).

Table 3

Raw and adjusted odds ratios (OR) for moderate to severe risk of neurodevelopment delay (MSND) in children, by migrant condition of the indigenous mother, timely early stimulation practices at home and relevant characteristics.

Characteristics	Model 1[a] OR	[CI95%][c]		SE[d]	*p*	Model 2[b] OR	[CI95%]		SE	*p*
Migrant mother in urban settlement[e]										
Yes	2.08	1.32	3.29	0.47	.00	1.92	1.05	3.49	0.56	.03
Gender of child[f]										
Male	0.86	0.60	1.24	0.15	.41	0.93	0.60	1.43	0.20	.73
Age in months[g] (n)										

Characteristics	Model 1[a]					Model 2[b]				
	OR	[CI95%][c]		SE[d]	*p*	OR	[CI95%]		SE	*p*
12 to 24	1.04	0.60	1.79	0.28	.90	1.15	0.61	2.16	0.36	.66
Birth position in relation to siblings[h]										
Second-born or later child	1.49	0.91	2.44	0.36	.11	1.61	1.05	2.47	0.34	.03
Residing with father[j]										
Yes	1.14	0.62	2.12	0.35	.66	1.00	0.56	1.78	0.28	1.00
Timely early stimulation[k]										
Insufficient (ITES)	12.6	2.66	59.6	9.59	.00	12.7	1.34	119.9	13.9	.03
Attends or has attended IE[l]										
Never	2.33	1.25	4.35	0.71	.01	2.30	1.18	4.48	0.75	.02
Pregnancy complications of mother[ll]										
Yes	1.00	0.49	2.03	0.35	.99	1.06	0.53	2.12	0.36	.87
Delivery complications of mother[m]										
Yes	0.89	0.55	1.44	0.21	.63	1.04	0.60	1.81	0.28	.88
Birth attendance for mother[n]										
Physician in hospital/health center	0.69	0.46	1.03	0.14	.07	0.66	0.40	1.10	0.17	.11
Breastfeeding during the first 30 minutes post-delivery[ñ]										
No	0.93	0.59	1.48	0.21	.76	0.76	0.46	1.28	0.19	.29
Mother time spent with child[o]										
≥ 1 hour apart	1.04	0.48	2.23	0.39	.92	0.97	0.49	1.89	0.32	.92
Child caretaker[p]										
Father/grandmother/sister	6.10	0.76	48.7	6.20	.09	14.9	3.43	65.2	10.8	.00
Marital status of mother[q]										
Single/divorced/widowed	0.91	0.45	1.87	0.32	.80	1.05	0.39	2.80	0.50	.93

Note: n = 265 child participants aged 12, 18, 24, 36 and 48 months (± 1 month) to whom were applied the PTNI, children of migrant and non-migrant mothers from three urban settlements and 29 rural localities. Data obtained from results of the PTNI and divided in two categories. Reference value: mild risk of neurodevelopment delay or normal neurodevelopment (MND/N).

[a]Raw ORs for each characteristic of interest, calculated through logistical regression.

[b]Adjusted ORs for each characteristic of interest, calculated through logistical regression and adjusted for all study variables.

[c]Confidence intervals.

[d]SE: standard error. Standard errors were adjusted by dependencies of the data in the interior of the localities/settlements.

[e]Reference value: indigenous non-migrant mother residing in rural locality.

[f]Reference value: female.

[g]Child age 12, 18 and 24 months (± 1 month). Reference value: age 36 and 48 months.

[h]Birth order of child among any living siblings of the same mother. Reference value: first-born.

[i]Child lives with his or her father. Reference value: no.

[k]Obtained through the EEO as it corresponds to age group, and divided into two categories. Reference value: favorable timely early stimulation (FTES).

[l]Initial Education = timely early stimulation sessions for children under four years of age coordinated by the National Council for Educational Advancement (in Spanish, CONAFE) in marginalized rural localities and urban settlements. Reference value: daily or up to three times/week.

[ll]Complications experienced by the mother over the course of the pregnancy. Reference value: no complications.

[m]Complications experienced by the mother or child during labor or delivery. Reference value: no complications.

[n]Person or persons present and attending child delivery, divided into two groups by type of attendance recieved. Reference value: Nurse/midwife at home or unattended birth.

[ñ]Immediately, during the first 30 minutes post-delivery. Reference value: yes.

[o]Time which the mother and child spend physically together. Reference: all day.

[p]Family member charged with childcare during the majority of the day. Reference value: mother.

[q]Marital and/or civil status of the mother. Reference value: married/domestic partnership.

Discussion

This study compares general and health care characteristics of mothers and their children of 12-48 months of age, among migrant and non-migrant indigenous mothers in Chihuahua, Mexico. It quantifies the existing association between the risk of moderate to severe neurodevelopment delay (MSND) in children, and the migrant condition of their mothers and timely early stimulation practices by parents. The rural localities studied were classified as indigenous, as well as marginalized, considerably poor, and geographically remote (Roldán et al., 2017). The urban settlements selected had some basic services, but were subject to overcrowded conditions and marginalization (Saucedo et al., 2012). Our study used the PTNI test to detect child risk for neurodevelopment delays, where results showed higher rates of MSND in the children of indigenous migrant mothers (75.6%) as compared to non-migrant mothers (56.8%). This coincides with previous evidence by Abdullahi et al (2018) and Schmengler et al (2019), who have reported that migration has negative repercussions for childhood neurodevelopment. Previous studies in Mexico have documented the prevalence of MSND using the PTNI in children aged 11-13 months in all 32 states residing in significantly disadvantaged populations both socially and politically, and in highly marginalized rural localities. Some reported a general MSND rate of

39.1%, less than that reported our study (69.2%) (Ávila-Curiel et al., 2018). The localities studied by Ávila-Curiel et al (2018) included beneficiaries of social programs with a component of early stimulation for children, which may explain the discrepancies with the present study. Furthermore, the age range selected by Ávila-Curiel et al (2018) was comparatively lower, which would favor a lower detectable risk of neurodevelopment delay (Shaffer, 2000).

Another study in Mexico confirmed high rates of childhood neurodevelopment abnormalities using the Early Childhood Development Assessment (in Spanish, EDI) to screen children aged 16 to 59 months in rural and urban settings of the state of Puebla. This study found general development abnormalities in up to 94.9% of all included children, and in 89.7% of children aged 16 to 24 months (Rizzoli-Córdoba, Martell-Valdez, et al., 2015).

Other studies with children under five years of age in Mexico have reported risks of developmental delays at rates below that reported herein. These include studies in the State of Mexico (Tirado-Callejas et al., 2017) and Coahuila (Rizzoli-Córdoba, Martell-Valdez, et al., 2015) where risk rates were reported at 26.5% and 16.2%, respectively. Of the latter, 9.9% were children less than one year of age, and 20.8% were children aged one to four. The studies referenced from Puebla and Coahuila observed that risk for developmental delay increases with age; in contrast, our study did not detect significant differences in MSND among age groups studied (68.7% for 12 - 24 months *vs.* 69.5% for 36 - 48 months).

In other low-income countries, evidence shows that up to 43% of children below five years of age are at risk to not reach optimal development (Black et al., 2017). Rates of up to 62.5% of psychomotor development disorders have been detected in Argentina using the National Screening Test (PRUNAPE from the acronym in Spanish) at the primary care level (Lejarraga et al., 2008). In Chile's 2006 Survey of Health and Quality of Life, developmental lags were observed in 29.9% of subjects (Government of Chile, 2006).

Migration is a social determinant of indigenous health whose impacts has been observed across multiple countries in the Americas (León-Pérez, 2019); in indigenous communities migration has specifically been shown to contribute to disparities in healthcare access (King et al., 2009). The Mexican indigenous population has less access to basic healthcare services than the non-indigenous population (Gutiérrez et al., 2019). Nonetheless, little is known about the potential for migration to improve this condition and favor health. Our study showed that a third of all mothers received no medical care during delivery (27.6%), while 18.1% reported labor complications. In both circumstances, the percentage was greater for mothers in rural localities. Independently of their areas of residence (rural or urban), indigenous groups have been shown to receive poor quality healthcare and minimal access to services (Roldán et al., 2017). In Mexico, outpatient healthcare in indigenous migrant populations is a problem with both social and cultural roots (Juárez-Ramírez et al., 2014). Our study showed that migrant mothers had greater rates of birth attendance by a physician (80.5%), which was demonstrated to be protective against MSND in their children. However, we also discovered that the majority of migrant mothers, as compared with non-migrant rural mothers, did not initiate breastfeeding within the first 30 minutes post-delivery (20.1%); this is contrary to the standard recommendation for fomenting adequate child neurodevelopment (Ospina et al., 2015). In one analysis not included in this report, 72.7% of migrant mothers who did not initiate immediate breastfeeding were attended by physicians at delivery. This may be interpreted as these mothers having not been given the opportunity to breastfeed their child. Roldán et al (2017) affirmed this, noting a possible discrimination towards the indigenous population within urban environments.

Studies have contributed evidence of adverse health conditions linked to the condition of migrant children, due to unmet needs for targeted interventions and vulnerability to psychological damage (Lu et al., 2019) and neurodevelopment disorders (Abdullahi et al., 2018). The latter point was demonstrated by our results, which showed that the migration of mothers to urban settlements was a predictor for MSND in their child. Another study demonstrated disadvantages in adequate care for the children of agricultural day workers with parents who migrated to fields in northeast Mexico; these children demonstrated poorer outcomes in health, education and nutrition (Vera-Noriega, 2007). Our study found that children not under the care of their mother were at a high risk for MSND.

Evidence indicates that the rural-urban migration process is a factor affecting early childhood psychosocial development (Abdullahi et al., 2018). We confirm this in our study, where the children of migrant mothers displayed considerably lower scores in the category of normal development as compared to their non-migrant rural counterparts despite the poverty in which most indigenous communities live (Meneses et al., 2018). In addition, insufficient timely early stimulation for children, particularly in urban settlements, was strongly associated with MSND. These multiple factors able to change the normal pace of development may be classified as biological or environmental risk factors for early childhood development. In our study, low PTNI and EEO scores indicating risks for the indigenous migrant population confirm that early stimulation practices are insufficient for young children. The households visited within urban settlements were observed to have few resources and limited conditions which favor adequate stimulation for children: necessary for optimal neurodevelopment (Vandell et al., 2016).

The migratory condition often implies significant life changes for parents, as noted by Salgado (2014), who reported that Mexican women who migrated to the United States developed anxiety and depression linked to discrimination, lack of familiarity in a new environment, and concern for the wellbeing of their families. This concept is highlighted by the converse situation of indigenous non-migrant mothers in our

study who, in contrast to migrant mothers, had greater opportunities to be present and share quality time with their children, favoring timely early stimulation. This finding reenforces previous findings in Mexico, which found that children of indigenous parents who remain in their native community and who receive training through the Initial Education program scored higher in psychomotor and cognitive tests as compared to non-indigenous non-migrant children (Knauer et al., 2018). Despite having few resources, parents can promote the development of their children through nurturing, open and committed childrearing habits (Knauer et al., 2016). Furthermore, exposure to open green spaces - generally more accessible to non-migrant mothers - is associated with improved cognition in children two years of age (Liao et al., 2019). The behaviors of parents, such as reading or singing with their children and dedicating time to play, benefit child neurodevelopment (Knauer et al., 2016; Powers, 2011). In an analysis not included in this report, we observed a greater probability that migrant mothers spend their days apart from their children, and that these children in turn did not receive timely early stimulation and showed a greater likelihood to demonstrate MSND.

In addition to the findings of our study, evidence from Australia, Europe, Africa and North America has indicated greater risks for neurodevelopment disorders in the children of immigrant parents (Abdullahi et al., 2018; Schmengler et al., 2019). This evidence confirms the declaration by the International Society for Social Pediatrics and Child Health (ISSOP-Migration Working Group, 2018) calling for greater knowledge generation and sharing about health, education and care access risks of children of migrant parents. It furthermore encourages relevant policy building, as stipulated in the United Nations Convention on the Rights of the Child to promote the right of migrant children to an optimal health and wellbeing (ISSOP-Migration Working Group, 2018).

Our study had certain limitations, including the lack of data collected on sociodemographic and housing characteristics; however, this does not invalidate the relevance of the findings presented. As a transversal study, our approach offers data useful for formulating new hypotheses, and may be compared to other similar populations in improved conditions. The PTNI screening test has the advantage of including direct observations of child habits, compared to other tests where this component is indirectly reported. The EEO demonstrates an acceptable reliability, however, it documents early stimulation practices through self-report without confirmation by the evaluator, and does not consider the duration and quality of practices reported.

In light of the new evidence presented, we recommend the implementation of public policies which support timely assessment of negative health and neurodevelopment impacts on young children as a basic measure to stabilize public health. The results of this study may be used towards the development of programs to address the needs of disadvantaged populations including the children of migrants. Reductions in both costs and negative outcomes could be achieved through primary-care-level screening and timely intervention in regions of potential migrant origin, using personnel trained in the application of early detection tools.

Our study concludes that the lack of timely early childhood stimulation at home has negative effects on the neurodevelopment of the children of indigenous mothers, and to a greater extent in migrants. Despite the characteristic economic and material disadvantages of rural indigenous populations, mothers in these settings are more likely to perform simple, easy and fun activities with their children which favor optimal childhood neurodevelopment; nonetheless, even among these mothers, early stimulation practices should be increased. Promoting family participation in early childhood learning and health may be an effective tool for enabling the maximum development potential for children in this population.

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