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Characterizing the Association between Household Stimulation during the first year of life and Child Development at seven years among Mexican Children

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Master's in Public Health

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Committee Chair

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B.A., Tsinghua University

2016

Thesis Committee Chair: Ines Gonzales Casanova, Ph.D.

An abstract of
A thesis submitted to the Faculty of the
Rollins School of Public Health of Emory University
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Abstract

Characterizing the Association between Household Stimulation during the first year of life and Child Development at seven years among Mexican Children

By Juhui Kim

Background: The Lancet 2017 reported that 250 million children under 5 years from low-income and middle-income countries were at risk of not meeting their full developmental potential. The household and family environment during early childhood provides important opportunities to improve childhood development. In Mexico, the household environment might be particularly important to promote childhood development because access to daycare is limited.

Objective: The objective of this research was to assess the potential role of the household learning environment on global cognitive development, independently of SES, maternal and child nutrition status, in a birth cohort from Cuernavaca, Mexico.

Methods: Data for this study come a birth cohort of children whose mothers participated in a randomized controlled trial (POSGRAD) of the impact of prenatal supplementation with Omega-3 on child growth and development. We used multivariate linear regression to test associations between the household objective measurement of the environment (HOME) inventory and intelligence quotient (IQ) measured at 7 years of age using the Weshcler Abbreviated Scale of Intelligence (WASI), and to adjust for maternal and child characteristics. We conducted stratified analysis to assess if predictors of cognitive development differed by sex.

Results: The sample for this study was of Mexican children with information on the HOME inventory in the first year of life and IQ at 7 years of age. After adjustment of all covariates, HOME inventory score was associated with all the IQ scores except performance IQ among overall population and among boys. HOME inventory score among girls was associated with none of IQ scores. SES was associated with all IQ scores among overall sample, however, when stratified by sex, SES was associated only with male verbal IQ.

Conclusions: We found positive associations between HOME inventory and child development, SES and child development as well as mothers' intelligence/education and child development. There were differences by sex in some predictors such as maternal schooling, which was positively associated with development in girls but not in boys. This work highlights the importance of sex in the study of predictors of development and can inform the design of targeted intervention to improve cognitive ability of girls and boys. Also, this study contributes to identifying early predictors which could be influencing child development among Mexican children.

Keywords: HOME inventory, cognitive development, SES, WASI IQ, gender difference, Mexico

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Table of Contents

Tables and Figures

List of Acronyms

BMI – Body mass index

BSF-R – Bayley Short Form-Research Edition

DHA – Docosahexaenoic acid

EASQ – Extended Ages and Stages Questionnaire

HAZ – height for age z score

HOME – Home Observation for Measurement of the Environment

IMSS – Institute of Social Security

IQ – Intelligence quotient

POSGRAD – Prenatal Omega-3 Supplementation on child Growth and Development

PPVT – Peabody Picture Vocabulary Test

rCMD – risk of maternal common mental disorders

SBIS – Stanford-Binet Intelligence Scale

SD – Standard deviation

SE – Standard error

SES – Socioeconomic status

SGA – small for gestational age

UK – United Kingdom

WASI – Weschler Abbreviated Scale of intelligence

WAZ – weight for age z score

WHO – World Health Organization

Chapter 1. Introduction

1.1 Introduction and rationale

The Lancet 2017 reported that 250 million children under 5 years from low-income and middle-income countries were at risk of not meeting their full developmental potential [1]. This was defined as suffering from stunting or poverty, which may lead to incomplete cognitive and social-emotional development and poor educational performance [2]. Furthermore, in studies from high income countries, childhood cognitive development measured by IQ has been associated with better adult health and survival, as well as with achievement, education and human capital [2].

Prevalence of chronic malnutrition among children under 5 is over 20% in 9 of the 20 Latin America and Caribbean countries [3]. Moreover, the rates of chronic malnutrition affect mostly the lowest-income groups. In this same study, the prevalence of stunting (height for age below 2 standard deviations for the standard) was of 48% higher in the lowest-income stratum, which contrasts with a prevalence of 5% among those with the highest-incomes [3]. Recently, many countries in the region have focused on childcare to improve child development. For example, Ecuador and Peru are putting efforts on public childcare services for better quality. Despite these efforts, due to lack of supports of appropriate policies and skilled healthcare staffs, impaired child development remains a major social problem in many of these countries [3].

In Mexico, there are 3 nationwide institutions which work for children—Programa Estancias Infantiles (funds childcare services for children under 6), Mexican Social Security Institute (provides child care services for individuals), and PEI-CONAFE (community-based program focusing on parenting) [3]. These programs may cover most children but not all of them. In addition, the quality of service varies depends on the program in which they participate. In addition, these programs do not cover all families in Mexico; hence, for many they will rely on the household environment to provide adequate stimulation. There is a risk that many families in the region are unable to access to any of childcare services or parenting services which might result in failure of child development.

The household and family environment during early childhood provides important opportunities to improve childhood development. Early stimulation, as well as the household learning and social environments have been identified as important determinants of childhood development. The home observation and measurement of the environment (HOME) inventory was specifically developed to measure these factors; it has been used extensively and adapted for diverse settings. Studies from high-income countries demonstrated cross-sectional correlations between the HOME inventory scores and cognitive development starting in the 1980s [4]. More recently, a few studies have assessed longitudinal relationships between the HOME inventory and cognitive development in high-income countries [5]. Similarly, a study in Indonesia found that the household stimulation and social environment measured with the HOME inventory during early childhood was positively associated with IQ during adolescence [6]. However, information from similar longitudinal studies from Latin America remains scarce.

As mentioned before, besides early childhood stimulation, household socioeconomic status (SES) and early nutritional status are also important determinants of cognitive development and potentially also affect the early household stimulation and social environment [7]. Therefore, identifying the role of early stimulation within the context of these other determinants of early cognitive development may lead to the development of interventions to help children reach their full developmental potential.

This research focused on assessing the determinants of household stimulation and learning environment, and its associations with global child cognitive development in a cohort of Mexican children who have been followed between birth and 7 years.

1.2 Problem statement

Early childhood is the most significant period throughout the life since child development has direct impacts on many aspects of adulthood life, such as health outcomes and social status. Negative health outcomes due to poor child development may include obesity, stunting, mental illness, heart disease, and social outcomes may include criminality, violence, poverty, isolation, among many others. [8]. Understanding the factors associated with child development is important to maximize adult potential and minimize negative outcomes. Previous studies have looked at factors associated with child development such as SES, parenting, and mother's age. However, most of these studies did not focus on the impact of the home environment on children's intelligence development during the school years while considering other significant factors such as maternal and child nutrition status. In addition, little research on this topic has been conducted in Mexican children.

1.3 Significance statement

The purpose of this study was to understand the impact of the household learning environment on child development while considering maternal and child nutrition status. By understanding the association between these factors, we can improve the design and targeting of interventions to promote child development and decrease the number of children who do not achieve full development during their early years. In addition, this study will help identify successful interventions for child development that can be applied to other similar locations and regions. This work also aimed to inform future research evaluating the impact of targeted interventions designed to strengthen the household learning environment.

1.4 Research goal, hypothesis and aims

The objective of this research was to assess the role of the household learning environment as a mediator of the associations between household SES, maternal and child nutrition status, and global cognitive development in a birth cohort from Cuernavaca, Mexico. The hypothesis to be tested is that the quality of the household learning environment at 1 and 5 years of age will be positively associated with child cognitive development at 7 years and will mediate the associations between SES and development, and maternal and child nutrition and development.

We addressed the following specific aims:

Specific aim 1- assess if HOME score measured during the first year of life predicted intellectual quotient measured with Weschler Abbreviated Scale of intelligence (WASI) at 7 years of age in a cohort of Mexican children, while controlling by SES, nutritional status, and sociodemographic predictors.

Specific aim 2- assess if the relationships between HOME score during the first year of life or other household, maternal, sociodemographic factors, and child cognitive development at 7 years measured by the WASI differs by sex.

Chapter 2. Literature Review

2.1 Importance of child development

Early child development especially during the first 5 years is a significant factor which has lifelong implications. Children who experience deficits in development during these early formative years have been found to have negative health effects such as mental illness and brain malfunction, or social issues such as lower economic capabilities later in life [9]. Children during this period require care, protection and guidance of parents and/or caregivers and they are more reliant at these younger ages [10]. There are many aspects of a child's life that they cannot control when they are young, thus, the household and family environment and stimulation is particularly important during this stage. This stimulation could help ameliorate other adverse circumstances and countries with high prevalence of child stunting and poverty could benefit from implementing strategies that improve early household stimulation [11].

2.2 World status of child development

Poverty and stunting – global overall status

According to the WHO, stunting indicates a failure to reach linear growth potential because of inadequate nutrition or poor health. Children are defined as stunted if their height-for-age is more than 2 SD below the WHO Child Growth Standards median [12]. For children under 12 months, recumbent length is used instead of height. The population who is not reaching developmental potential can be estimated by calculating the number of children living in extreme poverty and the number of stunted children. Considering that there were about 174 million (30%) stunted children and about 142 million children (25%) living in extreme poverty, an estimated

249 million children under 5 years of age likely did not reach developmental potential in 2010 [13]. By region, the highest population at risk of not reaching developmental potential due to stunting is about 111 million in South Asia and the highest prevalence is about 66% of the population in Sub-Saharan Africa [13].

<u>Poverty and Stunting – Latin America and Caribbean countries</u>

Among 54 million children under 5 years of age in Latin America and Caribbean countries, around 18% were estimated to be at risk of not reaching developmental potential in 2010 with 15% stunted and 6% living in extreme poverty [13]. Compared to the prevalence in 2004, the risk has decreased by 2%, which was the smallest change among all the regional groups [13]. It was found that maternal obesity/overweight and child stunting exist at the same time among 13.1% households in Ecuador while the same situation is seen in 20% households in

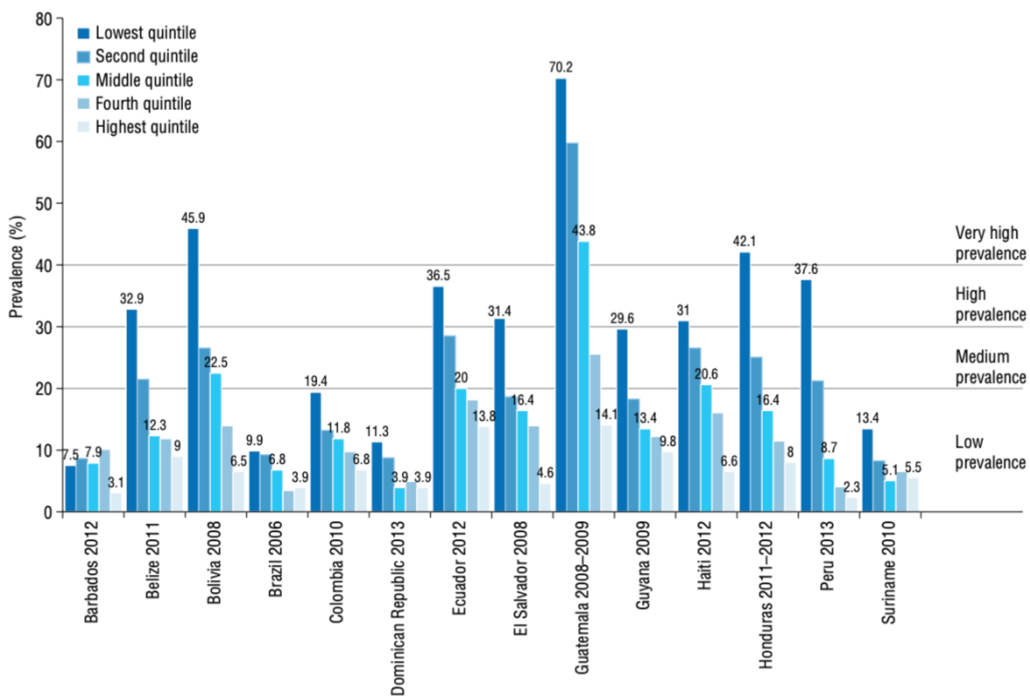

FIGURE 1: Prevalence of stunting in children under 5 years old, by wealth quintile, in countries with available nationally representative data, Latin America and the Caribbean, 1985-2014, adapted from "*Tackling malnutrition in Latin America and the Caribbean: challenges and opportunities*," Galicia, L., et al., Rev Panam Salud Publica, 2016: p. 9

Guatemala [14]. Compared to the 1980s and 1990s, the prevalence of stunting and underweight among children under 5 decreased in most countries in Latin America. However, there were still large populations living with 16 times higher risk of stunting than other households, especially in rural areas and in low-income families as shown in figure 1 [14].

Poverty and Stunting – Mexico

Within Mexico, the rate of poverty dropped from 46.1% to 45.5% between 2010 and 2012 [15]. Total poverty and social deprivations in Mexico in 2012 are shown in Figure 2. Despite the modest rate drop which was caused by population growth, actual number of people living in poverty was found to have increased from 52.8 million to 53.3 million [15]. One of the positive changes was that extreme poverty rate decreased as well as the population in extreme poverty between 2010 and 2012, from 11.3% (13.0 million) to 9.8% (11.5 million) [15].

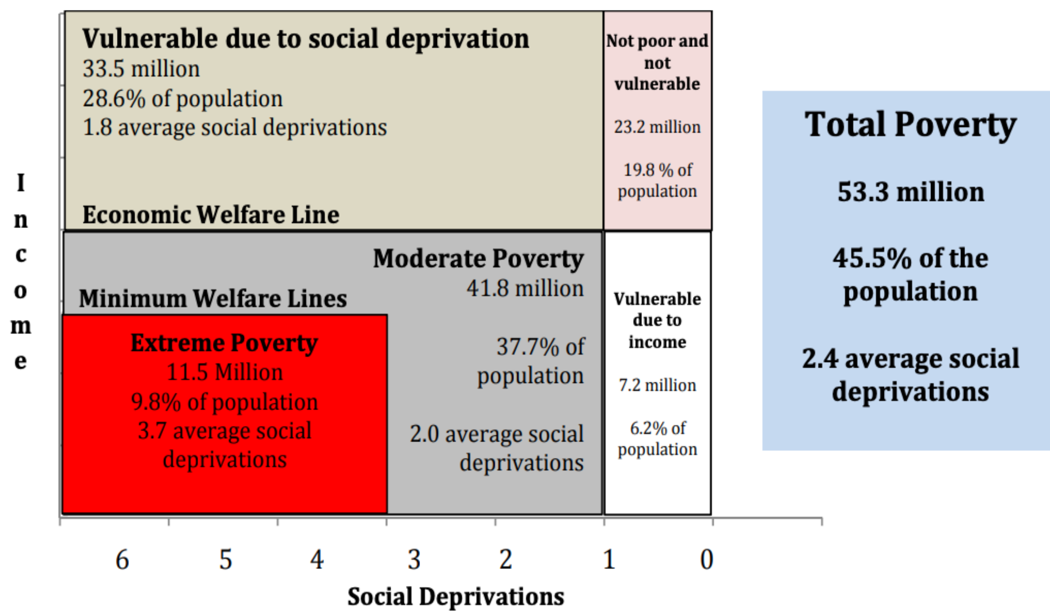

FIGURE 2: Poverty in Mexico in 2012, adapted from "*Mexico's Latest Poverty Stats,*" Wilson, C. and G. Silva, p. 8.

Stunting in Mexico was also reported to have decreased from 1988 (27%) to 2006 (16%) which was the result of improved access to health care systems and increased coverage of a cashtransfer program for families of low SES [16]. A more recent report shows that stunting in Mexico had further decreased to 13.6% according to a 2010-2011 national survey of Mexico [17].

2.3 Factors affecting child development

Parenting, interaction, and the learning environment

Studies conducted in high income countries have provided evidence that children in families with less educational opportunities and social advantages do not achieve full cognitive and social development [18, 19]. To investigate the relationship between parenting, parent-child interaction, and child development, a research study was recently conducted in Western Germany. The study followed a quasi-experimental and cross-sectional design within an intervention group (n=184) and a non-intervention group (n=58) [20]. Participants in the intervention group took parenting training courses as a part of the family support program, while the non-intervention group took courses not involved in the program. The study found that the quality of parent-child interactions and activities had a significant impact on child development [20].

Another study evaluated the effects of the parenting role and parent-child interactions on child development in Taiwan. The study focused on screening if motor skills of infants were fully developed. It was found that children of adolescent mothers and mothers who were not confident in themselves, did not develop fully. This was a meaningful result since mothers are more likely to be involved in early child caregiving than fathers [21]. However, there was a confounder in this study of mother’s education that was not appropriately addressed. Higher mother's education led to more competence for the mother's role and higher possibility of motor development of the infant as a result [21].

According to an early childhood longitudinal study in the United States which was conducted since 2001, there was an association between child cognitive development and parental cognitive stimulation [22]. The measurement was the mental scale of Bayley Short Form-Research Edition (BSF-R). More efforts of parents on child stimulation resulted in higher children's cognitive abilities and reading proficiency which attenuated genetic differences. Thus, this suggests that the impact of genetics on cognitive ability of children can be addressed by appropriate early stimulation [22].

Several other studies have investigated the role of home-based interventions on cognitive development of children. Home-based programs with high parenting skills had a strong effect on positive child development according to a meta-analysis of the outcomes from 1985 to 2005 [23]. The estimate number of overall effect on cognitive development was d=0.32 (SE=0.05) [23]. A study on home environment and parenting in the United States showed that children who had different environmental experiences including parenting and cognitive stimulation at several points, did not have large differences over the course of the evaluation period. This indicates that short term experiences related to parenting and interaction may not affect much on child cognitive development [22], however, more studies are needed to explain long-term effects.

A research study which assessed the role of the home learning environment was conducted using data from the UK millennium Cohort Study. The adjustment for home learning and other environmental factors led to reductions in gaps (between 27% and 49%) on the cognitive test scores for the high-income and low-income groups, respectively [24]. However, environmental factors did not have noticeable effects on cognitive test scores when children were 5 years old [24].

A study conducted in rural Mexico assessed child development using Extended Ages and Stages Questionnaire (EASQ). Here, the association between parenting and child development was statistically significant during infancy and prekindergarten. However, the association became weaker as children got older after controlling for the developmental effects during child infancy [25]. Furthermore, no difference was found between indigenous and non-indigenous communities regarding to the association between quality of parenting and child development [25]. While more research needs to be conducted, these trends suggest that timing is critical for targeting early child development interventions.

SES of the household

Socioeconomic status (SES) is one of the most significant factors to determine a child's development status. Children from low-income families are more likely to experience inadequate brain development [26]. This may be due to these infants having a higher likelihood of negative birth outcomes such as low birth weight, asphyxia, a disability or a birth defect, all of which are associated with low SES [27]. A study in southern Brazil found that SES influences child development as determined through a screening test (Denver II Test). In this study, the risk of failure to fully develop was twice as high among low-income children than the risk of those from higher income families ($p<0.001$) [28].

According to another recent study that looked at educational achievement, employment, nonmartial childbearing and criminal justice involvement by childhood poverty status, there was no association between these factors among children who were never poor. However, among the category “ever poor”, all of these variables were statistically significant [29]. For instance, only 13% of participants who were ever poor completed college by age 25 (p-value<0.01), while 36.5% of “never poor” participants completed college [29]. Exploring further into the “ever poor” category, when this was stratified by “not persistently poor” versus “persistently poor”, the significant associations were seen with the persistently poor category only. This indicates that the relationships are driven by being persistently poor.

In another study using a large UK-representative sample, the relationship between SES and children’s intelligence was evaluated using genetic factors. Here, the only significant mediation of the genetic influence on IQ was found at age 10 [30]. Also, more variance was observed in children’s IQ test scores among lower-SES families. These findings indicate that family-based environmental interventions such as playing and reading together might be more effective in accelerating cognitive development of children in lower-income families than in higher-income families [30].

Maternal education and intelligence

According to numbers of previous studies and analyses, low maternal education is associated with poor nutritional status of the child, which can hinder full development of the child [31]. A study showed that there was an association between maternal education and literacy level and nutritional status of children between 3 and 23 months based on data from 17 developing countries [32]. The research revealed that increased education of mothers is related to lower mortality rate (7% - 9% each year) among children under 5 in these countries [33]. In Mexico, it was found that mothers with more schooling years were more likely to visit health institutions for treatment within 3 days of illness onset [34].

In addition, a study showed that mothers of infants who were suffering from undernutrition were not educated in most cases [35]. For infants, appropriate feeding is of critical significance since the late introduction of semi-solid foods can lead to malnutrition, and in worse cases, child mortality. The majority of the uneducated mothers in this study were found to not start feeding semi-solid foods in time, or their feeding frequency was not appropriate. The reason seemed to be lack of awareness and education, which could be improved with the support of local programs for childcare and nutrition [34].

In a recent study, maternal intelligence was examined as a significant predictor of language and intellectual abilities of children at age 5, considering the interaction with cognitive stimulation by home environment. One of the findings was that maternal IQ scores were positively associated with children's IQ scores as well as language scores at age 5 among those born before 32 weeks from pregnancy [36] which was a similar result from a former research [37]. However, the association was weaker among those children who were born full term, which means that prematurity is a risk factor which limits cognitive development of children [36].

There was a study which looked at the relationships between children's cognitive development, maternal intelligence, home environment and SES status together. It was found that maternal IQ had a significant effect on the child motor development as well as on the mediation of the effect of home environment [38]. This indicated that the role of maternal IQ on children's cognitive development could vary depending on home environment and shared experiences [30, 38, 39].

Maternal status at reproductive age

Maternal underweight before pregnancy is known as one of the risk factors for negative infant outcomes including low birthweight [40]. However, some inconsistencies have been found with this association, for instance with another study which analyzed data from 27 countries from sub-Saharan Africa, there was not an association between maternal underweight and infant underweight as well as infant mortality [41]. On the other hand, maternal overweight and obesity did not appear to be as high of a risk factor for having underweight children. This study emphasized that the focus should be on maternal underweight rather than overweight, to effectively decrease risks of infant mortality or other negative health outcomes [42]. In addition, high BMI before pregnancy was found to be associated with child development at 6 years from another study [43]. Mothers with severe obesity resulted in higher risks of children's emotional and social problems, psychosocial difficulties in addition to developmental problems, thus, the study concluded that maternal obesity should be considered as a potential predictor of deficiency of child development [43].

Maternal physical status is associated with SES. as well as other factors. For example, women in higher SES families barely experience underweight. According to a study in United States, offspring of adolescent mothers had significantly lower verbal skills, composition skills, quantitative skills and had shorter memory than those of adult mothers at 6 years of age [31]. The average test score of children with teen mothers was 7 points lower than those with adult mothers after adjusting for significant interventions such as maternal cognitive ability and household environment, which was assessed by Stanford-Binet Intelligence Scale, fourth edition (SBIS) [31]. This showed that mother's age at birth is positively related to child's intelligence. In addition, the study showed that the impact of home environment was weaker among children with teenage mothers than among those children with adult mothers [31]

In addition, a recent study in 4 low-income and middle-income countries (Ethiopia, India, Peru, and Vietnam) has examined the association between maternal mental health and child development. The study found that the risk of maternal common mental disorders (rCMD) was negatively associated with child development in India and Vietnam in the first year of age, but not in other countries. Those negative outcomes of child development persisted to 8 years of age [44]. Maternal rCMD in early childhood appeared to be associated with low life satisfaction in children at age 8 in Ethiopia. PPVT was used to examine cognitive ability of the children in this study [44].

Child status at birth

There was a study which found that infants with low birth weight (<2,500g) were lighter and shorter at 7 years than infants born with normal weight [45]. From several studies, low birth weight was shown to be a risk factor of children's development [45, 46]. Conversely, there were deficits shown on child development only among those children who were born with smaller head circumferences and low birth weight. The study suggested that there is no need to overfeed children with low birth weight to improve child's growth since there was no association found [45]. In addition, it was emphasized that intellectual ability of children with low birth weights and small head circumferences may be influenced by nutrition supplement during pregnancy. [46].

Childhood undernutrition

There are 3 common indicators of undernutrition: stunting, wasting and underweight. These indicators usually show the relationship with inappropriate child development such as the study in India [47]. Also, several studies found that there is a positive relationship between early childhood nutrition and child development [48, 49]. For stunting, there is a study which proved the association with the poor child development. Despite the finding, the study left the question that at what ages the impact of stunting on child development is maximized [50]. The study suggested that more studies which are designed to examine several nutritional factors including stunting at the same time in order to reach more refined conclusion.

There were studies rarely existing about the association between child underweight and cognitive development as well as the association between child wasting and cognitive development. However, there was a study which found no association between these factors [51]. Instead, the relationships between underweight and working memory, academic performance were found to be negative [51].

Child sex

In a recent study in Brazil, there was a meaningful finding regarding to child sex difference and child development. The boys born small for gestation age (SGA) had more than one standard deviation less HAZ and WAZ than those born normal size [52]. On the other hand, girls showed smaller reductions among SGA in HAZ and WAZ than boys. However, the difference in HAZ and WAZ was not shown when gestation ages were adjusted, which indicates that SGA is an important factor to control in order to benefit physical growth of children. Looking at social communication skills, verbal and nonverbal developmental skills, there were no sex differences found in this study [52].

There was a study which insisted that the study results among children under 5 cannot fully explain sex difference because of immaturity [53]. However, the study result showed that scores on cognitive tests were similar between boys and girls.

Child education

Child education is a significant factor for cognitive development, and both pre-school education and education at school are important for improvement of children's cognitive ability. Since quality and intensity of education varies depending on location, school and even class, it is hard to certain the role of education on child development. There was a study which assessed the role of preschool programs in the United States from 1962 to 1965. Mother's involvement in child's education was found to be a powerful influence on educational attainment of the child [54]. However, the study added that it is not clear if preschool programs have strong positive impacts on intellectual abilities of children since school achievements do not always show the level of intelligence [54].

There was another study conducted in the UK assessed preschool education and child development. It was found that pre-school children had lower abilities in reading than those children in informal care. Also, there was no benefit found in private or public pre-school education forms existing in 1973 [55].

However, there were no researches found about the association between education on school-aged children and their cognitive development. Hence, more studies are needed to be done to assess the role of school educations and out-of-school educations on child cognitive development using more recent data.

2.4 Summary

Numbers of factors which are considered to have influences on child development have been reviewed throughout the chapter. Many studies are already done and published on child development and the various interventions through diverse measurements deducing meaningful results until a recent date.

Among household environmental factors, parent-child interaction, parental cognitive stimulation and home environment were found to be associated with child development as well as SES in many cases. Also, maternal factors such as maternal education and intelligence, maternal health, mother’s age at birth were related to child development. In addition, there were studies which showed the effects of birth weight, birth head circumference, stunting, child sex and child education on child cognitive development.

However, more studies are needed to prove associations between more predictors and child development in more places in the world, not only the areas with higher prevalence of stunting or poverty. Child development can be improved with findings on predictors and more efforts to control those factors.

Chapter 3. Methods

3.1 Parent study

Data for this study were from a randomized controlled trial of Prenatal Omega-3 Supplementation on child Growth and Development (POSGRAD) [56] designed to test associations between the home learning environment during the first year of life and childhood IQ at 7 years. In the POSGRAD trial, pregnant women were recruited at the Mexican Institute of Social Security (IMSS) General Hospital I, which is located in Cuernavaca, Mexico, and 3 health clinics within IMSS system in the same city. Then, they enrolled in the study at their 18-22 weeks of gestation between 2005 and 2007, and followed through delivery [57]. Children of these women were then followed prospectively from birth through 7 years, and information on child development, anthropometry and other maternal and child characteristics has been measured at various time points using established methods [58]. Mothers provided consent form for themselves and their children that describes their participation in the study was voluntary.

3.2 Variables of interest

Variables of interest included: total IQ, verbal IQ, cognitive IQ, performance IQ measured by WASI at 7 years of age as the outcome. WASI is a short version of the general measurement of Wechsler Intelligence Scale for children, which produces verbal, performance and full IQ test scores [59, 60]. In the study, Spanish versions of the tests were used for participants which have been used in previous studies with Mexican children [61, 62].

The main exposure was household learning environment measured through the HOME inventory [63] between 6 and 12 months of age. The HOME scale includes 6 categories:

emotional and verbal responsivity of mother, acceptance of child, organization of the environment, provision of appropriate play materials, maternal involvement with child, and variety in daily stimulation [64]. A new variable was created to include the latest HOME inventory score among data at 6 months and 12 months since there were many missing data for HOME at 6 months and 12 months respectively.

Other variables related to the child include weight at birth, length at birth, head circumference at birth, weight, height, BMI, stunting (0=no 1=yes), underweight (0=no 1=yes) and overweight status (0=no 1=yes) at 60 months, as well as if the child went to public school (0=private school, 1=public school).

Variables describing maternal characteristics at randomization were included, such as age, gestational, height, weight, BMI, number of schooling years, non-verbal intelligence score, marital status (0=not single 1=single); additionally, gestational age at delivery was also included. Raven score was used as an assessment instrument of maternal intelligence which is 60-question non-verbal test. Raven's Progressive Matrices is known to summarize the correlations among several tests of cognitive ability, which makes the matrices the most complex and general measurement of intelligence [65].

In addition, group status that describes which supplementation group the mother participated in (0=placebo 1=DHA) at randomization was considered. DHA group received an algal DHA supplement (400 mg/d) while the placebo group was provided a corn and soy-oil-based placebo from mid-gestation until delivery.

Lastly, variables assessing the environment of the family were included: HOME inventory at 6 months, HOME inventory at 12 months, latest HOME inventory score, and SES score in quintile (1=low 5=high) (Table 1). The Spanish version of the HOME exam was conducted between 6 months and 12 months from the child's birth. Socioeconomic status (SES) was measured using an inventory of assets. The SES variable was created using principal component analysis.

3.3 Statistical analysis

For this analysis, only children with valid information on HOME inventory at 6 or 12 months, and WASI at 7 years were included, and twin births were excluded. In order to clean the data and explore the distribution of all variables of interest, mean, standard deviation of continuous variables, and frequency of categorical variables with their observation numbers in total study population and by child's sex were calculated. T-tests and chi-squared tests were conducted to assess differences between those included in this analysis and those with missing information, and by child sex. Then, pairwise Pearson correlation tests were performed between total IQ, HOME Inventory score, and all the other continuous variables. To assess categorical variables' relationship with total IQ, several t-tests were carried out.

Multivariate linear regression was used to test associations between HOME inventory and WASI scores while controlling for other relevant factors. Model building was based on previous evidence of factors associated with child development and home stimulation. Based on the extensive evidence on the differences between boys' and girls' development [66], the multiple linear regression for adjusted and unadjusted models was conducted separately among boys and girls (Table 2, Table 3).

To minimize the impact of item-specific missing data, multiple imputation procedure was used with fully conditional specification. The imputation number was 20 which is greater than the percentage of missing values (11%) to replace fully.

All analyses were conducted using SAS 9.4 (Copyright © 2002-2012 by SAS Institute Inc., Cary, NC, USA).

3.4 Ethical considerations

This was a secondary data analysis of the POSGRAD project approved by the Institutional Review Board (IRB) of Emory University in the United States (IRB00024976; PI: Usha Ramakrishnan). The informed consent was obtained from every participant before being enrolled in this study and was obtained again from the parent or a caretaker at the time of the child's birth.

Chapter 4. Results

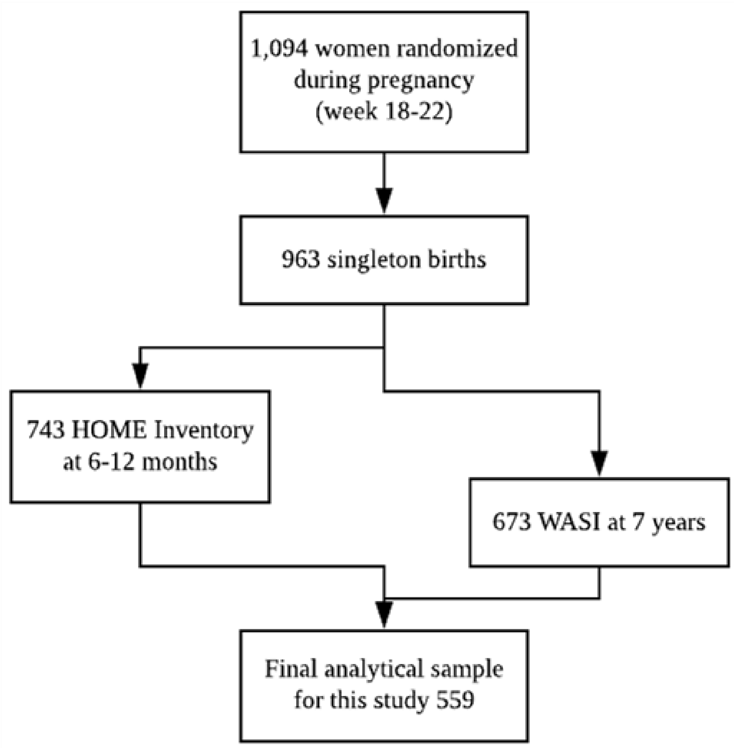

FIGURE 3: Flowchart for the assessment of the relationship between HOME inventory and WASI through 7 years.

4.1 Sample size

A total of 1,094 women were enrolled in the study at the beginning with 963 live births. 743 among those 963 infants had HOME, WASI IQ data was available for 673 children, which resulted in 559 children who have information on both HOME and WASI and were included in the study (Figure 3).

4.2 Descriptive data

Table 1 shows descriptive data with all the variables included showing mean, standard deviation, frequency and sample size for overall population as well as for boys and girls. The average score of total IQ was 88.84 (SD=9.76) among 559 children and mean of latest HOME score was 36.31 (SD=4.66). Most numbers were similar between boys and girls except frequency of stunting and underweight. Stunting among 293 boys was only 0.91% while stunting among 257 girls was 2.91%. Underweight among 293 boys was 0.55% while underweight among 257 girls was 1.64%.

T-tests and chi-square tests were then carried out to see if there are any differences between boys and girls. Results were considered statistically significant with p-values less than 0.05. T-tests showed that the average WASI performance IQ among male children was higher than female children (T statistic=2.45, p-value=0.01). The mean values of birth length (T statistic=2.26, p-value=0.02), birth head circumference (T statistic=3, p-value <0.01), height at 60 months of boys (T statistic =2.81, p-value=0.01) and HOME score among boys (T statistic=2.24, p-value=0.03) also appeared higher than among girls. In addition, chi-square tests led to the result that the percentage of girls who experienced underweight was higher than the boys (p-value=0.05).

4.3 Associations between HOME and WASI

Pearson Correlation Coefficient procedure was conducted to evaluate the associations between WASI and HOME score overall and by sex, not considering other variables. All the values were between 0 and 1 with p-values under 0.05 (Table 2), indicating all of the WASI IQ score increases as HOME inventory score increases. For example, when tested unadjusted associations between HOME and total IQ, the r value was 0.25 for overall population (p-value<0.001), 0.28 for male children (p-value<0.001) and 0.21 for female children (p-value=0.001).

When multivariate linear regressions were conducted after adjusting for all other covariates which were considered to be predictors of IQ score of children, different results came out—HOME inventory score was not associated with performance IQ score among overall participants (mean=0.08, SE=0.08, p-value=0.35). Then, when the same procedure was done separately among boys and girls, the result for the boys was the same as the result among the overall population; HOME score was not associated with performance IQ only (mean=0.07, SE=0.13, p-value =0.64). However, HOME inventory score among girls was associated with none of total IQ, verbal IQ, cognitive IQ and performance IQ.

4.4 Associations between SES and WASI

Pearson Correlation Coefficient procedure was conducted to check the associations between SES score and WASI IQ overall and by sex, not considering other variables. All the values were between 0 and 1 with p-values under 0.05 (Table 3), indicating that all of the WASI IQ score increased as SES score increases. This was constant with the result of the correlation test between IQ score and schooling of mother. The children of more educated mothers had higher IQ scores.

The result of multivariate linear regressions was that both SES score and schooling of mother were associated with total IQ, verbal IQ, cognitive IQ but not with performance IQ for overall population. Higher SES score in quintile resulted in higher IQ score for children, and longer schooling years of mothers also led to higher IQ of children. When this procedure was conducted separately for males and females, SES was associated only with male verbal IQ (mean=1.31, SE=0.51, p-value=0.007). Schooling of mothers was associated with total IQ, verbal IQ and cognitive IQ of female children while there was no association between schooling of mothers with IQ scores of males.

4.5 Other significant confounders

One of the findings is that males and females had different directions of association between single mother status and performance IQ. Parameter estimates for this variable had different directions among male and female, but p-values were higher than 0.05. For boys, mothers' marriage status was negatively associated with performance IQ which means that boys with single mothers appeared to have higher performance IQ than those with married mothers (mean=-2.25, SE=1.76, p-value=0.17). On the contrary, girls of single mothers seemed to have lower performance IQ than daughters of married mothers (mean=1.01, SE=1.61, p-value=0.59). Another confounder was mother's gestation age at randomization which was associated with all IQ scores in positive directions among girls while the directions were opposite among boys. Furthermore, the relationship between mother's gestation age at randomization and cognitive IQ in both groups were statistically significant. Younger gestation age of mothers at randomization was associated with higher cognitive IQ of boys (mean=-0.52, SE=0.26, p-value=0.05) while older gestation age of mothers at randomization was associated with higher cognitive IQ of girls (mean=0.5, SE=0.24, p-value=0.03).

The group status of randomization seemed to be related to different directions with all IQ scores in both groups as well. All IQ scores were higher among male participants in the intervention group than in placebo group and associations with total IQ (p-value=0.01), verbal IQ (p-value=0.001) and cognitive IQ (p-value=0.01) were statistically significant. On the other hand, female children in placebo group had higher IQ scores than those in intervention group even though p-values were higher than 0.05.

Chapter 5. Discussion

The purpose of this study was to characterize the association between the home environment and child cognitive development, independently of household SES and maternal and child nutrition status in a cohort of Mexican children and to assess if the predictors of cognitive development differed by sex.

5.1 Results for the overall sample

Overall, the last HOME Inventory which was measured between 6 and 12 months was positively associated with WASI scores measured at 7 years of age. The result was consistent even after controlling for other sociodemographic predictors. This is consistent with previous studies from different settings [20, 22, 25]. For example, according to a study in rural Mexico, there was a positive association between parenting and child development during infancy and prekindergarten [25].

Socioeconomic status was positively associated with all the IQ scores when evaluated the overall population. This finding is consistent with the previous study which found that the risk of not reaching full development was associated with family income [28]. However, it is uncertain why the study by Ratcliffe, C. did not find the associations between educational achievement of children and their poverty status [29]. A possible explanation is that child cognitive development does not always result in school achievements, which are believed to be the main mechanism linking wealth to child development. The association between SES and IQ scores remains significant after adjusting for other maternal and child characteristics (except for the performance IQ score where the result is not significant, but the estimate remains the same). Overall, prenatal household SES was a significant predictor of children's cognitive abilities at 7 years in this cohort of Mexican children.

Maternal BMI during the second and early third trimester of pregnancy was inversely associated with children's IQ at 7 years. In models adjusted for gestational age at the time of BMI measurement, maternal BMI was inversely associated with all IQ scores except verbal. This could be reflecting a negative association between excessive maternal weight and/or weight gain during pregnancy and cognitive development during childhood. These results are consistent with recent studies that found associations between maternal obesity and childhood cognitive functioning and supports addressing obesity in this context as a potential strategy to improve childhood development [43, 67].

There was no association found between low birth weight and IQ score of children in all cases, perhaps due to the low prevalence of low birth weight in this sample, which suggest that other factors such household stimulation during the early life could be more important in this context.

5.2 Results stratified by sex

There was a positive association found between the last HOME Inventory conducted during the first year of life and WASI among boys and girls in unadjusted models. However, after adjusting for maternal and child sociodemographic confounders the association remains only among boys and is attenuated among girls. Notably, maternal schooling is one of the strongest predictors of IQ among girls and contributes to significantly attenuates the relationship between HOME Inventory and IQ. The other predictor attenuating this relationship among girls but not boys is maternal BMI during pregnancy. This is a significant finding that suggests that maternal socioeconomic and nutritional status during early life might be more important for girls' cognitive development; while early childhood stimulation as measured by the HOME inventory might be more important for boys. To our knowledge, this is the first study to report this difference in Mexican children. These results highlight the need of considering child sex when designing interventions to improve development.

From unadjusted tests, both girls and boys showed that SES scores were associated with their IQ scores. Meanwhile, SES was found to be associated only with male verbal IQ when the adjusted tests were conducted separately for male and female. This indicated that sex difference is not significant among participants regarding to the relationship between SES and cognitive development.

As the finding from overall participants, tests stratified by sex carried out the same results that low birth weight was not associated with IQ scores. Maternal and external factors might be more important explaining the sex differences in cognitive development.

5.3 Additional findings

The adjusted analysis revealed that mother's marital status was associated with child development in the overall sample, but not among boys or girls separately. This is potentially due to sample size issues when we stratified by sex.

This analysis was not directed to assess the impact of the supplement; however, this variable was added to the models as a confounder. There was no association found in unadjusted tests, however, adjusted tests showed that group status was positively associated with boys' IQ, and inversely (although not statistically significant) with girls IQ. Previous studies have suggested negative effects of prenatal supplementation with n-3 fatty acids on girls' cognitive development [68]. Further studies are needed to elucidate this finding.

5.4 Limitations

There are some limitations existing in this study. First, the sample size got smaller because it was conducted among all live singleton births, some participants did not have HOME inventory or WASI IQ score. If all data had been available, the sample size would have been much larger than 559 (963 children). In this sense, 220 participants were missing at least one HOME inventory score and 70 children among the participants who had HOME score did not have data of WASI score. Missing data on potential confounder was imputed 20 times; however, imputation may have lowered the accuracy of the analysis.

Maternal mental health is an important predictor of child's development, and it was not available for this analysis.

Another limitation of this study is that the information which was self-reported by mothers might have resulted in less accurate results and interpretations. For example, answers to some questionnaires could have been affected by desirability bias. However, the HOME inventory and WASI scores do not rely on self-report, which helps minimize the bias of our analysis.

5.5 Strengths

This study had a relatively large sample size (n=559). Although the samples of boys and girls were different sizes, both were over 200. These large samples helped reduce bias. In addition, the study design was considered to be effective for the analysis. It was set with low resource since the randomized trial has been conducted with plenty of data.

Other strengths include that a large number of confounders were included in the model, which allowed us to assess important predictors at the household, maternal and child levels.

5.6 Conclusion

In this study, we proved that there were positive associations between HOME inventory and child development, SES and child development as well as mothers' intelligence/education and child development. In many cases, cognitive development of boys and girls was influenced by factors such as SES, birth weight, mother's marital status in similar ways. Nevertheless, predictors such as maternal schooling and BMI resulted in different associations with child development by sex.

This work can inform the design of targeted intervention to improve cognitive ability of girls and boys. Also, this study contributes to identifying predictors which could be influencing child development among Mexican children.

Chapter 6. Implications and Recommendations

6.1 Public health implications

The study has contributed to further studies on child development which found several predictors which were not addressed in previous studies in detail. Also, the study emphasized the gender difference in association between cognitive development and multiple factors while previous studies rarely focused on gender differences. This can also be considered an important finding for more gender-related studies of children.

6.2 Recommendations

There are not many factors that we can control based on the results. The first one is home environment with parenting, interaction with children as well as parenting. These can be improved by education and studying which can directly result in development of child cognitive ability, especially for boys. The results also highlight the importance of investing in women's nutrition and education, which can translate into better development outcomes for the next generation of women. Comprehensive programs and supportive policies that address child stimulation in daycare settings and within the households, especially in those of low SES, are needed to make sure that children meet their full developmental potential. This study also highlights the importance of considering sex in research and policies related to child development.

Tables

Table 1: Descriptive data

Variable	Male		Female		Overall	
	Mean ± SD	**n**	**Mean ± SD**	**n**	**Mean ± SD**	**n**
Child						
Total IQ from WASI 7y, score	89.51±10.63	298	88.07±8.61	261	88.84±9.76	559
Verbal IQ from WASI 7y, score	88.97±12.08	298	88.41±11.18	261	88.71±11.66	559
Cognitive IQ from WASI 7y, score	89.51±10.63	298	88.07±8.61	261	88.84±9.76	559
Performance IQ from WASI 7y, score	92.44±10.16	298	90.56±7.60	261	91.56±9.10	559
Birth weight, g	3278.08±468.86	276	3210.00±452.07	246	3246.00±461.84	522
Birth length, cm	50.69±2.30	275	50.25±2.11	246	50.48±2.22	521
Birth head circumference, cm	34.64±1.61	244	34.20±1.43	210	34.44±1.54	454
Weight at 60 months, kg	18.52±2.81	293	18.20±3.11	257	18.37±2.95	550
Height at 60 months, cm	108.79±4.10	293	107.77±4.38	257	108.31±4.26	550
BMI at 60 months, kg/m²	15.59±1.68	293	15.59±1.84	257	15.59±1.75	550
Stunting, %	0.91%	293	2.00%	257	2.91%	550
Underweight, %	0.55%	293	1.64%	257	2.18%	550
Overweight, %	21.16%	293	17.12%	257	19.27%	550
Low birth weight, %	2.11%	276	2.11%	246	4.21%	522
Public School, %	79.52%	293	84.17%	259	81.70%	552
Intervention group (DHA), %	46.55%	290	48.43%	254	47.43%	544
Mother						
Mother age at randomization, year	26.56±4.87	298	26.29±4.88	261	26.44±4.87	559
Gestation age at birth, week	38.99±1.65	297	39.10±1.80	260	39.04±1.72	557
Gestation age at randomization, week	20.54±2.04	298	20.46±1.97	261	20.50±2.01	559
Maternal height, cm	154.80±5.78	276	155.33±5.45	246	155.05±5.63	522
Maternal weight, kg	62.80±10.40	276	63.73±12.74	246	63.24±11.56	522
Maternal BMI, kg/m²	26.20±4.11	276	26.37±4.72	246	26.28±4.41	522
Schooling of mother, year	11.92±3.55	275	11.72±3.58	246	11.83±3.56	521
Total Raven score of mother, score	40.95±9.13	298	40.55±9.20	261	40.76±9.15	559
Single mother, %	5.75%	276	3.83%	246	9.58%	522
Other						
HOME at 6 months, score	34.12±4.77	176	33.76±4.88	142	33.96±4.81	318
HOME at 12 months, score	37.33±4.05	238	36.34±4.76	219	36.86±4.43	457
Latest HOME, score	36.72±4.41	298	35.84±4.91	261	36.31±4.66	559
SES in quintile, score	3.13±1.40	276	3.08±1.41	246	3.11±1.40	522

Table 2: Correlation between WASI IQ and HOME score

	Overall	Male	Female
Total IQ and HOME	0.24953*	0.27987*	0.20628*
Verbal IQ and HOME	0.23874*	0.30335*	0.16688*
Cognitive IQ and HOME	0.24953*	0.27987*	0.20628*
Performance IQ and HOME	0.17615*	0.16311*	0.18253*

* p<0.05

Values represent correlation coefficients and p-value for each from Pearson correlation coefficients.

Table 3: Correlation between WASI IQ and SES score

	Overall	Male	Female
Total IQ and SES	0.25638*	0.29248*	0.20909*
Verbal IQ and SES	0.26803*	0.32095*	0.2051*
Cognitive IQ and SES	0.25638*	0.29248*	0.20909*
Performance IQ and SES	0.15567*	0.17101*	0.1338*

* p<0.05

Values represent correlation coefficients and p-value for each from Pearson correlation coefficients.

Table 4: Predictors of IQ at 7 years among Mexican children (n=559)

	Total IQ		**Verbal IQ**		**Cognitive IQ**		**Performance IQ**	
	Mean	**SE**	**Mean**	**SE**	**Mean**	**SE**	**Mean**	**SE**
Latest HOME, score	0.19	0.08*	0.27	0.10*	0.20	0.08*	0.08	0.08
SES in quintile, score	0.67	0.30*	1.04	0.37*	0.66	0.29*	0.17	0.29
Mother age at randomization, years	0.15	0.08	0.05	0.10	0.14	0.08	0.23	0.08*
Maternal height, cm	0.15	0.07*	0.06	0.08	0.14	0.07*	0.18	0.07*
Maternal BMI, kg/m²	-0.27	0.09*	-0.19	0.11	-0.26	0.09*	-0.29	0.09*
Schooling of mother, year	0.33	0.13*	0.44	0.16*	0.32	0.13*	0.17	0.13
Total Raven score of mother, score	0.17	0.05*	0.12	0.06*	0.17	0.05*	0.19	0.04*
Single mother vs. married	-3.02	1.28*	-3.80	1.60*	-2.87	1.28*	-1.12	1.25
Gestation age at birth, weeks	-0.30	0.24	-0.32	0.29	-0.31	0.24	-0.28	0.23
Gestation age at randomization, weeks	-0.14	0.18	-0.13	0.22	-0.14	0.18	-0.08	0.18
Low birth weight (<2,500g) vs. normal	-0.42	2.05	0.59	2.53	-0.44	2.08	-1.60	2.01
Female vs. male	-0.94	0.72	0.05	0.89	-0.92	0.72	-1.56	0.71*
Private school vs. public school	4.73	1.04*	5.45	1.26*	4.80	1.04*	2.84	1.00*
Intervention group (DHA) vs. placebo	0.80	0.73	1.21	0.90	0.83	0.72	-0.06	0.71

* p<0.05

Values represent parameter estimates (mean and standard error) from multivariate linear regressions after adjustment for all other covariates in the table. Multiple imputation was used to account for missing values in the predictors.

Table 5: Predictors of IQ at 7 years among Mexican male children (n=298)

	Total IQ		Verbal IQ		Cognitive IQ		Performance IQ	
	Mean	**SE**	**Mean**	**SE**	**Mean**	**SE**	**Mean**	**SE**
Latest HOME, score	0.34	0.13*	0.53	0.15*	0.33	0.13*	0.07	0.13
SES in quintile, score	0.77	0.44	1.31	0.51*	0.75	0.44	0.14	0.43
Mother age at randomization, years	0.15	0.12	-0.08	0.13	0.15	0.12	0.37	0.12*
Maternal height, cm	0.23	0.10*	0.12	0.11	0.23	0.10*	0.29	0.10*
Maternal BMI, kg/m²	-0.06	0.14	0.13	0.16	-0.07	0.14	-0.26	0.14
Schooling of mother, year	0.29	0.19	0.36	0.22	0.31	0.19	0.13	0.19
Total Raven score of mother, score	0.17	0.07*	0.08	0.08	0.17	0.07*	0.23	0.07*
Single mother vs. married	-2.57	1.79	-2.87	2.03	-2.97	1.76	-2.25	1.76
Gestation age at birth, weeks	-0.33	0.36	-0.07	0.42	-0.32	0.36	-0.57	0.36
Gestation age at randomization, weeks	-0.51	0.26	-0.44	0.30	-0.52	0.26*	-0.41	0.26
Low birth weight (<2,500g) vs. normal	-0.52	3.12	1.22	3.63	-0.35	3.12	-2.82	3.08
Private school vs. public school	5.94	1.45*	6.77	1.67*	5.92	1.44*	3.71	1.44*
Intervention group (DHA) vs. placebo	2.72	1.06*	3.38	1.23*	2.68	1.06*	1.17	1.09

* $p<0.05$

Values represent parameter estimates (mean and standard error) from multivariate linear regressions after adjustment for all other covariates in the table. Multiple imputation was used to account for missing values in the predictors.

Table 6: Predictors of IQ at 7 years among Mexican female children (n=261)

	Total IQ		Verbal IQ		Cognitive IQ		Performance IQ	
	Mean	**SE**	**Mean**	**SE**	**Mean**	**SE**	**Mean**	**SE**
Latest HOME, score	0.05	0.10	0.03	0.14	0.05	0.10	0.06	0.10
SES in quintile, score	0.48	0.38	0.65	0.51	0.49	0.39	0.24	0.35
Mother age at randomization, years	0.15	0.10	0.20	0.14	0.15	0.10	0.09	0.09
Maternal height, cm	0.06	0.09	0.03	0.12	0.06	0.09	0.09	0.09
Maternal BMI, kg/m²	-0.44	0.11*	-0.48	0.15*	-0.45	0.11*	-0.34	0.10*
Schooling of mother, year	0.46	0.17*	0.61	0.22*	0.46	0.17*	0.25	0.16
Total Raven score of mother, score	0.16	0.06*	0.14	0.08	0.16	0.06*	0.15	0.05*
Single mother vs. married	-1.43	1.75	-3.05	2.39	-1.41	1.74	1.01	1.61
Gestation age at birth, weeks	-0.44	0.30	-0.66	0.40	-0.43	0.30	-0.17	0.28
Gestation age at randomization, weeks	0.51	0.24*	0.53	0.32	0.50	0.24*	0.41	0.22
Low birth weight (<2,500g) vs. normal	-0.62	2.61	-0.06	3.54	-0.66	2.61	-1.09	2.42
Private school vs. public school	2.64	1.40	3.36	1.86	2.59	1.41	1.00	1.32
Intervention group (DHA) vs. placebo	-1.50	0.93	-1.40	1.27	-1.47	0.94	-1.48	0.87

* $p<0.05$

Values represent parameter estimates (mean and standard error) from multivariate linear regressions after adjustment for all other covariates in the table. Multiple imputation was used to account for missing values in the predictors.

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