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Influences of early child nutritional status and home learning environment on child development in Vietnam

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Abstract

Early childhood development plays a key role in a child's future health, educational success, and economic status. However, suboptimal early development remains a global challenge. This study examines the influences of quality of the home learning environment (HOME) and child stunting in the first year of life on child development. We used data collected from a randomized controlled trial of preconceptional micronutrient supplementation in Vietnam ($n = 1,458$). The Bayley Scales of Infant Development-III were used to assess cognition, language, and motor development domains at 2 years. At 1 year, 14% of children were stunted, and 15%, 58%, and 28% of children lived in poor, medium, and high HOME environments, respectively. In multivariate generalized linear regression models, living in a high HOME environment was significantly associated with higher scores (0.10 to 0.13 SD) in each of the developmental domains. Stunted children scored significantly lower for cognitive, language, and motor development (-0.11 to -0.18), compared to nonstunted children. The negative associations between stunting on development were modified by HOME; the associations were strong among children living in homes with a poor learning environment whereas they were nonsignificant for those living in high-quality learning environments. In conclusion, child stunting the first year of life was negatively associated with child development at 2 years among children in Vietnam, but a high-quality HOME appeared to attenuate these associations. Early interventions aimed at improving early child growth as well as providing a stimulating home environment are critical to ensure optimal child development.

KEYWORDS

child development, home learning environment (HOME), stunting, Vietnam

1 | INTRODUCTION

Early childhood development plays a key role in a child's future health, educational success, and economic status (Feinstein & Duckworth, 2006). However, suboptimal early development remains a global challenge despite recommended interventions that combine stimulation, nutrition, and health programs (Engle et al., 2007, 2011). It is estimated that over 249 million children in developing countries are not reaching their full developmental potential, with almost 53% (89 million) of these living in South Asia (Black et al., 2016).

The 2016 Lancet series on early child development advocates for policies and programs to "promote, protect, and support" child development as early as possible, including the critical time of pregnancy and the first 2 years of life (Richter et al., 2016; Black et al., 2016;

Britto et al., 2016). The child's nutritional status and quality of the home learning environment (HOME) have been suggested as key factors that influence early child development. During the first 1,000 days of life, the child's brain is rapidly growing and has a high demand for energy, protein, essential fats, and key micronutrients such as iron, zinc, and iodine (Cusick & Georgieff, 2016; Georgieff, 2007). Nutrient deficiencies during this critical period may have long-term and irreversible effects on brain development (Walker et al., 2007). In addition to the direct effects, poor nutrition during early childhood may also have indirect effects on early childhood development and subsequent learning outcomes (Pollitt, Gorman, Engle, Martorell, & Rivera, 1993). For example, parents and caregivers may interact differently with a stunted child (e.g., carrying them more) as they may appear younger; this in turn may influence the child's opportunities

for independent exploration, which is important for child development. In addition, a malnourished child may be more likely to be sick, smaller, and/or have reduced energy levels, all of which make them less likely to explore and engage with his/her environment (Lozoff et al., 1998; Prado & Dewey, 2014). Previous research has supported the associations between child nutritional status (using anthropometric indicators as a proxy of poor nutrition) and cognitive development. For example, being born small for gestational age (SGA) or stunted during the first 2 years of life has been associated with delays in cognitive development (Sudfeld et al., 2015). However, the evidence is less clear for wasting (Sudfeld et al., 2015) and inconclusive for head circumference (Alamo-Junquera et al., 2015). Understanding the relationship between child growth and development is important for targeting children that may benefit from nutritional and child development programs.

A child's home environment and early parental stimulation likewise have been reported as important predictors of child cognitive development and other behavioural outcomes (Britto et al., 2016). For example, in a longitudinal study among Bangladeshi children, stimulation within the home environment, child growth, and parental education were found to mediate 86% of the effects of poverty on child IQ in the first 5 years, in addition to having independent effects (Hamadani et al., 2014). Similarly, the quality of the home environment also mediated the socioeconomic status (SES) gap in cognitive, language, fine motor, and socioemotional development in children 6–42 months in Colombia (Rubio-Codina, Attanasio, & Grantham-Mcgregor, 2016). In a community-based, cluster-randomized, controlled trial designed to promote sensitive and responsive caregiving in Pakistan, the quality of current home stimulation independently mediated the intervention effects on cognitive skills at age 4 years (Obradovic, Yousafzai, Finch, & Rasheed, 2016). Interventions based on early childhood stimulation and facilitation of learning opportunities have been successful in improving early cognitive development (Attanasio et al., 2014; Bradley, 1993; Walker, Wachs, et al. 2007; Yousafzai, Rasheed, Rizvi, Armstrong, & Bhutta, 2014), but evidence on the benefits of combining nutritional and psychosocial stimulation interventions on child development is still limited (Grantham-Mcgregor, Fernald, Kagawa, & Walker, 2014). Studies assessing interactions between nutrition and stimulation have often relied on proxy measures of stimulation, such as SES (Torche & Echevarria, 2011) or education (Watanabe, Flores, Fujiwara, & Tran, 2005) as opposed to observed assessments of early stimulation within the HOME. There is also limited empirical evidence on the combined negative effects of undernutrition and lack of stimulation on cognitive development (Prado & Dewey, 2014).

Examining different indicators of nutritional status and their associations with child development, along with exploring the potential moderating effects of the quality of the HOME, may help to shed light on when and under what circumstances nutrition and the quality of the HOME may be most important for child developmental outcomes. The aims of the this study were to answer three questions: (a) Which indicators of child nutritional status at 1 year of age are most predictive of child development at 2 years?; (b) is HOME predictive of child development; and (c) does the quality of the HOME modify the associations between child nutritional status and development in early life?

Key messages

- Poor growth during the first year of life negatively influenced child cognitive, language, and motor development at 2 years among children in Vietnam.
- The developmental disadvantage associated with stunting was seen primarily in children living in low-quality home environments and was absent among children living in high-quality home environments, suggesting that stimulating environmental factors may buffer the potential negative effects of undernutrition on child development.
- Early interventions aimed at improving pregnancy outcomes and child growth, along with promoting a stimulating home environment, are critical to ensure optimal child development.

2 | METHODS

2.1 | Data sources and study population

This study used data from a randomized controlled trial (PRECONCEPT study), which evaluated the effects of preconceptional micronutrient supplementation on maternal and child health outcomes (identification number NCT0166537; Nguyen et al., 2012). The parent study was approved by the Ethical Committee of the Institute of Social and Medicine Studies in Vietnam and Emory University's Institutional Review Board in Atlanta, Georgia, USA. Written informed consent was obtained from all study participants following approved procedures. Eligible women ($n = 5011$) were randomly assigned to one of three prepregnancy groups to receive weekly supplements containing either (a) 2,800 µg folic acid (FA; control); (b) 60 mg iron and 2,800 µg folic acid (IFA) or (c) multiple micronutrients (MM) containing the same amount of IFA. Women were then followed up prospectively to identify pregnancies ($n = 1,813$) and evaluate birth outcomes ($n = 1,579$). Results from the original trial show that weekly supplementation with MM or IFA before conception did not affect birth outcomes compared with FA (Ramakrishnan et al., 2016), but resulted in modest increases in maternal and infant iron stores (Nguyen, Young, et al., 2016) and improved maternal mental health among women at risk for depression (Ramakrishnan et al., 2015). In the second phase, all live singleton births were followed up for growth at 1 year and child development at 2 years of age ($n = 1,458$), the sample used in the current analyses.

2.2 | Measurements

2.2.1 | Outcomes

Child development at age 2 years was assessed using the Bayley Scales of Infant Development-III (BSID-III; Bayley, 2005), which includes the cognitive, expressive language, receptive language, fine motor, and gross motor subscales. The BSID-III was translated into Vietnamese and back translated by a group of bilingual psychologists and health

researchers. Some of the picture items were adapted for cultural relevance. This adaptation was used in previous studies to describe associations between maternal iron status and cognitive development in Vietnamese children (Tran et al., 2013; Tran et al., 2014). We also pilot-tested the study tools in our study population and found them to be comprehensible and meaningful in rural Vietnam. The BSID-III was administered in a quiet room at community health centers by six well-trained female researchers (with a Bachelor's degree in public health), supervised by a local psychologist. Weekly field-based supervision and monthly staff meetings were used for quality control of the assessment. Site visits and periodic review of videotaped sessions were also carried out by senior investigators, and refresher training sessions were conducted every 6 months after the initial training. Our data showed high internal consistency, with reliability coefficients ranging from 0.87 to 0.90, values close to those in the original validation study conducted in the United States (ranged from 0.89 to 0.97). Results from our standardization also showed high inter-rater reliability with the coefficients of 0.91–0.94 for cognitive, 0.80–0.89 for language and 0.82–0.94 for motor domains.

The raw summary scores for each of the domains were computed and then transformed to standardized Z-scores to facilitate comparisons across domains and with other studies that use other child development assessment tools. Results from the three main developmental subscales were used in the analyses: cognition, language (comprising expressive and receptive language), and motor (comprising fine and gross motor skills).

2.2.2 | Predictor variables

Predictor variables included SGA at birth and child anthropometric measurements (height, weight, and head circumference) and quality of the home and learning environment (HOME) at 1 year of age.

SGA was defined as a birth weight below the 10th percentile for gestational age based on the multicountry INTERGROWTH-21st Project (Villar et al., 2014). Birth weight was measured as early as possible within 7 days after birth using standard procedures (Cogill, 2003; Lohman, Roche, & Martorell, 1988), and gestational age was based on the date of last menstrual period that was obtained prospectively by village health workers during their biweekly home visits (Ramakrishnan et al., 2016).

All anthropometric measurements were obtained at 12 months in duplicate by trained study staff using standard procedures (Cogill, 2003; Lohman et al., 1988). Weight was measured using electronic weighing scales precise to 10 g. Recumbent length was measured by UNICEF collapsible length boards, which were precise to 1 mm. Head circumference was measured with a narrow, flexible, nonstretch tape. Results from our standardization showed that the intra-observer reliability was 95% for length and 97% for weight and head circumference. Weight, length, and head circumference were converted into height-for-age Z-scores, weight-for-age Z-scores, weight-for-height Z-scores, and head circumference-for-age Z-scores using the 2006 WHO child growth standards (WHO, 2010). Stunting, underweight, wasting, and small head circumference were defined as <-2 Z-score of height-for-age Z-scores, weight-for-age Z-scores, weight-for-height Z-scores and head circumference-for-age Z-scores, respectively.

The quality of the learning environment at home was measured using the latest version (2003) of the Infant/Toddler HOME (IT-HOME, 0–3 years; Caldwell & Bradley, 2003), which assesses the quality and quantity of the social, emotional, and cognitive support available to a child in the home environment. Six subscales of the HOME were considered: responsivity, acceptance, organization, learning materials, involvement, and variety. Possible total scores ranged from 0 to 45, with scores <25 indicating a poor home environment, 25–30 as moderate quality, and >30 as a high-quality home environment (Bradley & Caldwell, 1988). These instruments were translated to Vietnamese and back-translated by two independent researchers supervised by the first author and verified for construct validity during pretesting sessions. Results of the pilot test showed that the instrument was applicable to the Vietnam context and only required minor modifications in the translated version to ensure linguistic and functional equivalence. Specifically, we adapted five items related to punishment to make it easier for the parents and field workers to report the occurrence of events (rather than the absence of events) and then reversed the coding during data analysis. Female interviewers were carefully trained in conducting the HOME assessment and included practice sessions in homes. The importance of specific interviewing techniques such as being nonjudgmental, flexible, and engaging were addressed when administering the HOME. Results from our standardization showed high inter-rater reliability with the coefficients of $>90\%$.

2.2.3 | Confounding factors

Several factors at the child, maternal, and household levels were also measured. At the child level, we included child age and sex. At the maternal level, we included age, ethnicity (Kinh—a major ethnicity vs. other ethnic minority), occupation, education (completion of primary, middle, high school, or college and higher), and intelligence. Maternal intelligence was assessed using the Ravens Progressive Matrices (Raven, Raven, & Court, 2003) when the child is at 1 year. Maternal depressive symptoms was measured before conception and when the child was at 1 year using the Center for Epidemiologic Studies Depression Scale (Radloff, 1977), but we did not include this variable in our analyses due to low prevalence of depressive symptoms ($<5\%$). Household characteristics included SES that was calculated using a principal components analysis of a variety of variables, including house and land ownership, housing quality, access to services (electricity, gas, water, and sanitation services), and household assets (productive assets, durable goods, animals, and livestock). The first component derived from component scores was used to divide household SES into quartiles (Gwatkin et al., 2007; Vyas & Kumaranayake, 2006).

2.2.4 | Statistical analysis

Descriptive analyses were used to report characteristics of the study population. First, we examined whether the HOME score was predictive of child development using the following approaches: (a) basic models that only adjusted for child age and gender and (b) linear multivariate regression models that adjusted for potential confounding factors at child (age, gender, and birthweight percentiles by gestational age and gender), maternal (ethnicity, occupation, education, and

TABLE 1 Characteristics of participants assessed with BSID-III at 2 years of age, overall and by home learning environment and child nutritional status

	Overall All (n = 1,458) % or mean ± SD	By home learning environment ^b			By child nutritional status ^c	
		Low environment (n = 201)	Moderate environment (n = 848)	High environment (n = 404)	Stunted children (n = 174)	Nonstunted children (n = 1,107)
		% or mean ± SD	% or mean ± SD	% or mean ± SD	% or mean ± SD	% or mean ± SD
Household characteristics ^a						
Quality of home learning environment						
Low	13.83				12.20	13.35+
Moderate	58.43				67.07	56.91
High	27.74				20.73	29.74
Household SES						
Low	33.63	50.75	36.67	19.11***	42.07	32.16*
Medium	33.97	37.81	34.91	30.27	31.10	33.97
High	32.40	11.44	28.42	50.62	26.83	33.87
Maternal characteristics ^a						
Mother education						
Elementary school	7.96	13.93	8.72	3.47***	14.02	7.40**
Middle school	54.94	58.71	59.13	44.67	60.37	54.08
High school	25.51	24.38	24.50	28.04	19.51	26.00
College or higher	11.59	2.99	7.66	23.82	6.10	12.52
Occupation as farmer	80.81	93.53	85.36	65.09***	86.50	79.75*
Maternal IQ	86.53 ± 16.90	83.54 ± 16.29	85.83 ± 16.74	89.48 ± 17.16***	84.26 ± 16.61	87.48 ± 16.75*
Ethnicity	50.14	61.69	49.11	46.38**	54.60	48.48
Child characteristics						
SGA at birth	11.96	13.47	13.07	9.02	26.11	9.33***
Gender (male)	50.46	50.00	51.65	48.33	56.10	50.19
Undernutrition at 1 year						
Stunting	13.46	12.50	15.56	9.83*		
Underweight	6.65	6.25	8.20	3.76*		
Wasting	3.04	2.50	3.39	2.60		
Small head	10.76	8.13	12.73	8.09*		
Age at measurement of BSID-III	24.41 ± 0.90	24.53 ± 0.59	24.42 ± 0.93	24.35 ± 0.95	24.40 ± 0.81	24.38 ± 0.94

Note. BSID-III = Bayley Scales of Infant Development-III; SD = standard deviation; SES = socioeconomic status; SGA = small for gestational age.

^aMeasured prior conception.

^bFive cases missing measures on home environment.

^c177 cases missing measures child nutritional status at 1 year.

* $p < .05$;

** $p < .01$;

*** $p < .001$.

intelligence) and household levels (SES). All models also adjusted for the group assignment (preconception supplementation with IFA, MM, or FA) as per the original study design; results on the main study have been previously reported (Nguyen et al., 2016). Second, we examined whether SGA at birth and child undernutrition at 1 year (using dichotomous variables of stunting, underweight, wasting, and small head circumference for age) was predictive of child development at 2 years by building separate linear multivariate models for each indicator of child undernutrition as the predictor of interest and adjusting for covariates as described above. Finally, we assessed if associations between measures of child undernutrition and development in early life were modified by the HOME by first testing for interactions and conducting stratified analyses. All data analyses were performed using STATA version 13 (StataCorp, 2009). Results for these models were presented either as coefficients and 95% CI in the table or adjusted means and significant levels in the figure.

3 | RESULTS

Participant characteristics (overall, by levels of HOME and by stunting) are presented in Table 1 for the sample of 1,458 children with development data at age 2 years. The mean age of the mothers was 26 years at baseline (before conception), and all of them were married. The majority were farmers (81%), and half of them were ethnic minorities. More than half of the mothers had also completed middle school (54.9%), and a third had completed high school or higher (37.1%). At birth, nearly 12% of children were SGA and 9.5% were preterm (< 37 weeks gestation). At age 1 year, the prevalence of stunting, underweight, wasting, and small head circumference was 13.5%, 6.7%, 3.0%, and 10.8%, respectively. The mean total score on the quality of the home environment (HOME) at age 1 year was 28.3 ± 3.8 (range 15–42) and 13.8%, 58.4%, and 27.7% of children had poor, moderate, and high quality of home environment, respectively. Baseline characteristics for the final analytic sample were similar to those who were not included due to missing data (results not shown). There were, however, significant differences in maternal baseline characteristics by HOME category. High HOME scores were positively associated with higher SES,

higher education, and higher maternal IQ and negatively associated with being a farmer and/or minority ethnic (Table 1). There were also significant differences in baseline characteristics by child nutritional status. Stunted children were more likely to live in lower SES households and have poorer HOME scores, have mothers with lower education and lower IQ, and more likely to be born SGA (Table 1).

Distribution of the development composite scores at age 2 years was normally distributed (Figure 1). Compared to the mean standardized score $\pm$ SD of 100 ± 15 , children in this study were within the range of the mean for cognitive (99.7 ± 9.9), receptive language (102.7 ± 10.7), expressive language (101.5 ± 9.8), and gross motor (101.8 ± 11.2). The mean fine motor score in our sample was slightly higher than the norms (108.1 ± 13.0).

Mean BSID-III scores at age 2 years differed significantly by HOME at age 1 year (Figure 2). Compared to children living in settings with lower HOME scores, those living in more stimulating environments (i.e., higher HOME scores) had 0.23, 0.21, and 0.20 higher z-scores in cognitive, language, and motor development, respectively. The positive associations between HOME and each of the developmental domains at 2y were attenuated after adjusting for several confounding factors but remained statistically significant for cognitive, $\beta = 0.13$, 95% CI [0.01, 0.25], $p = .04$) and motor development, $\beta = 0.11$, 95% CI [−0.01, 0.23], $p = .06$.

Children who were stunted at 1 year had lower developmental scores at 2y for all three developmental subscales: cognition, $\beta = -0.15$, 95% CI [−0.26, −0.04], $p = .008$, language, $\beta = -0.23$, 95% CI [−0.33, −0.13], $p = .001$, and motor scores, $\beta = -0.21$, 95% CI [−0.32, −0.10], $p = .001$, when compared to those who were not stunted in the basic model (Table 2). These associations were attenuated after adjusting for potential confounding factors, but children who were stunted by age 1 year still had 0.11, 0.18, and 0.18 lower z-scores in cognitive, language, and motor development, respectively ($p < .05$ for all) when compared to those who were not stunted. Children who were underweight at 1 year also had lower language and motor developmental scores at 2 years compared to nonunderweight children, but there were no associations for wasting. Children with small head circumference measurements at 1 year also had lower scores on cognitive and motor development at 2 years. These

FIGURE 1 Distribution of child development composite scores

FIGURE 2 Child development z-score at 2 years, by home learning environment^{1, 2}. (a) Cognitive. (b) Language. (c) Motor. ¹Values are adjusted mean. ²Basic models adjusted for child age and child gender. Full models adjusted for household SES, maternal ethnicity, occupation, education, IQ, child age, gender, birth weight centile, and group assignment. + $p < .1$, * $p < .05$, ** $p < .01$, *** $p < .001$. SES = socioeconomic status

associations of underweight and small head circumference with child development were attenuated and not statistically significant after adjusting for potential confounding factors. There were no significant associations between SGA and any measure of child development.

Because stunting was the indicator of nutritional status that most strongly associated with child development, we examined for effect modification by HOME and found evidence of significant heterogeneity for cognitive development ($p = .04$) and possible effects for motor development ($p = .12$). We found that in low-quality HOMEs, stunting at 1 year strongly predicted poorer child development at 2 years for cognitive, $\beta = -0.45$, 95% CI $[-0.78, -0.11]$, $p = .01$, and motor z-scores, $\beta = -0.41$, 95% CI $[-0.76, -0.06]$, $p = .02$, but no differences were found between stunted and nonstunted children living in high-quality home environments (Figure 3).

4 | DISCUSSION

Improving child growth and development during the first 1,000 days is recognized as a key window of opportunity to improve lifelong health,

development, and income-earning potential (Black et al., 2016; Britto et al., 2016; Richter et al., 2016). Our findings confirm prior research on the influence of nutrition and home environment on child development and provide key insights on the interaction between nutrition and environment in a low-resource setting.

We found that stunting was the primary indicator of undernutrition most strongly associated with poor developmental outcomes, supporting its use as a key global indicator for child health and development (Grantham-Mcgregor et al., 2007). Previous research in developing countries found that SGA was strongly associated with lower child cognitive scores and developmental levels (Walker, Wachs, et al., 2007). Studies from developed countries also showed that these negative associations persisted through adolescence and adulthood (Strauss, 2000). In our study, we found only a weak and statistically insignificant inverse correlation between SGA and development scores, which suggest that postnatal growth and other factors may be playing a greater role in the early development of this cohort of Vietnamese children.

Evidence from other studies on the association between child wasting and development has been mixed, with some studies reporting

TABLE 2 The influence of SGA and child undernutrition at age 1 year on child development at age 2 years

	Cognitive		Language		Motor	
	Basic model ^a	Full model ^b	Basic model ^a	Full model ^b	Basic model ^a	Full model ^b
SGA at birth						
Yes	-0.08 (-0.19, 0.02)	-0.07 (-0.18, 0.04)	-0.08 (-0.18, 0.02)	-0.07 (-0.17, 0.03)	-0.07 (-0.18, 0.04)	-0.06 (-0.16, 0.05)
No	Ref.	Ref.	Ref.	Ref.	Ref.	Ref.
Child undernutrition at 1 year						
Stunting						
Yes	-0.15** (-0.26, -0.04)	-0.11* (-0.23, 0.01)	-0.23*** (-0.33, -0.13)	-0.18** (-0.29, -0.08)	-0.21*** (-0.32, -0.10)	-0.18** (-0.30, -0.06)
No	Ref.	Ref.	Ref.	Ref.	Ref.	Ref.
Underweight						
Yes	-0.12 (-0.27, 0.04)	-0.03 (-0.19, 0.13)	-0.15* (-0.29, -0.01)	-0.07 (-0.22, 0.08)	-0.14* (-0.30, 0.01)	-0.08 (-0.24, 0.08)
No	Ref.	Ref.	Ref.	Ref.	Ref.	Ref.
Wasting						
Yes	0.03 (-0.19, 0.25)	0.16 (-0.07, 0.39)	0.01 (-0.20, 0.21)	0.11 (-0.10, 0.32)	-0.04 (-0.26, 0.17)	0.05 (-0.18, 0.28)
No	Ref.	Ref.	Ref.	Ref.	Ref.	Ref.
Small head						
Yes	-0.16* (-0.28, -0.04)	-0.13* (-0.26, -0.01)	-0.09 (-0.21, 0.02)	-0.06 (-0.18, 0.05)	-0.14* (-0.26, -0.02)	-0.13* (-0.26, -0.01)
No	Ref.	Ref.	Ref.	Ref.	Ref.	Ref.

Note. SGA = small for gestational age.

^aBasic models adjusted for child age and child gender.^bFull models adjusted for birth weight centile, household SES, maternal ethnicity, occupation, education, IQ, child age, gender, and group assignment.* $p < .1$;* $p < .05$;** $p < .01$;*** $p < .001$.

FIGURE 3 Influences of child growth on child development in different home learning environments^{1, 2}. (a) Cognitive. (b) Language. (c) Motor. ¹Values are adjusted mean. ²Models adjusted for household SES, maternal ethnicity, occupation, education, IQ, child age, gender, birth weight centile, and group assignment. * $p < .1$, * $p < .05$, ** $p < .01$, *** $p < .001$. SES = socioeconomic status

a significantly negative association (Sudfeld et al., 2015) whereas others did not find any relationship (Berkman, Lescano, Gilman, Lopez, & Black, 2002). The prevalence of underweight and wasting at 1 year was low in our study, 7% and 3%, respectively; therefore, these results need to be interpreted with caution because we may not have adequate power to detect a relationship with child development. Although head circumference has been hypothesized as an important factor for children's optimal brain growth and development, the relationship between head circumference measured at birth or during the postnatal period and neurodevelopment has been inconclusive, with some studies reporting null associations (Alamo-Junquera et al., 2015). In our study, we found a negative association between having a small head circumference ($HC < -2$ z-score) and child cognitive and motor development, but not with language development. Therefore, our results support the use of early childhood stunting as the best proxy in this context for identifying children to target for early intervention.

Although there is ample evidence to support the role of a stimulating home environment in promoting optimal child development (Britto et al., 2016), there is less evidence on the potential modifying effect of a positive home environment for undernourished children. In a study in Jamaica, stunted and nonstunted children participated in a randomized trial of supplementation and psychosocial stimulation in the first 2 years of life. Although both treatments improved development short-term, only home stimulation had a long-term sustained impact on cognitive functioning among stunted children (Walker, Chang, Powell, & Grantham-Mcgregor, 2005; Walker, Grantham-Mcgregor, Powell, & Chang, 2000; Walker, Chang, et al., 2007). Previous studies have demonstrated the role of the HOME as a mediator between adverse situations, such as poor SES (Hamadani et al., 2014; Rubio-Codina et al., 2016; Obradovic et al., 2016) or maternal depression (Black et al., 2007), and deficits in cognitive development. Our study expands these results and highlights the potential role of the HOME in modifying the relationship between early child growth failure and cognitive

development. Our findings show robust negative effects of child stunting at 1 year on cognitive, language, and motor development at 2 years. Furthermore, the developmental disadvantage associated with stunting was seen primarily in children living in low-quality home environments and was absent among children living in high-quality home environments. This supports the hypothesis that stimulating environmental factors may buffer the potential negative effects of undernutrition on child development (Prado & Dewey, 2014). Thus, our study has implications for the value of integrated nutrition and child development programs, which have demonstrated promising additive and synergistic impacts and other settings (Ruel et al., 2013). This is particularly relevant for Vietnam where approximately 7 million children live in poor household (Unicef, 2012) and one out of four children under 5 years of age is stunted (Nin, 2014). In recent years, the Government of Vietnam has declared improving child nutrition a high priority, with particular emphasis on reducing stunting. However, early childhood development has not received much attention as part of the public health agenda in the country. Results from our study could be leveraged to increase awareness of the benefits of investing in integrated nutrition and child development programs during the first 1,000 days in Vietnam for later schooling and productivity (Black et al., 2016).

A limitation of this study is the lack of formal validation of the use of the BSID-III in Vietnam, although previous studies have successfully tested the scales and found them to be comprehensible and meaningful in rural Vietnam (Tran et al., 2013; Tran et al., 2014). In addition, in our study, care was taken to appropriately contextualize and pilot test tools to ensure high data quality. Another concern is the interpretation of the effect modification of HOME on the association between child stunting and development; we examined this association by using the standard approach of testing for interactions, followed by stratified analysis to explain the observed interactions based on our a priori hypothesis. However, given the temporality of when these two indicators were collected (i.e., both at 12 months), the observed interaction could be interpreted either way (i.e., the effect of home environment differs by stunting status or vice versa). Finally, the follow-up for cognitive, language, and motor development was limited only to the first 24 months of life; further research is needed to fully understand the long-term impact of early nutrition and home environment on child development in this setting.

A key strength of the study is the use of high-quality longitudinal data and a strong analytic approach. The prospective study design of the PRECONCEPT allows for accurately measured child growth and development indicators at birth, at 1 and 2 years of age. We were able to collect data on multiple domains of development to add to the literature on both cognitive and noncognitive domains, using the widely accepted and well-validated Bayley-III Scale. We were also able to collect rich information on the quality of the home environment and other potential confounders.

In conclusion, among children in Vietnam, poor growth during the first year of life negatively influenced child development at 2 years, but living in a stimulating home environment appeared to modify these effects. Early interventions aimed at improving pregnancy outcomes and child growth, along with promoting a stimulating home environment, are critical to ensure optimal child development.

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CONFLICT OF INTEREST

The authors declare that they have no conflicts of interest.

CONTRIBUTIONS

PHN is a coinvestigator of the study and contributed to developing the research questions and study design, writing the research proposal and obtaining funding, overseeing implementation of the trial and data collection, conducting the statistical analysis of data, and writing the manuscript. AMG participated in developing the research questions, reviewed, and provided inputs for data interpretation, editing, and revising the manuscript. IG participated in the interpretation of findings and writing the manuscript. MY participated in the interpretation of findings and writing the manuscript. NK participated in the interpretation of findings and writing the manuscript. SN provided support for the fieldwork and administrative support at TUMP and interpretation of findings. RM is a coinvestigator of the study and contributed to developing the research questions and study design, reviewed and provided inputs for data interpretation, and reviewed the manuscript. UR is the principal investigator of the study and contributed to developing the research questions and study design, writing the research proposal and obtaining funding, overseeing the study at all stages of implementation, and writing the manuscript. All authors contributed to the development, review, and approval of the final manuscript.

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