Early Child Stimulation, Linear Growth and Neurodevelopment in Low Birth Weight Infants

Ravi Prakash Upadhyay (✉ ravi.p.upadhyay@sas.org.in)

Society for Applied Studies

Sunita Taneja

Society for Applied Studies

Tor Arne Strand

Innlandet Hospital Trust

Halvor Sommerfelt

University of Bergen

Mari Hysing

University of Bergen

Sarmila Mazumder

Society for Applied Studies

Nita Bhandari

Society for Applied Studies

Jose Martines

University of Bergen

Tarun Dua

World Health Organization

Patricia Kariger

University of California

Rajiv Bahl

World Health Organization

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Abstract

Background

Children with low birth weight (LBW) are at risk of linear growth faltering and developmental deficits. Evidence suggests that early child stimulation and care reflected as responsive caregiving and opportunities for learning can promote development. The current analysis aimed to measure the extent to which linear growth and early child stimulation modify each other's association with neurodevelopmental outcomes among LBW infants.

Methods

This is a secondary data analyses from a randomized controlled trial on the effect of community-initiated kangaroo mother care in LBW infants on their neurodevelopment at 12 months of corrected age. Bayley Scales of Infant and Toddler Development was used to assess cognitive, motor and language scores. Stimulation at home was assessed by the Pediatric Review of Children's Environmental Support and Stimulation (PROCESS) tool. PROCESS scores were categorized into three groups: $< \text{Mean}-1\text{SD}$ (*low stimulation*); $\text{Mean} \pm 1 \text{SD}$ (*moderate stimulation*) and $> \text{mean} + 1\text{SD}$ (*high stimulation*).

Results

A total of 516 infants were available for neurodevelopment assessments. Interactions were observed between length for age z-score (LAZ) and PROCESS score categories. In the low stimulation group, the adjusted regression coefficients for the association between LAZ and cognitive, motor and language scores were substantially higher than in the moderate and high stimulation group. Stimulation was positively associated with neurodevelopmental outcomes in both stunted and non-stunted infants; however, the association was twice as strong in stunted than in non-stunted.

Conclusion

Moderate to high quality stimulation may alleviate the risk of sub-optimal development in LBW infants with linear growth deficits

Clinical Trial Registration:

The primary trial whose data are analysed is registered at clinicaltrials.gov (<https://clinicaltrials.gov/ct2/show/NCT02631343>)

What Is Already Known On This Topic?

- Linear growth and quality of stimulation and nurturance are independently known to influence neurodevelopment, especially in children born with low birth weight (LBW).
- The extent to which they influence each other's association with cognitive, motor and language scores is unknown.

What this study adds?

- High quality stimulation and nurturance could protect LBW infants with growth deficits from poor development scores.
- Association of stimulation with neurodevelopmental outcomes was twice as strong in stunted than in non-stunted infants.

Introduction

The first 1000 days i.e., from conception through age 24 months, are foundational for brain development [1]. Both adverse and positive experiences during this period may critically shape children's developmental trajectories [2, 3]. Children born with low birth weight (LBW) are at risk of linear growth faltering, cognitive and motor deficits as well as lower academic performance and behavioural problems compared to their normal birth weight counterparts [4–7]. Linear growth faltering in the first 2 years of life has been shown to be negatively associated with cognitive performance in childhood [8, 9]. There is also strong evidence that a child's positive home environment reflected as responsive caregiving and opportunities for early learning, can promote development [10–12].

Less is known on whether linear growth and quality of stimulation/responsive caregiving at home influence each other's association with cognitive, motor and language scores. Using a sample of 513 infants from rural India, Black *et al.* showed that a nurturant home environment attenuated associations between linear growth and fine motor and receptive language development [13]. Similarly, another study from rural Vietnam did not detect significant associations between linear growth and child development in the context of a high-quality home environment [14]. These findings indicate that in the presence of an environment characterized by nurturance and learning opportunities, children with low length-for-age z score (LAZ) can acquire developmental skills at the same level as their peers. Contrasting these findings, recent studies from Malaysian and Jamaican infants found no significant influence of home environment quality on the association between LAZ status and cognitive outcomes [15, 16]. More evidence is required on the interactive effects of linear growth and home environment in relation to developmental outcomes, particularly for the vulnerable subset of LBW infants. Further, evidence is required on whether in a setting with socio-economic constraints, a moderate to high-quality home environment can protect LBW infants with growth deficits from poor development scores and whether there is a differential effect of stimulation on developmental outcomes based on whether the LBW infant is stunted or not. The present analysis was aimed at providing insights on these pertinent issues of global importance.

Methods

Study design and participants

This secondary data analysis was conducted using data from an individually randomized controlled trial (RCT) aimed to evaluate the effect of community-initiated Kangaroo Mother Care (ciKMC) on neurodevelopmental outcomes of infants born low birth weight at 12 months of corrected age (ClinicalTrials.gov identifier NCT02631343) [17]. The study was conducted in resource constrained settings of rural and semi-urban Haryana, North India. In this study population, ciKMC was not associated with the neurodevelopment measures at 12 months [17]. A total of 552 stable preterm or small for gestational age term infants identified within 72 hours of birth and weighing between 1500 and 2250 g were included in the trial and followed up till 12 months of age. Details of the trial have been published elsewhere [17, 18]. Ethical clearances for the primary trial were obtained from the Institutional Ethics Review Committee of Society for Applied Studies, New Delhi (SAS/ERC/KMC-GCC/2015), the World Health Organization (WHO) Ethics Review Committee, Geneva (ERC0002629) and the Regional Committee for Medical and Health Research Ethics in Norway. In the primary trial, written informed consent was obtained from all subjects and/or their legal guardian(s).

Exposure and outcomes

Baseline information was collected on maternal and paternal age and education, birth order, parity and sex of the infant. Gestational age was documented from an ultrasound report, hospital records or maternal recall, whichever was available, in the given order of preference. The wealth of the family was determined by an index created through a principal component analysis based on household assets [19]. Information on vital status, illnesses (including any hospitalization) along with anthropometric measurements (weight and length) were captured by an independent trained team during their home visits at infant age 1, 3, 6 and 12 months. Caregivers were asked about illness(es) and hospitalization(s) in the 2 weeks preceding the visit. Length was measured using infantometers reading to the nearest 0.1 cm. Exclusivity of breastfeeding was assessed at 1, 3 and 6 months of infant age through a structured questionnaire.

Developmental outcomes were ascertained in the study clinic by trained psychologists using the Bayley Scales of Infant and Toddler Development, 3rd Edition (BSID-III) at 12 months of corrected age [20]. The BSID-III was adapted for use in the study setting. Details of the adaptation have been provided elsewhere [17]. Child stimulation at home was assessed at 12 months of age by trained psychologists using “Pediatric Review of Children’s Environmental Support and Stimulation (PROCESS)” questionnaire [21–23]. PROCESS was created for use with parents of children 2–18 months of age and can be administered in a clinic or in a home setting [21]. It consists of three components: a parent questionnaire, clinical observation, and a toy checklist. The parent questionnaire includes 24 items about the physical environment, household organization, and stimulation practices for development. The 20 observational items focus primarily on the emotional quality of parent-child interactions and the toy checklist consists of 40 items. Total scores are summed across the three sections [21]. Higher scores reflect better

stimulation and support to infants. PROCESS scores have been shown to have a good correlation ($r=0.84$) with the most widely used measure of the household environment i.e., Home Observation for Measurement of the Environment (HOME) scores [22, 23].

Plan of analyses

All analyses were done using STATA version 16.0 and R version 3.3.3 (2017-03-06). Baseline characteristics were summarized as mean (SD) or proportion. Length-for-age z score (LAZ) was calculated based on the WHO Child Growth Standards [24]. Stunting was defined as LAZ <-2 , based on the standard WHO definition.²⁴ PROCESS scores, reflecting stimulation environment at home, were categorized into three groups: *Low stimulation group* ($< \text{Mean}-1\text{SD}$); *moderate stimulation group* ($\text{Mean} \pm 1\text{SD}$) and *high stimulation group* ($> \text{Mean} + 1\text{SD}$). The mean (SD) PROCESS score was 124 (17).

Neurodevelopmental outcomes consisted of cognitive, motor and language composite scores assessed by BSID-III at 12 months of corrected age. We first measured the association of LAZ at 6 months and PROCESS scores with scores obtained on BSID-III. We selected covariates for adjustment in the model based on their biological plausibility to influence the exposure and the outcomes and purposive selection principle i.e., covariates that brought at least 15% change in the univariate beta-coefficient were included in the multivariable model [25, 26].

We assessed the interaction between LAZ scores at 6 months of age and the PROCESS scores using likelihood ratio test comparing models with and without interaction terms. Analyses were stratified following the identification of a possible interaction. We initially did a screening where a P-value for interaction of less than 0.20 was investigated further [27]. The investigation was focussed on examining whether the magnitude of association between LAZ and outcome(s) of interest differed between the subgroups based on PROCESS score categories. Stratified results were presented at differing levels of PROCESS scores (low, moderate and high stimulation). For each of the categories of PROCESS score, we used linear regression with the composite scores for cognition, motor or language as an outcome and LAZ score as the exposure variable. Selection of variables for adjustment in the models was based on biological plausibility and purposive selection principle [25, 26].

Similarly, to assess whether the association between PROCESS scores and neurodevelopmental outcomes was modified by whether the babies were stunted or not, the interaction between the PROCESS score categories and stunting status was assessed using likelihood ratio test comparing models with and without interaction terms. In instances where the P-value of interaction was less than 0.20, the analyses were stratified and the effect sizes for the association between PROCESS categories and outcome(s) of interest were presented by the stunting categories. We used generalized additive models (GAM) in the *mgcv package* in R statistical package to depict non-linear associations between PROCESS score, LAZ and outcome scores (composite cognitive, motor and language scores) [28].

Ethics approval

No ethical approval was required for this secondary data analysis. However, the authors obtained written permission from the principal investigator of the primary trial to use the data for this secondary analysis.

Results

Characteristics of the sample

Baseline characteristics of the 516 infants included in this analysis have been presented in Table 1. The mean (SD) composite cognitive, motor and language scores of the sample were 102.1 (11.8), 90.2 (10.4) and 84.9 (9.1) respectively. A total of 52.5% (271/516) of the infants were stunted at 6 months of age.

Table 1
Baseline characteristics of the infants included in this secondary data analysis (N=516)

Variables	Number (%)
HOUSEHOLD CHARACTERISTICS	
Yearly family income (in USD); Median (IQR)	1316 (948-2368)
Proportion of families below poverty line	122 (23.7)
Religion	423 (81.9)
Hindu	89 (17.3)
Muslim	4 (0.8)
Others ^a	
Social class ^b	133 (25.8)
General	167 (32.4)
Other Backward Class (OBC)	216 (41.8)
Scheduled Caste/Tribe (SC/ST)	
Type of family	135 (26.2)
Nuclear	381 (73.8)
Joint	
MATERNAL AND PATERNAL CHARACTERISTICS	
Mean maternal age (years; SD)	23.1 (3.8)
Median years of education of mother (IQR)	5 (0-9)
Mother's occupation	507 (98.3)
Home maker	
Mean father's age (years; SD)	26.4 (4.7)
Median years of education of father (IQR)	8 (5-12)
BIRTH RELATED CHARACTERISTICS	

^a Others: Christian/Sikh/Jain/Parsi/Zoroastrian/Buddhist/neo Buddhist; ^b General- group that do not qualify for any of the positive discrimination schemes by Government of India (GOI), OBC- term used by the Government of India to classify castes which are socially and educationally disadvantaged, SC/ST- official designations given to groups of historically disadvantaged indigenous people in India; USD- United States Dollar; SD- standard deviation; IQR- Inter-quartile range

Variables	Number (%)
Place of delivery	148 (28.7)
Home	266 (51.5)
Government facility	102 (19.8)
Private facility	
Type of delivery	511 (99.0)
Normal	
Birth order	191 (37.0)
1	232 (45.0)
2-3	93 (18.0)
≥4	
Parity	191 (37.0)
Primiparous	
INFANT CHARACTERISTICS	
Sex of the baby	208 (40.3)
Male	
Mean birth weight (grams, SD)	2058.7 (165.3)
Birth weight (range; in grams)	1550 - 2250
Mean gestational age (weeks, SD)	35.7 (1.9)
Gestational age (range; in weeks)	24 - 40
Early initiation of breastfeeding (within an hour of birth) present	323 (62.6)
Exclusive breastfeeding at 3 months	250 (48.4)
^a Others: Christian/Sikh/Jain/Parsi/Zoroastrian/Buddhist/neo Buddhist; ^b General- group that do not qualify for any of the positive discrimination schemes by Government of India (GOI), OBC- term used by the Government of India to classify castes which are socially and educationally disadvantaged, SC/ST- official designations given to groups of historically disadvantaged indigenous people in India; USD- United States Dollar; SD- standard deviation; IQR- Inter-quartile range	

LAZ, PROCESS score and cognitive outcome

LAZ and PROCESS scores were associated with cognitive scores (Table 2).

Table 2

Association of length for age z score (LAZ) and PROCESS score with cognitive, motor and language scores at 12 months of corrected age (N=516)

Variables	Cognitive score	Motor score	Language score
Adjusted mean difference, b (95% CI) ^a ; p value			
LAZ at 6 months	1.78 (0.74, 2.83); p=0.001	2.02 (1.11, 2.94); p<0.001	1.15 (0.37, 1.93); p=0.004
Stunting status at 6 months	Ref	Ref	Ref
Non-stunted	-2.99 (-5.11, -0.87); p=0.006	-3.42 (-5.28, -1.55); p<0.001	-2.53 (-4.11, -0.95); p=0.002
Stunted			
PROCESS score at 12 months	0.25 (0.18, 0.31); p<0.001	0.16 (0.10, 0.22); p<0.001	0.22 (0.17, 0.27); p<0.001
PROCESS categories	Ref	Ref	Ref
<Mean-1 SD (Low)	9.52 (6.47, 12.56); p<0.001	6.60 (3.85, 9.36); p<0.001	7.76 (5.53, 9.99); p<0.001
Mean $\pm$ 1 SD (Moderate)			
>Mean+1SD (High)	12.94 (8.95, 16.95); p<0.001	8.60 (4.98, 12.23); p<0.001	11.82 (8.89, 14.76); p<0.001
^a Adjusted for wealth quintile, gestational age, birth weight, mother's education, birth order, exclusive breastfeeding at 3 months, study groups (intervention and control) and hospitalization for severe illness.			

There was an interaction between LAZ and PROCESS score categories for the cognitive composite score (P=0.08) (Table 3).

Table 3

Association between length for age z score and neurodevelopmental outcomes, by PROCESS score categories

Variable	N=516		
	Adjusted regression coefficient (b) ^a	95% CI	P-value
Cognitive composite score			
(P-value for interaction between PROCESS score categories and LAZ score=0.08)			
In low stimulation group (n=72)			
LAZ score	3.63	1.22, 6.03	0.004
In moderate stimulation group (n=367)			
LAZ score	1.41	0.25, 2.56	0.02
In high stimulation group (n=77)			
LAZ score	1.69	-1.15, 4.52	0.24
Motor composite score			
(P-value for interaction between PROCESS score categories and LAZ score=0.03)			
In low stimulation group (n=72)			
LAZ score	4.08	1.69, 6.46	0.001
In moderate stimulation group (n=367)			
LAZ score	1.54	0.50, 2.58	0.004
In high stimulation group (n=77)			
LAZ score	1.05	-1.14, 3.25	0.34
Language composite score			
(P-value for interaction between PROCESS score categories and LAZ score=0.12)			
In Low stimulation group (n=72)			
LAZ score	2.47	0.56, 4.38	0.01
In moderate stimulation group (n=367)			

^a Adjusted for wealth quintile, maternal age, maternal education, father's age, father's education, parity, birth order, sex of the infant, gestational age, exclusive breastfeeding at 3 months, study groups (intervention and control) and hospitalization for severe illness during infancy; Low stimulation group (PROCESS score; < Mean-1SD); moderate stimulation group (PROCESS score; Mean $\pm$ 1 SD) and high stimulation group (PROCESS score; > Mean + 1SD); LAZ- Length for age Z score; PROCESS- Pediatric Review of Children's Environmental Support and Stimulation; SD- Standard Deviation

Variable	N=516		
	Adjusted regression coefficient (b) ^a	95% CI	P-value
LAZ score	1.02	0.21, 1.86	0.02
In high stimulation group (n=77)			
LAZ score	0.40	-1.78, 2.58	0.72
^a Adjusted for wealth quintile, maternal age, maternal education, father's age, father's education, parity, birth order, sex of the infant, gestational age, exclusive breastfeeding at 3 months, study groups (intervention and control) and hospitalization for severe illness during infancy; Low stimulation group (PROCESS score; < Mean-1SD); moderate stimulation group (PROCESS score; Mean $\pm$ 1 SD) and high stimulation group (PROCESS score; > Mean + 1SD); LAZ- Length for age Z score; PROCESS- Pediatric Review of Children's Environmental Support and Stimulation; SD- Standard Deviation			

In the low stimulation group, the adjusted regression coefficient ($b = 3.63$, 95% CI; 1.22, 6.03) was substantially higher than in the moderate stimulation group ($b = 1.41$, 95% CI; 0.25, 2.56) and the high stimulation group ($b = 1.69$, 95% CI; -1.15, 4.52) (Table 3). The GAM plot supports the findings obtained in regression models (Figure 1). An interaction was observed between stunting and PROCESS score categories (Table 4).

Table 4

Association between PROCESS score categories and neurodevelopmental outcomes, by stunting status

Variable	N=516		
	Adjusted regression coefficient (b) ^a	95% CI	P-value
Cognitive composite score			
(P-value for interaction between PROCESS score categories and stunting categories=0.17)			
LAZ <-2 (n=271)			
Low stimulation	Ref	7.26, 14.92	<0.001
Moderate stimulation	11.09	9.66, 20.68	<0.001
High stimulation	15.17		
LAZ ≥ -2 (n=245)			
Low stimulation	Ref	1.77, 10.97	0.007
Moderate stimulation	6.37	3.54, 15.08	0.002
High stimulation	9.31		
Motor composite score			
(P-value for interaction between PROCESS score categories and stunting categories=0.12)			
LAZ <-2 (n=271)			
Low stimulation	Ref	4.49, 11.88	<0.001
Moderate stimulation	8.19	6.44, 17.06	<0.001
High stimulation	11.76		
LAZ ≥ -2 (n=245)			
Low stimulation	Ref	-0.53, 7.09	0.09
Moderate stimulation	3.28	-0.54, 9.03	0.08
High stimulation	4.24		
Language composite score			
(P-value for interaction between PROCESS score categories and stunting categories=0.05)			

^a Adjusted for wealth quintile, maternal age, maternal education, father's age, father's education, parity, birth order, sex of the infant, gestational age, exclusive breastfeeding at 3 months, study groups (intervention and control) and hospitalization for severe illness during infancy; Low stimulation (PROCESS score; < Mean-1SD); moderate stimulation (PROCESS score; Mean ±1 SD) and high stimulation (PROCESS score; > Mean + 1SD); LAZ- Length for age Z score; PROCESS- Pediatric Review of Children's Environmental Support and Stimulation; SD- Standard Deviation

Variable	N=516		
	Adjusted regression coefficient (b) ^a	95% CI	P-value
LAZ <-2 (n=271)			
Low stimulation	Ref	6.58, 11.95	<0.001
Moderate stimulation	9.26	10.32, 18.05	<0.001
High stimulation	14.19		
LAZ ≥ -2 (n=245)			
Low stimulation	Ref	0.82, 7.75	0.02
Moderate stimulation	4.29	3.13, 11.83	0.001
High stimulation	7.48		
^a Adjusted for wealth quintile, maternal age, maternal education, father's age, father's education, parity, birth order, sex of the infant, gestational age, exclusive breastfeeding at 3 months, study groups (intervention and control) and hospitalization for severe illness during infancy; Low stimulation (PROCESS score; < Mean-1SD); moderate stimulation (PROCESS score; Mean ±1 SD) and high stimulation (PROCESS score; > Mean + 1SD); LAZ- Length for age Z score; PROCESS- Pediatric Review of Children's Environmental Support and Stimulation; SD- Standard Deviation			

In both stunted and non-stunted infants, PROCESS scores were associated with cognitive scores with a clear dose response relationship (Table 4). The adjusted regression coefficient was comparatively higher in stunted infants.

LAZ, PROCESS score and motor outcome

LAZ and PROCESS scores were associated with motor scores (Table 2). There was an interaction between LAZ and PROCESS score categories for the motor composite score (P=0.03) (Table 3). In the low stimulation group, the adjusted regression coefficient ($b = 4.08$, 95% CI; 1.69, 6.46) was higher than in the moderate stimulation ($b = 1.54$, 95% CI; 0.50, 2.58) and the high stimulation group ($b = 1.05$, 95% CI; -1.14, 3.25) (Table 3). The GAM plot confirmed the findings obtained in regression models (Figure 1). An interaction was observed between stunting and PROCESS score categories (Table 4). In stunted infants, PROCESS scores were associated with motor composite scores with a dose response relationship. In non-stunted infants, the adjusted regression coefficient was comparatively lower and did not reach statistical significance.

LAZ, PROCESS score and language outcome

LAZ and PROCESS scores were associated with language scores (Table 2). A potentially relevant interaction (P=0.12) was observed between LAZ and PROCESS score categories (Table 3). In the low stimulation group, the adjusted regression coefficient ($b = 2.47$, 95% CI; 0.56, 4.38) was substantially higher than in the moderate stimulation ($b = 1.02$, 95% CI; 0.21, 1.86) and high stimulation group ($b = 0.40$,

95% CI; -1.78, 2.58) (Table 3). The GAM plot confirmed the findings obtained in regression models (Figure 1). An interaction was observed between stunting and PROCESS score categories ($P=0.05$) (Table 4). In both stunted and non-stunted infants, PROCESS scores were associated with language scores with a distinct dose response relationship. The adjusted regression coefficient was comparatively higher in stunted infants.

Discussion

The current analyses aimed at providing answers to questions with programmatic implications, specifically whether within a setting with socio-economic constraints, a moderate to high-quality home environment can alleviate the risk of low development scores in LBW infants with linear growth deficits. We observed that with increase in stimulation and nurturance at home, the association between linear growth and neurodevelopmental outcomes weakened. Additionally, we also observed that while stimulation at home was associated with neurodevelopmental outcomes in both stunted and non-stunted infants, the association was stronger in stunted than non-stunted infants.

Our findings corroborate the studies done in Bangladesh and Vietnam where the authors noted that among non-low birth weight children, a nurturant home environment attenuated the association between linear growth and neurodevelopmental outcomes [13, 14]. However, findings contrast with the results of the studies among the Malaysian and Jamaican children where no significant influence of home environment quality on the association between LAZ status and cognitive outcomes was noted. The observed difference might be due to fairly smaller sample sizes in these studies, thereby reducing the power to detect significant interactions [15, 16].

There is lack of consensus with regards to the consideration of P-value to indicate presence of an interaction. While some investigators propose to adhere to the conventional P-value of <0.05 , others suggest that usually the power to test for interactions is low in many epidemiologic studies and therefore, testing for interaction tests based solely on P-value of <0.05 may be misleading and could probably miss out important effect modifications [27, 29–31]. Based on this consideration, the suggestion is to increase the type 1 error rate to 20% while assessing tests of interaction [27]. Some researchers argue that consideration of a P-value for interaction tests is a part of the entire spectrum of information to be utilized in the assessment of effect modification and other components should be considered such as stratum-specific measures and prior biological knowledge [32, 33]. In our study, we considered a P-value of less than 0.20 to further investigate for potential interaction. Subsequently, we placed emphasis on the magnitude of effect size within the subgroups and attempted to make careful interpretations. Our findings were also supported by the GAM plots that depicted non-linear relationships between LAZ, PROCESS score and neurodevelopment outcomes.

There are strengths and limitations of this secondary data analyses. The data utilized is from a robust and well conducted randomized controlled trial with very low attrition. The measurements, including the anthropometry, and outcome data were collected by trained and standardized study team. One of the

limitations is that the study lacks reliable data on gestational age. Weight was measured within 72 hours of birth by trained study team and inclusion of infants with weight between 1500-2250 g meant that these infants would be either preterm or term small for gestational age. Therefore, the findings could be extended only to a specific population of LBW infants i.e., stable late preterm or term small for gestational age (SGA) infants. There could also be a possibility that in babies with poorer linear growth or smaller attained length at 6 months of age or rather the factors that lead to such growth faltering may lead to poorer home stimulation which is measured 6 months later by PROCESS. Measurement of home stimulation at one time point only i.e., at 12 months is also a limitation. We also acknowledge that this being an observational study, the results may be affected by unmeasured confounding.

Our findings support the promotion of stimulation to LBW infants in order to offset the negative effect of growth faltering on neurodevelopmental outcomes. While such intervention should be provided to all infants, this should particularly be directed to LBW infants and among them, to those with linear growth deficits. Our findings indicate that through focusing only on nutrition for growth, we may miss to capitalize the important developmental effects of early child stimulation and responsive caregiving. The findings call for a comprehensive approach with nutrition and nurturing care at the forefront. This approach underlies the comprehensive framework of Nurturing Care that incorporates health, nutrition, responsive caregiving, opportunities for early learning, and child protection as a way to help children not only survive but also thrive [34].

Conclusion

The findings suggest that a moderate to high-quality stimulation at home may alleviate the risk of poor development scores in LBW infants with linear growth deficits. Early child stimulation may particularly be beneficial for LBW infants with linear growth deficits/stunting. Efforts for improving child development should be comprehensive with promotion of adequate nutrition and optimal nurturing care as integral components.

Abbreviations

LBW- Low birth weight

PROCESS- Pediatric Review of Children's Environmental Support and Stimulation tool

LAZ- Length for age Z score

RCT- Randomized controlled trial

CiKMC- Community initiated Kangaroo Mother Care

HBPNC- Home Based Post Natal Care

BSID-III – Bayley Scales of Infant and Toddler Development, 3rd Edition

HOME- Home Observation for Measurement of the Environment

GAM- Generalized additive models

SGA- Small for gestational age

AGA- Appropriate for gestational age

Declarations

Ethics approval and consent to participate

No ethical approval was required for this secondary data analysis. Ethical clearances for the primary trial were obtained from the Institutional Ethics Review Committee of Society for Applied Studies, New Delhi, the World Health Organization (WHO) Ethics Review Committee, Geneva and the Regional Committee for Medical and Health Research Ethics in Norway.

Consent for publication

Not applicable

Availability of data and materials

The dataset analysed in the present study is publicly available at:
<https://figshare.com/s/c932d11ff5101e2268bf>

Competing interests

No competing interest to declare

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Contributor's statement

RPU, ST, TAS and MH were involved in conceptualization, data acquisition, analysis, interpretation of data and drafting of the manuscript.

ST, NB and SM were involved in designing and conducting the primary trial.

NB and SM also provided administrative and technical support for this secondary data analysis exercise.

HS, JM, TD, PK and RB provided critical feedback on the statistical analysis and drafting of the manuscript.

All authors critically reviewed the manuscript, provided important intellectual content and approved the final manuscript as submitted. The authors agree to be accountable for all aspects of the work.

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Figures

Figure 1

GAM plot depicting the relationship between length-for-age Z score, PROCESS score and cognitive, motor and language composite score.