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REGULAR ARTICLE

Parental height modifies the association between linear growth and neurodevelopment in infancy

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ABSTRACT

Aim: To estimate the extent to which maternal and paternal height modify the association between length-for-age *Z*-score (LAZ) and neurodevelopmental outcomes assessed by the Bayley Scales of Infant and Toddler Development, 3rd Edition (Bayley-III).

Methods: Baseline data from a clinical trial in 600 Nepalese infants aged six to 11 months with LAZ less than −1 were utilised. The primary exposure was the LAZ score, interaction variables were maternal and paternal height, and the outcomes were Bayley-III cognitive, language and motor scaled scores. Linear regression and generalised additive model (GAM) were used to identify potential interactions.

Results: Linear regression analysis stratified by parental height categories showed that association between unit increase in LAZ and cognitive scaled score differed across maternal (normal height: ß 1.16, 95% CI; 0.75, 1.57 and short height: ß 0.67, 95% CI; 0.28, 1.05) and paternal (normal height: ß 1.32, 95% CI; 0.91, 1.72 and short height: ß 0.61, 95% CI; 0.03, 1.18) height categories. Maternal height also modified the association between LAZ and fine motor scaled score.

Conclusion: The association between LAZ and neurodevelopmental outcomes was attenuated when maternal and paternal height was taken into account. Parental stature should be considered when using LAZ as a proxy for neurodevelopment among infants.

INTRODUCTION

Stunted growth in children is associated with sub-optimal neurodevelopment and poor academic performance (1–4). A recent meta-analysis from low- to middle-income countries (LMICs) provides evidence for the association between improvement in linear growth and child development (5). Each unit increase in height-for-age *z*-scores (HAZ) for young children was associated with 0.24 SD increase in their cognitive ability and 0.38 SD increase in motor scores (5). Substantial global public health efforts have been directed to improve linear growth in early childhood with one of the intentions to enhance child development (6–8). This is particularly important in early life until two to three years after birth since brain development is at its acme and sensitive to environmental factors such as nutritional deficiencies, infections and stress (9,10).

Abbreviations
Bayley-III, Bayley Scales of Infant and Toddler Development, 3rd edition; CI, Confidence interval; GAM, Generalised additive model; GWAS, Genome-wide association studies; HAZ, Height-for-age *z*-score; ICC, Intraclass correlation; IQ, Intelligence quotient; IQR, Inter-quartile range; LAZ, Length-for-age *z*-score; LMICs, Low- to middle-income countries; SD, Standard deviation; WHO, World Health Organization.

Key notes
- The extent to which association between linear growth and neurodevelopment in children is influenced by parental height is unknown.
- Our findings indicate that the association between length-for-age *z*-scores (LAZ) and neurodevelopmental outcomes in infancy is attenuated when taking parental stature into account.
- Parental stature should be considered when using LAZ as a proxy for neurodevelopment among infants.

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A recent analysis of 109 demographic and health survey data from 54 LMICs showed that short maternal height (<150 cm) is associated with nearly two times higher risk of having a stunted child compared to mothers with height ≥160 cm (11). This supports the argument that stunting is an intergenerational process wherein women who were themselves stunted in early life tend to have stunted offspring. Studies have also suggested that paternal height influences birth length, head circumference and linear growth till two years of age (12–14). These findings, along with some recent genome-wide association studies (GWAS), seem to suggest that adult stature is inherited and therefore maternal and paternal stature can be used as a proxy for the growth potential of a child (15,16). The current public health perspective is to look at all children with growth deficit and/or stunting from the same lens; both in terms of their risk of neurodevelopmental impairments, and in terms of expected improvements in neurodevelopmental scores from interventions targeted at accelerating growth. We do not intend to challenge the evidence base that establishes the linkage between growth deficits with neurodevelopmental deficits. However, we want to test the hypothesis that among infants and children with linear growth deficits, the association between linear growth and neurodevelopment is influenced by maternal and paternal height, a reasonable proxy for the child's growth potential.

The current analysis was done using baseline data from an individually randomised double-blind placebo-controlled trial in Nepal (17). The objective of the analyses was to test whether maternal and paternal height has an interaction effect on the association between length-for-age *Z*-score (LAZ) and cognitive, motor and language scores on Bayley-III.

PATIENTS AND METHODS

Study site

The study was conducted in Bhaktapur municipality located ~15 km east of Kathmandu, the capital city of Nepal. It is a peri-urban agriculture-based community with a total population of 80 000. Bhaktapur is a relatively homogenous community where most residents practise either Hindu or Buddhist religions. Most of the families are traditionally engaged in agriculture. Ownership of land and houses is key socio-economic indicators.

Study design and participants

The present analyses derive data from a community-based, individually randomised, double-blind, placebo-controlled trial (clinicaltrials.gov; NCT02272842). Details of the trial and main objectives have been published elsewhere (17). The trial included 600 children aged six to 11 months with LAZ less than −1 SD. We excluded infants with severe systemic illness requiring hospitalisation, severe malnutrition (weight for length <−3SD), severe anaemia (Hb <7 g/dL) and ongoing acute infections requiring treatment (17). The intent was to include apparently healthy infants in the trial.

Baseline assessments

Baseline data were collected on socio-demography and infant feeding practices. Length/height and weight of the child, mother and father were measured at the clinic during enrolment according to standard guidelines (18,19). The neurodevelopmental assessment at enrolment was done using the Bayley Scales of Infant and Toddler Development 3rd edition (Bayley-III). It is a comprehensive assessment tool of developmental functioning in infants and toddlers aged 1–42 months (20,21). The test is administered directly with the child, takes 40–60 minutes to administer and includes five subscales: cognitive, receptive language, expressive language, gross motor and fine motor. It represents the gold standard in the developmental assessment of this age group and has American norms from a representative sample. The Bayley-III raw scores are converted into scaled scores with a mean (SD) of 10 (3) and a range from 1 to 19 (20,21). Psychologists responsible for assessing children were trained and standardised in the use of the Bayley-III. A local psychologist served as 'gold standard' during both training and throughout the study. The study psychologists were required to achieve a high inter-rater agreement (ICC > .90) before testing study children. Seven per cent of all sessions were scored by two examiners for quality assurance with ICCs ranging from 0.97 to 1.00 indicating excellent inter-rater agreement (22).

Ethical clearances

The primary trial obtained approval from the Nepal Health Research Council (NHRC, #233/2014) and from the Regional Committee for Medical and Health Research Ethics (REC #2014/1528) in Norway and is registered at clinicaltrials.gov (NCT02272842). Written-informed consent from one of the parents (usually mother) was obtained. For illiterate parents, thumbprints in the presence of an impartial witness were taken.

Data analysis

All analyses were done using STATA version 15.0 (Statacorp, College Station, TX, USA) and R package version 3.3.3 (R Foundation for Statistical Computing, Vienna, Austria) (2017-03-06). Mean (SD; standard deviation) or median (IQR; inter-quartile range) was calculated for continuous variables and proportions for categorical variables. We categorised maternal and paternal height into short and normal based on the standard WHO definition (23). Distribution of baseline characteristics was presented and compared across the two categories of maternal height, that is short maternal height (<150 cm) and normal maternal height (≥150 cm) using chi-square test. Similarly, comparison of baseline characteristics was also done based on paternal height, that is short paternal height (<161.9 cm) and normal paternal height (≥161.9 cm).

Length-for-age *Z*-score was calculated based on the WHO Child Growth Standards. An interaction variable was generated using LAZ at baseline and maternal height (categorical). We used linear regression with the scaled scores on each of the five Bayley-III subscales as outcomes,

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LAZ score as the exposure variable, and with the interaction term in the model. We also adjusted for baseline variable(s) that differed across the maternal height categories (i.e. variables with $p < 0.05$). We initially did a screening where an interaction p-value of <0.20 was considered relevant and investigated further. The subsequent investigation was based on the principle suggested by Matthews et al. (24), where rather than looking at p-value for interaction for statistical significance, more focus was placed on comparing the effect sizes for the association between LAZ and outcome(s) of interest, by the maternal height categories. Similar analyses were undertaken with paternal height (categorical) as the interaction variable for the association between LAZ score and scores on the Bayley-III subscales. For analyses related to both maternal and paternal height, linear regression was done for the full sample of infants (LAZ < −1). In addition, we did the analyses in a sub-group comprising of stunted infants (LAZ < −2), since stunting is a widely used parameter to characterise infants with increased risk of poor neurodevelopmental outcomes. We used generalised additive models (GAM) in the *mgcv package* in R statistical package to estimate and depict non-linear associations and interactions between maternal or paternal height with LAZ on the Bayley subscale scores (25).

RESULTS

Baseline characteristics

Infants aged six to 11 months were enrolled in the study. The mean (SD) age of infants at the time of enrolment was 8.05 (1.79) months. Table 1 presents the baseline characteristics of the enrolled infants, by maternal and paternal height categories. There were 310 infants with short mothers and 290 infants with normal heighted mothers. Out of a total of 443 available paternal height measurements, 175 had short paternal height and the remaining 268 had normal paternal height. There were no differences in the mean gestational age, mean birthweight and in the proportion of infants with low birthweight across the maternal and paternal height categories. For the maternal height categories, the enrolled infants differed in paternal education, whereas for father's height categories, baseline differences were observed for maternal education and birth order.

Maternal height and neurodevelopment

In the overall sample of infants, the p-values for interaction between maternal height (dichotomous) and LAZ in the linear regression for the cognitive and fine motor scaled scores were 0.10 and 0.16, respectively (Tables 2 and 3). In the GAM, the interaction p-values for cognitive and fine motor scaled scores with maternal height (continuous) were 0.023 and 0.012, respectively. For the other outcomes, the interaction p-values were as follows: gross motor scaled score (0.39 and 0.23), receptive language scaled score (0.95 and 0.88) and expressive language scaled score (0.61 and 0.43) in the linear regression and GAM analyses, respectively.

Maternal height and association between LAZ and cognitive scaled score

Linear regression analysis using the overall sample, stratified by maternal height, showed that the association between LAZ and cognitive scaled score was different in infants with mother of normal and short height. This difference was even larger when we restricted the analyses to infants with LAZ < −2 (Table 2). Our GAM analysis confirmed the presence of an interaction and the regression line depicts the effect modification and shows that the association between LAZ and cognitive scaled score varies across maternal height (continuous) (Fig. 1).

Maternal height and association between LAZ and fine motor scaled score

Linear regression analysis using the overall sample, stratified by maternal height, showed that the increase in fine motor scaled score with each unit increase in LAZ was higher in infants with mothers having normal height compared to those with short heighted mothers (Table 3). Restricting the analyses to infants with LAZ < −2 revealed that in infants with mothers of normal height, each unit increase in LAZ was associated with higher increase in fine motor scaled score compared to those with short heighted mother, where the association between LAZ and fine motor scaled score was substantially attenuated (Table 3). The GAM analysis supports the presence of an interaction and shows that the association between LAZ and fine motor scaled score varies across maternal height (continuous) (Fig. 2).

Paternal height and neurodevelopment

In the linear regression model with the overall sample of infants, p-value of interaction between LAZ and height of the father was 0.05 for cognitive scaled score (Table 4). For gross motor, fine motor, expressive language and receptive language scaled scores, the P-values for interaction were 0.26, 0.33, 0.67 and 0.95, respectively. In the GAM analysis, the p-value of interaction for cognitive scaled score was 0.042; for gross motor, fine motor, expressive language and receptive language scaled scores, the interaction p-values were 0.32, 0.77, 0.92 and 0.39, respectively.

Paternal height and association between LAZ and cognitive scaled score

Linear regression analysis using the overall sample, stratified by paternal height, showed that the association between LAZ and cognitive scaled score was different in infants with father of normal and short height (Table 4). Restricting the analysis to infants with LAZ < −2 also revealed that magnitude of association between unit increase in LAZ and cognitive scaled score differed between infants with fathers of normal and short height (Table 4). The GAM analysis confirmed the presence of an interaction and shows that the association between LAZ and fine motor scaled score varies across paternal height (continuous) (Fig. 3).

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Table 1 Baseline socio-demographic characteristics and infant feeding practices in the study participants, by maternal and paternal height

Characteristics	Short maternal height (<150 cm) (N = 310)	Normal maternal height (≥150 cm) (N = 290)	p-value	Short paternal height (<161.9 cm) (N = 175)	Normal paternal height (≥161.9 cm) (N = 268)	p-value
Socio-demographic characteristics[†]						
Ethnic group						
Newar	214 (69.0)	208 (71.7)	0.55	126 (72.0)	209 (78.0)	0.49
Lama/Tamang	46 (14.8)	45 (15.5)		25 (14.3)	29 (10.8)	
Brahman/Chhetri	25 (8.1)	22 (7.6)		11 (6.3)	16 (6.0)	
Other	25 (8.1)	15 (5.2)		13 (7.4)	14 (5.2)	
Type of family						
Nuclear	158 (51.0)	150 (51.7)	0.85	87 (49.7)	134 (50.0)	0.95
Joint	152 (49.0)	140 (48.3)		88 (50.3)	134 (50.0)	
Family having ownership of land	136 (43.8)	146 (50.3)	0.28	95 (54.3)	134 (50.0)	0.63
Drinking water supply						
Mineral water/packaged water	20 (6.5)	26 (9.0)	0.09	10 (5.7)	25 (9.3)	0.37
Tanker supply	15 (4.8)	6 (2.1)		7 (4.0)	9 (3.4)	
Tap water	261 (84.2)	251 (86.5)		149 (85.2)	226 (84.3)	
Well, Hand pump, other	14 (4.5)	7 (2.4)		9 (5.1)	8 (3.0)	
Type of cooking fuel						
Clean fuel (Gas, electricity)	248 (80.0)	239 (82.4)	0.44	134 (76.6)	211 (79.0)	0.54
Unclean fuel (Fire wood, kerosene)	62 (20.0)	51 (17.6)		41 (23.4)	56 (21.0)	
Maternal and paternal characteristics[†]						
Mother's age (in years)						
<20	12 (3.9)	8 (2.8)	0.24	5 (2.9)	4 (1.5)	0.61
20–25	98 (31.6)	108 (37.2)		55 (31.4)	94 (35.1)	
26–30	119 (38.4)	115 (39.7)		67 (38.3)	105 (39.1)	
>30	81 (26.1)	59 (20.3)		48 (27.4)	65 (24.3)	
Literacy of mother						
Illiterate or up to grade 5	130 (41.9)	93 (32.1)	0.09	72 (41.1)	74 (27.6)	0.02
Secondary completed	56 (18.1)	57 (19.7)		33 (18.9)	52 (19.4)	
Intermediate completed	71 (22.9)	77 (26.5)		41 (23.4)	83 (31.0)	
Bachelor or above	53 (17.1)	63 (21.7)		29 (16.6)	59 (22.0)	
Literacy of father						
Illiterate or up to grade 5	127 (41.0)	85 (29.3)	0.01	64 (36.6)	77 (28.7)	0.12
Secondary completed	68 (21.9)	63 (21.7)		35 (20.0)	62 (23.1)	
Intermediate completed	66 (21.3)	83 (28.6)		50 (28.6)	69 (25.8)	
Bachelor or above	49 (15.8)	59 (20.4)		26 (14.8)	60 (22.4)	
Occupation of father						
Unemployed	7 (2.3)	9 (3.1)	0.35	6 (3.4)	7 (2.6)	0.33
Daily wage earner	130 (41.9)	103 (35.5)		69 (39.4)	97 (36.2)	
Self-employed	93 (30.0)	100 (34.5)		64 (36.6)	87 (32.5)	
Private/Govt. job	64 (20.6)	56 (19.3)		30 (17.2)	69 (25.7)	
Working abroad	16 (5.2)	22 (7.6)		6 (3.4)	8 (3.0)	
Infant characteristics[†]						
Age of infant (months); Mean (SD)	7.99 (1.73)	8.08 (1.84)	0.51	8.18 (1.81)	7.99 (1.76)	0.27
Birthweight; Mean (SD)[‡]	2789.2 (483.2)	2786.1 (512.6)	0.94	2813.4 (469.3)	2757.6 (511.7)	0.25
Proportion with birthweight (<2500 g) [‡]	58 (19.3)	57 (20.4)	0.74	29 (17.2)	51 (19.5)	0.54
Gestational age; Mean (SD)[§]	39.3 (1.58)	39.2 (1.71)	0.39	39.4 (1.59)	39.1 (1.84)	0.14
Sex of the infant						
Male	168 (54.2)	141 (48.6)	0.17	93 (53.1)	137 (51.1)	0.68
Female	142 (45.8)	149 (51.4)		82 (46.9)	131 (48.9)	
Place of delivery[¶]						
Home	11 (3.5)	12 (4.2)	0.70	8 (4.6)	7 (2.6)	0.27
Health facility	299 (96.5)	277 (95.8)		167 (95.4)	261 (97.4)	
Type of delivery[¶]						
Normal	206 (66.7)	203 (70.0)	0.07	119 (68.0)	168 (63.0)	0.26
Caesarean	102 (33.0)	81 (27.9)		55 (31.4)	93 (34.8)	
Assisted	1 (0.3)	6 (2.1)		1 (0.6)	6 (2.2)	

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Table 1 (Continued)

Characteristics	Short maternal height (<150 cm) (N = 310)	Normal maternal height (≥150 cm) (N = 290)	p-value	Short paternal height (<161.9 cm) (N = 175)	Normal paternal height (≥161.9 cm) (N = 268)	p-value
Birth order						
1	145 (46.9)	147 (50.7)	0.25	74 (42.3)	146 (54.7)	0.01
2	117 (37.9)	112 (38.6)		72 (41.1)	97 (36.3)	
≥3	47 (15.2)	31 (10.7)		29 (16.6)	24 (9.0)	
Hospitalisation in the 1st month after birth	28 (9.0)	26 (8.9)	0.98	17 (9.7)	26 (9.7)	0.99
Infant feeding characteristics†						
Infant breastfed at time of enrolment	301 (97.1)	285 (98.3)	0.34	171 (97.7)	260 (97.0)	0.66
Median (IQR) duration of exclusive breastfeeding (in months)	2 (0–5)	2 (0–4)	0.99	2 (0–5)	2 (0–4)	0.38
Exclusive breastfeeding for 3 months or more	142 (46.3)	132 (45.9)	0.95	76 (43.4)	112 (42.3)	0.81
Exclusive breastfeeding for 6 months or more	38 (12.4)	26 (9.1)	0.19	12 (6.9)	18 (6.8)	0.98
Mean (SD) age of start of complementary feeding (semisolid or solid) (months)	4.01 (1.89)	3.84 (1.86)	0.28	3.80 (1.83)	3.82 (1.89)	0.94
Start of complementary feeding within three months of age (semisolid or solid)	118 (38.3)	120 (41.7)	0.40	76 (43.9)	110 (41.2)	0.57
Infant morbidity						
No hospitalisation during the neonatal period††	282 (90.9)	264 (91.0)	0.90	158 (90.1)	242 (90.3)	0.81
No hospitalisation in the post-neonatal period††	297 (95.8)	277 (95.5)	0.86	167 (95.4)	256 (95.5)	0.96
Mean (SD) number of days with loose water stools since birth	1.47 (3.59)	1.04 (2.73)	0.10	1.38 (2.69)	1.32 (3.84)	0.84

†Data presented as number (%) unless otherwise specified.
‡Among 579 infants whose birthweights were recorded.
§Among 407 infants for whom data on gestational age was available.
•Data not available for one infant.
††Hospitalisation considered as an indicator for severe morbidity.

Table 2 Findings of the linear regression analysis exploring the role of maternal height as an 'interaction variable' on the association between LAZ score and the Bayley-III cognitive subscale score

Variable	At LAZ < −1 SD (N = 599)			At LAZ < −2 SD (N = 194)†		
	ß coefficient‡	95% CI	p-value	ß coefficient‡	95% CI	p-value
Interaction variable (Height of mother*LAZ score)§	−0.46	−1.02, 0.09	0.10	−0.89	−2.18, 0.40	0.17
Mother with normal height (≥150 cm)						
LAZ score	1.16	0.75, 1.57	<0.001	1.41	0.37, 2.44	0.01
Mother with short height (<150 cm)						
LAZ score	0.67	0.28, 1.05	0.001	0.42	−0.44, 1.28	0.34

†For normal maternal height group (n = 72), for short maternal height group (n = 122).
‡Adjusted for maternal and paternal education.
§Maternal height is categorised as <150 cm and ≥150 cm.

DISCUSSION

Our findings show that the association of LAZ score with cognitive scores is modified by parental height. This effect modification was more evident in the sub-group of stunted infants (LAZ < −2). We got similar findings for the fine motor scaled score in relation to maternal height. There was no difference in the mean gestational age and birthweight across the maternal and paternal height categories, and therefore, it is unlikely that these factors contributed to the observed findings.

We found that maternal height only modified the association between LAZ and cognition and fine motor scaled scores but not gross motor and language outcomes. Previous studies have shown correlations between cognitive and fine motor skills and suggest fine motor skills to be related to a wide range of academic achievements (26,27). These findings might be explained by the fact that in young children, fine motor and cognitive skills have similar developmental timeframe and probably share common neural basis, that is simultaneous co-activation of the

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Table 3 Findings of the linear regression analysis exploring the role of maternal height as an 'interaction variable' on the association between LAZ score and the Bayley-III fine motor scores

	At all values of LAZ (N = 599)			At LAZ < −2 SD (N = 194)[†]		
Variables	ß coefficient[‡]	95% CI	p-value	ß coefficient[‡]	95% CI	p-value
Interaction variable (Height of mother*LAZ score)[§]	−0.46	−1.11, 0.19	0.16	−1.74	−3.37, −0.12	0.04
Mother with normal height (≥150 cm)						
LAZ score	0.89	0.40, 1.38	<0.001	1.65	0.25, 3.05	0.02
Mother with short height (<150 cm)						
LAZ score	0.45	0.01, 0.90	0.04	−0.12	−1.21, 0.98	0.83

[†]For normal maternal height group (n = 72), for short maternal height group (n = 122).
[‡]Adjusted for maternal and paternal education.
[§]Maternal height is categorised as <150 cm and ≥150 cm.

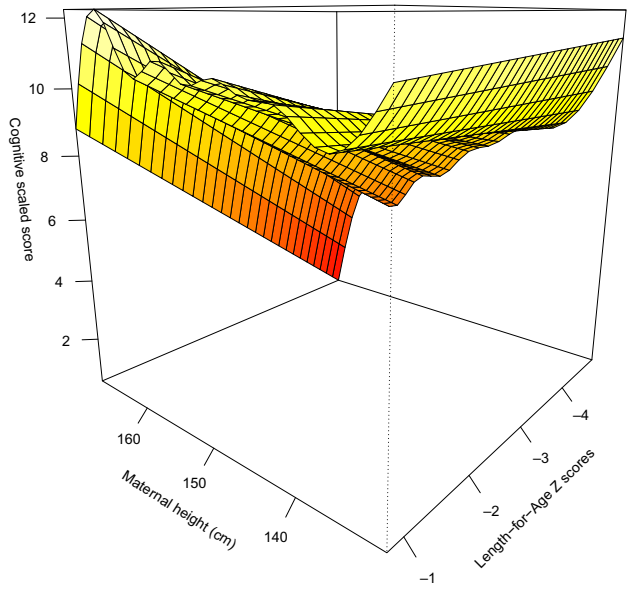

Figure 1 Perspective plot using generalised additive model (GAM) to show the interaction between maternal height and length-for-age *Z*-scores in infants for the Bayley-III cognitive scaled score.

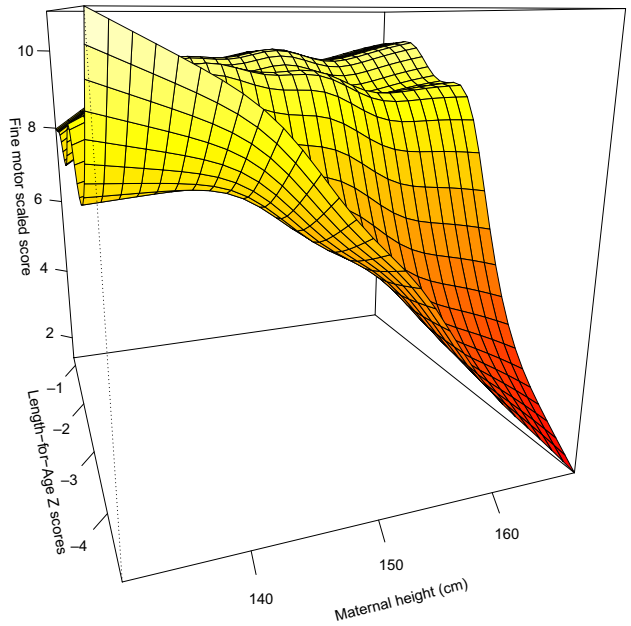

Figure 2 Perspective plot using generalised additive model (GAM) to show the interaction between maternal height and length-for-age *Z*-scores in infants for the Bayley-III fine motor scaled score.

cerebellum, basal ganglia and prefrontal cortex (26,28). Further, fine motor skills require higher-order cognitive skills whereas tasks that require gross motor skills require less cognitive engagement (26). It is quite likely that any exposure or intervention that affects cognition would affect fine motor skills as well. The lack of findings concerning the impact of parental height on the relationship between LAZ and language scores could be because of poor internal consistency and reliability of the language subscales (22). We used a version where certain components of the language subscales were adapted for cultural appropriateness particularly for this study setting (29). However, we acknowledge that language subscales are the hardest to adapt and low rates of vocalisation during infancy in this setting may also have impacted the language scaled scores (22).

Our findings challenge the current global practice to consider all children with linear growth deficits/stunting to be at similar risk of poor neurodevelopment, and hence the use of stunting as a direct proxy indicator to identify children at risk of poor neurodevelopment. The findings indicate that the relationship between growth deficits and poor neurodevelopment is not straightforward and dependent on the child's growth potential. Growth potential is probably controlled by genetic and epigenetic mechanisms which are again inherited from both parents (15,16). Considering stunting, in particular, as a direct indicator of poor neurodevelopment is an oversimplification and may lead to overestimation of the number of children unable to attain their full developmental potential. In a recent article on global research priorities in accelerating early child

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Table 4 Findings of the linear regression analysis exploring the role of paternal height as an 'interaction variable' on the association between LAZ score and the Bayley-III cognitive subscale score

	At all values of LAZ (N = 442)			At LAZ <−2 SD (N = 141)[†]		
Variable	ß coefficient[§]	95% CI	p-value	ß coefficient[§]	95% CI	p-value
Interaction variable (Height of father*LAZ score)[‡]	−0.70	−1.38, −0.007	0.05	−0.80	−1.77, 0.17	0.10
Father with normal height (≥161.9 cm)						
LAZ score	1.32	0.91, 1.72	<0.001	1.15	0.60, 1.71	<0.001
Father with short height (<161.9 cm)						
LAZ score	0.61	0.03, 1.18	0.04	0.36	−0.47, 1.19	0.390

[†]For normal paternal height group (n = 72), for short paternal height group (n = 69).
[‡]Paternal height is categorised as <161.9 cm and ≥161.9 cm.
[§]Adjusted for maternal education, paternal education and birth order.

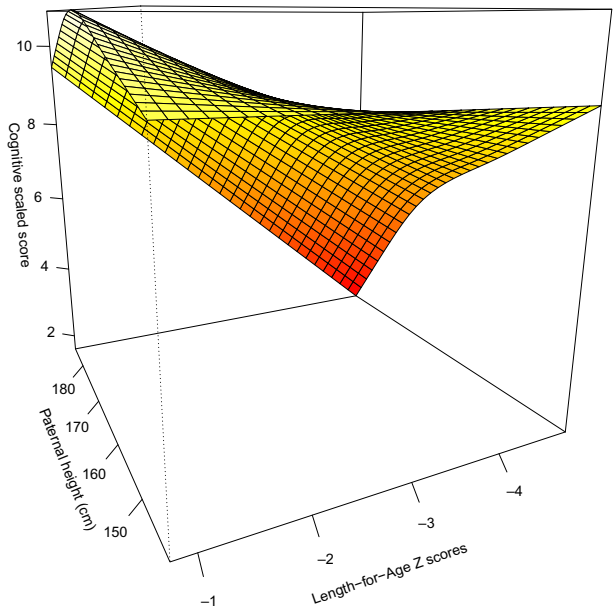

Figure 3 Perspective plot using generalised additive model (GAM) to show the interaction between paternal height and length-for-age *Z*-scores in infants for the Bayley-III cognitive scaled score.

development, the need to ascertain and establish the strength of association between stunting and cognitive development was identified as a key issue (8). Stunting was originally intended as a population level anthropometric indicator of children's social and economic deprivation (30). Utilising this population level indicator to draw inferences about individual children within the population may not be scientifically acceptable.

Our study has some limitations. First, the study was not primarily designed to undertake this analysis and statistical power may be limited for the outcomes considered. However, for cognition, the findings reached statistical significance even with this sample size. Second, we did not take into account parental IQ in the analysis which might influence the associations observed. Nonetheless, we accounted for differences in the maternal and paternal education across the groups which, in part, may be a proxy for maternal and paternal IQ. Third, we did not ascertain the causal pathways and underlying mechanisms that lead parental stature to modify the association of LAZ with cognitive scores and future studies should aim to understand this. Brain development is highly dynamic and influenced by the environment in which the child is reared. Our study population was limited to infants and future studies should explore whether the interaction effect of parental stature on neurodevelopment persists beyond infancy, till childhood and later. We used Bayley-III for neurodevelopmental assessments in infants from this study. The Bayley-III has shown strong predictive value for IQ at four years in a high-risk sample. However, the predictive value is weaker and more uncertain in younger children.

CONCLUSION

We found that the association between LAZ and cognition was attenuated when taking maternal and paternal height into account. Future studies to establish the association between stunting and neurodevelopment as well as those that aim to understand the effect of growth promotion on neurodevelopment in children should take parental height into consideration. We argue that a more nuanced approach to linking LAZ to risk of poor neurodevelopment is warranted.

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DISCLOSURE

The authors declare no conflict of interest.

DATA SHARING STATEMENT

All queries on the data used in the analysis can be directed to the corresponding author.

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