Maternal care mediates the effects of nutrition and responsive stimulation interventions on young children's growth

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Abstract

Background   Undernutrition contributes to at least half the estimated six million annual childhood deaths worldwide. Furthermore, one in three children fails to meet their developmental potential because of risks including stunting, illness, under-stimulation, poor responsive interactions and maternal depressive symptoms. Our study investigates the role of caregiving processes on children's height-for-age at 2 and 4 years.

Methods   The Pakistan Early Child Development Scale-up study assessed the longitudinal effectiveness of early nutrition and responsive stimulation interventions on growth and development at 4 years of age. In total, 1302 children were followed up from birth to 4 years. We leveraged path analyses to explore potential mediators of early intervention effects on children's height-for-age at 4 years, including maternal depressive symptoms, mother–child interaction quality, diarrhoeal illness and height-for-age at 2 years.

Results   Our final model had excellent model fit (comparative fix index = 0.999, Tucker–Lewis index = 0.998, root mean square error of approximation = 0.008) and showed that mother–child interaction quality mediated the effects of both enhanced nutrition and responsive stimulation interventions on height-for-age at 4 years via its longitudinal stability from 2 years of age ($\beta = 0.016$, $p = 0.005$; $\beta = 0.048$, $p < 0.001$, respectively). Further, diarrhoeal illness mediated the effects of maternal depressive symptoms at 1 year post partum on children's height-for-age at 4 years via the longitudinal stability of height-for-age z-score from 2 years of age onwards ($\beta = -0.007$, $p = 0.019$).

Conclusions   The quality of early caregiving experience mediated the association between both interventions and height-for-age. The effect of maternal depressive symptoms on growth was mediated by diarrhoeal illness. Programmatic approaches to child nutrition and growth must address all these potentially modifiable factors.

Introduction

Undernutrition contributes to at least half of all deaths in preschool children (Oruamabo 2015). Chronic undernutrition, marked best by stunting, is defined as a height-for-age z-score (HAZ) at least two standard deviations below the age-specific and sex-specific norms. An estimated 28% of children under the age of 5 years in low-income and middle-income countries (LMIC) are stunted (Black *et al.* 2013). Stunting is a marker of exposure to nutritional deprivation during crucial

developmental windows and is detrimental to neuro-cognitive development and is compounded by poverty (Caulfield et al. 2006; Grantham-McGregor et al. 2007; Walker et al. 2007; Adair et al. 2013; Black et al. 2013).

Poverty is often compounded by additional negative biological and psychological factors, such as diarrhoeal illness and under-stimulation, increasing the risk to children's brain development. Many children enter a lifelong, potentially intergenerational, cycle of unfulfilled development and growth potential and increased risk of adult chronic disease (Gale 2004; MacIntyre et al. 2014; Addo et al. 2015; Walker et al. 2015).

Many areas appropriate for intervention have already been identified including breastfeeding promotion, enhancing maternal dietary quality, screening for acute malnutrition and intervention in the form of ready-to-use food. Undernutrition-related mortality could be reduced by an estimated 15% if core nutrition interventions were implemented and accessible (Bhutta et al. 2013). It is also recognized that nutrition-sensitive approaches are needed to support core interventions and promote child outcomes (Ruel et al. 2013). Growth is a multifactorial process involving dietary intake, illness (particularly diarrhoea) and cognitive and emotional well-being (Oruamabo 2015), and one potentially pivotal mediator in this complex pathway is maternal depression.

In LMIC, maternal depressive symptoms affect 15.6% of women prenatally and 19.8% of women postnatally (Fisher et al. 2012). Risk factors, including inadequate social and family support, low-quality relationships with partners or close relatives and poor coping strategies, may contribute to increased likelihood of women developing depressive symptoms in these contexts (Chandran 2002; Rahman et al. 2003; Faisal-Cury et al. 2004; Tomlinson et al. 2004; Rahman & Creed 2007; Nguyen et al. 2015).

Maternal depression is associated with a number of child outcomes including poor child growth and is estimated to account for 29% of the population-attributable risk to stunting (Surkan et al. 2014). A cohort study in Pakistan found that maternal depression independently predicted multiple diarrhoeal episodes in infancy with a relative risk of 2.3 (95% confidence interval 1.6–3.1), although the mechanisms were unclear (Rahman et al. 2007). The mechanisms are poorly understood and are likely to be more complex than a reduction in the ability of a depressed woman to feed her child. Evidence from a study in Bangladesh showed that the effect of maternal depression on child development is partially mediated through poor quality of care and stimulation in the home (Black et al. 2007). Without support, maternal depression may reduce a mother's emotional availability to provide sensitive, attentive and responsive care for her child's health, nutrition and development needs (Eshel et al. 2006). Studies have shown that higher quality of responsive caregiving, measured by assessing caregiver–child interactions, is associated with a number of beneficial child outcomes including decreased hospitalizations, increased well-baby visits, increased mouthfuls fed to the child and developmental gains (Eshel et al. 2006). More evidence is needed to elucidate the pathways from maternal caregiving capacity and skills with child health and growth outcomes.

The Pakistan Early Child Development Scale-Up was a community-based factorial, cluster-randomized effectiveness trial implemented in the Naushahro Feroze district of Sindh, Pakistan, in which primary recruitment and follow-up were undertaken between 2009 and 2012. It tested enhanced nutrition and responsive stimulation interventions against standard care for several development-related and growth-related outcomes. Mother–child dyads enrolled at birth have now been followed up to the age of 4 years.

In the context of the Pakistan Early Child Development Scale-Up (PEDS) trial, we sought to test the a priori hypothesis that the association between our trial interventions (enhanced nutrition and responsive stimulation) and height-for-age (our main outcome) was mediated by maternal depression and mother–child interaction quality.

The Pakistan Early Child Development Scale-up trial

The PEDS trial (national clinical trial 00715936) was a pragmatic, community-based factorial, cluster-randomized effectiveness trial implemented in the Naushahro Feroze district of Sindh, Pakistan. It tested enhanced nutrition and responsive stimulation interventions against standard care for several development-related and growth-related outcomes. Mother–child dyads were enrolled at birth and followed up initially for 2 years with a further reassessment at 4 years. Recruitment was undertaken between June 2009 and March 2012 (Yousafzai et al. 2014). Clusters were defined by the catchment areas of the Lady Health Workers (LHWs), and each of the four arms was allocated an equal number of clusters. The groups were as follows: (1) standard care as comparison group ($n = 368$); (2) enhanced nutrition ($n = 364$); (3) responsive stimulation ($n = 383$); and (4) combined responsive stimulation and enhanced nutrition ($n = 374$). All four groups received the standard health care provided by the LHW programme, a government-supported community health service delivering health, hygiene and basic nutrition education.

The responsive stimulation group mothers received, in addition to standard care, a locally adapted version of the United Nations International Children's Emergency Fund

and World Health Organization (WHO) 'Care for Child Development' intervention, which promotes developmentally appropriate play and communication activities (UNICEF & WHO 2011). Caregivers were provided an opportunity to practise a play or communication activity with their infant and received coaching from the LHW on how to observe and respond to their infant's cues and signals during the play interaction. The materials used for the play and communication activities included home-made toys (e.g. a rattle made from a plastic water bottle with pebbles) and everyday items in the household (e.g. cups for stacking). The enhanced nutrition group received, in addition to standard care, nutrition education and, for children aged more than 6 months, a multiple micronutrient powder (Sprinkles, Genera Pharmaceuticals, Pakistan), which contained iron, folic acid, vitamin A and vitamin C. Interventions were integrated in the LHW programme and delivered by the LHWs as components of their routine monthly home visits and at monthly community meetings. All infants in the study received the intervention from birth to 2 years old. The LHWs received basic training to deliver the interventions as part of their routine service and were given additional support by an early child development facilitator who observed and provided feedback on improving quality and integration two time per month.

In the first study phase, effectiveness of both interventions was assessed at 2 years of age across several child development, growth, morbidity and caregiving outcomes (Yousafzai et al. 2014; Yousafzai et al. 2015). At 2 years of age, infants exposed to the responsive stimulation (either alone or in combination with enhanced nutrition) had significantly higher cognitive, language and motor development scores assessed using the Bayley Scales of Infant and Toddler Development, Third Edition (Yousafzai et al. 2014). No significant differences were seen as a result of either intervention on child growth. For the mother, there was significant enhancement of caregiving skills in the responsive stimulation group (either alone or in combination with enhanced nutrition) compared with enhanced nutrition alone (Yousafzai et al. 2015). Large effect sizes were reported for maternal–child interaction (Cohen's d = 0.8), caregiving environment as assessed using the Home Observation for Measurement of the Environment Inventory (Cohen's d = 0.9–1.0) and knowledge and practices (Cohen's d = 0.7–1.1) and a small, but significant, protective effect against maternal depressive symptoms for the combined responsive stimulation and enhanced nutrition intervention (Cohen's d = −0.2).

The cohort was assessed again at 4 years old when data were collected on 1302 children representing 87% of the original enrolled sample. No significant differences were observed between the re-enrolled sample and those lost to follow-up. At 4 years, children exposed to the responsive stimulation intervention had significantly higher IQ, executive function and pre-academic skills (Yousafzai et al. 2016). The enhanced nutrition intervention had no effect on these cognitive outcomes. There were no significant intervention effects on child growth indicators at 4 years. Two years after the intervention, mothers exposed to both interventions demonstrated significantly higher quality of mother–child interaction (Cohen's d = 0.2–0.3).

Measures

Child health and growth variables

Illness burden was expressed as episodes of diarrhoea over the first 2 years and collected by maternal monthly reports. An episode was defined as a child experiencing three or more loose stools in 1 day. Height-for-age was measured to the nearest 0.1 cm (Length Boards, Life Care, Karachi, Pakistan, in infancy at 2 years and ShorrBoard®, Weigh and Measure LLC, Olney, MD, USA, at 4 years), and assessments were made at birth and 6, 12, 18 and 24 months. Anthropometric indices were expressed as z-scores using standard WHO anthropometric software (World Health Organization 2011). To check inter-observer reliability of anthropometric measurements, the supervisor visited a random 10% sample of enrolled children. The relative technical errors of measurement (TEM) were found to be good at both 2 (height TEM = 0.7%, R = 0.9) and 4 years (height TEM = 1.9%, R = 0.99).

Maternal depressive symptoms

Maternal depressive symptoms were measured 1 year post-partum, so all the children had been exposed for a year of intervention using a translated and validated version of the Self-Reporting Questionnaire-20. The questionnaire is widely established internationally (Beusenberg & Orley 1994; Rahman et al. 2003) and comprises 20 items designed to identify mental distress experienced over the last 30 days including depression and anxiety-related symptoms, such as tearfulness. The mother responded to each question with a 'yes' or 'no.' In Pakistan, the threshold for clinical risk of depression in mothers is 9 (Rahman et al. 2005). At age 1 year, the inter-observer reliability between assessors and their supervisors, as measured by the Bland–Altman test, was good (n = 51, R = 0.99, p < 0.001) with a good internal consistency (Cronbach's α = 0.800).

Mother–child interaction quality

Mother–child interaction quality was measured using the observation of mother–child interaction tool, which was developed and validated for the PEDS trial (Rasheed & Yousafzai 2015). Trained assessors observed a 5-minute live mother–child book reading activity and rated the frequency of 19 items indicating sensitive and responsive caregiving behaviours including maternal affect, maternal touch, maternal verbalization, sensitivity and contingent responses, scaffolding, language stimulation, focus, child affect, child focus, child's communication efforts and mutual enjoyment. Items were rated such that higher scores indicated more responsive behaviours, and all 19 items were summed to create a total mother–child interaction quality score. At age 2 years, the inter-observer reliability between assessors and their supervisors, as measured by the Bland–Altman test, was good

($n = 154$, $R = 0.85$, $p < 0.001$) with a good internal consistency (Cronbach's $\alpha = 0.886$). At age 4 years, the inter-observer reliability was good ($n = 126$, $R = 0.75$, $p < 0.0001$) with a good internal consistency (Cronbach's $\alpha = 0.807$).

Analytical plan

Path analysis (MPLUS, version 7.3; Muthén & Muthén 2014) was used to explore whether maternal depressive symptoms, mother–child interaction quality and diarrhoeal illness burden mediated the effects of the enhanced nutrition and responsive stimulation interventions on children's HAZ at age 4 years. Each pathway was adjusted for family wealth and maternal education and enabled assessment of time co-variation among constructs. We used robust Huber–White standard errors and CLUSTER command to account for the non-independence of observations
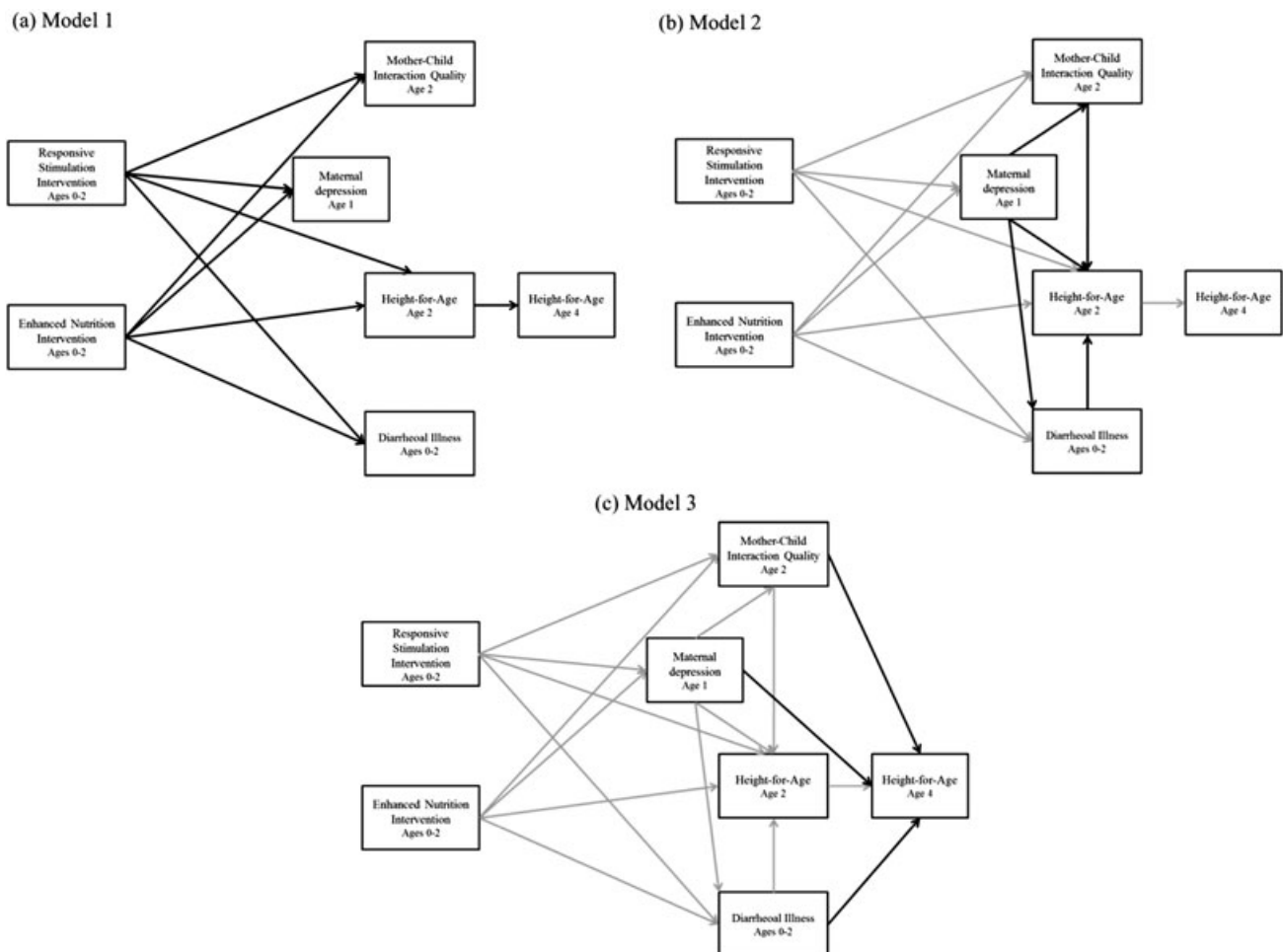

Figure 1. Proposed nested models. All pathways control for household socio-economic status and maternal education. New pathways in each model are shown in black, whereas pathways from the previous model are shown in grey.

arising from the clustering of children into 80 catchments. The percentage of missing data ranged from 0.00% to 2.69%. We used robust maximum-likelihood estimators to account for missing data and non-normality of some variables. We tested the strength of indirect effects using MODEL INDIRECT in MPLUS.

We tested our main hypotheses using a series of nested path analytical models, as shown in Fig. 1. Model 1 estimated pathways from the interventions to the age 1 and age 2 mediators along with a pathway from HAZ at 2 years to HAZ at 4 years. Model 2 estimated additional pathways from maternal depression to the age 2 mediators, and from mother–child interaction quality and diarrhoeal illness to height-for-age at 2 years. Model 3 estimated additional pathways from maternal depression, mother–child interaction quality and diarrhoeal illness to HAZ at 4 years. To evaluate acceptable absolute fit of the models, we used the following fit indices: comparative fit index (values ≥0.95 indicate good model fit), Tucker–Lewis index (values ≥0.95) and root mean square error of approximation (values ≤0.06). Relative model fit was evaluated using a scaled chi-squared difference test for nested models. Each model was compared with the next most parsimonious model to evaluate if the additional parameters resulted in better fit. A significant chi-squared difference test indicated that the additional pathways improved model fit, and thus, the more complex model was selected (Satorra 2000).

The study was approved by the Ethics Committee of the Aga Khan University.

Results

In total, 1302 children were followed up from birth to 4 years (Table 1). Children experienced four episodes of diarrhoeal illness during the first 2 years, on average, and 16% were stunted at age 4 years. On average, there were 4.16 children in each household, and one-third lived in food-insecure households. Mothers had completed 2 years of formal education, on average, and 36% had depressive symptoms.

Bivariate correlations

Both the responsive stimulation and enhanced nutrition interventions were significantly correlated with decreased food insecurity and higher mother–child interaction quality at age 2 years. Further, the enhanced nutrition intervention was significantly associated with decreased maternal depressive symptoms age 1 year post partum and higher maternal education. Maternal depression was associated with negative child health indicators, including higher rates of diarrhoeal illness and decreased HAZ at both 2 and 4 years, as well as worse socio-economic indicators, including lower maternal education and family wealth, a higher rate of food insecurity and a higher

Table 1. Descriptive statistics and correlations among study and demographic variables

	1	2	3	4	5	6	7	8	9	10	11	12	13
1. RS	—												
2. EN	−0.01	—											
3. Mat dep (age 1)	0.02	−0.09***	—										
4. OMCI (age 2)	0.34***	0.12***	−0.03	—									
5. Diar ill (ages 0–2)	0.02	0.05[+]	0.18***	−0.01	—								
6. HAZ (age 2)	−0.04	0.03	−0.09**	0.21***	−0.11***	—							
7. HAZ (age 4)	−0.01	0.05[+]	−0.07*	0.14***	−0.13***	0.74***	—						
8. Wealth (age 0)	0.04	−0.01	−0.12***	0.21***	−0.13***	0.27***	0.20***	—					
9. Mat edu (years)	0.01	0.08**	−0.10***	0.20***	−0.14***	0.22***	0.16***	0.37***	—				
10. Child male	0.03	−0.05	0.01	0.01	−0.03	−0.02	0.06*	−0.01	0.01	1			
11. Mat age (years)	−0.03	0.04	0.06*	−0.03	−0.02	−0.04	0.01	−0.05	−0.13***	0.00	1		
12. Food ins (age 2)	−0.07*	−0.14***	0.21***	−0.14***	0.11***	−0.17***	−0.15***	−0.25***	−0.21***	0.04	0.04	1	
13. Num children	0.03	−0.03	0.15***	−0.09**	0.05	−0.10***	−0.10***	−0.11***	−0.18***	−0.01	0.47***	0.12***	1
Valid N	1302	1302	1267	1301	1294	1278	1294	1294	1291	1302	1252	1301	1302
M/%	50.69%	48.08%	6.61	32.36	4.32	−2.33	−0.87	0	2.03	53.92%	28.16	32.74%	4.16
SD			(4.46)	(10.02)	(2.82)	(1.12)	(1.17)	(1.00)	(3.76)		(5.87)		(2.25)

Note. RS, responsive stimulation intervention; EN, enhanced nutrition intervention; Mat dep, maternal depression; OMCI, quality of mother–child interaction; Diar ill, diarrhoeal illness; HAZ, height-for-age; Mat edu, maternal education; Mat age, maternal age at baseline; Food ins, food insecurity; Num children, number of children.
[+] $p < .10$.
*$p < .05$.
**$p < .01$.
***$p < .001$.

number of children in the household. Higher-quality mother–child interactions were significantly correlated with child HAZ at both 2 and 4 years, as well as better socio-economic indicators. As expected, children with higher rates of diarrhoeal illness had lower HAZ at both 2 and 4 years and higher rates food insecurity. Children with higher rates of diarrhoeal illness also came from families with lower socio-economic backgrounds. Finally, both measures of HAZ were positively correlated with household wealth and maternal education and negatively correlated with food insecurity and number of children in the home.

Model comparisons

As shown in Table 2, the comparison of the most parsimonious model 1 with model 2 revealed that the addition of five pathways from maternal depressive symptoms to the age 2 mediators and from mother–child interaction quality and diarrhoeal illness to HAZ at 2 years significantly improved the relative model fit, as indicated by a significant chi-squared difference test ($\Delta\chi^2(5) = 61.159$, $p < 0.001$). Model 3, which added pathways from maternal depression and the age 2 mediators to HAZ at 4 years, did not significantly improve the relative model fit. Therefore, we selected model 2 as our final model.

Direct paths

All direct pathways are reported in Table 3, and significant pathways are shown in Fig. 2. The enhanced nutrition intervention predicted reduced maternal depressive symptoms at 1 year post partum ($\beta = -0.091$, $p = 0.005$). The responsive stimulation and enhanced nutrition interventions both predicted mother–child interaction quality at 2 years ($\beta = 0.331$, $p < 0.001$; $\beta = 0.110$, $p = 0.001$, respectively). Further, mother–child interaction quality at 2 years was linked to children's HAZ at 2 years ($\beta = 0.196$, $p < 0.001$). Maternal

depressive symptoms at 1 year post partum was associated with increased episodes of diarrhoeal illness over the first 2 years of the infant's life ($\beta = 0.167$, $p < 0.001$), which in turn was linked to decreased height-for-age at 2 years ($\beta = -0.059$, $p = 0.011$). Finally, we found a weak positive association of enhanced nutrition and diarrhoeal illness in the first 2 years.

Indirect paths

All indirect pathways are reported in Table 3. With respect to indirect effects, the effect of maternal depression at 1 year post partum on children's on HAZ at 4 years through its effects on HAZ at 2 years is partially mediated by diarrhoeal illness ($\beta = -0.007$, $p = 0.019$). Moreover, mother–child interaction quality mediated the effects of both interventions (nutrition and responsive stimulation) on HAZ at 4 years, through its associations with HAZ at 2 years ($\beta = 0.016$, $p = 0.005$; $\beta = 0.048$, $p < 0.001$, respectively).

Discussion

This study shows the importance of early maternal depressive symptoms and maternal–child interactions on early child health and height-for-age. There are two key findings. The first is that maternal depressive symptoms were linked to height-for-age at age 4 through its effect on diarrhoeal illness and longitudinal stability of height-for-age between ages of 2 and 4 years. The second is that both interventions enhanced mother–child interaction quality, which, in turn, was associated with improved height-for-age.

It is now clear that assumptions of a direct effect of early childhood interventions on growth are an oversimplification of a process that involves physical well-being, caregiver–child interaction, maternal education and the child–environment interface (Santos *et al.* 2008). Growth is a multifactorial process and includes dietary intake, diarrhoeal illness burden (Kotloff

Table 2. Fit statistics and model comparisons for hierarchically nested path analysis models

Model	d.f.	c	χ^2	cd	χ^2 (diff)	d.f. (diff)	P-value	CFI	TLI	RMSEA	RMSEA 95% CI
3	7	2.673	6.654					1.000	1.001	0.000	(0.000, 0.033)
2	10	2.281	10.866	1.367	5.12	3	0.1631	0.999	0.998	0.008	(0.000, 0.032)
1	15	1.854	61.159	N/A	50.29	5	0.0000	0.962	0.925	0.049	(0.036, 0.062)

Note. c, weighting constant for computing the χ^2 statistic using robust estimation method; *cd*, weighting constant for the difference between two χ^2 values using robust estimation method; CFI, comparative fix index; TLI, Tucker–Lewis index; RMSEA, root mean square error of approximation; CI, confidence interval.
Model 1: Responsive stimulation and enhanced nutrition intervention effects on maternal depression, mother–child interaction quality, height-for-age (2 years) and diarrhoeal illness. Height-for-age (2 years) effect on height-for-age (4 years). All other pathways held constant at zero.
Model 2: Adds pathways from maternal depression to mother–child interaction quality, height-for-age (2 years) and diarrhoeal illness.
Model 3: Adds pathways from mother–child interaction quality, maternal depression and diarrhoeal illness to height-for-age (4 years).

Table 3. Final model direct and indirect pathways

Pathway		SE	P-value
Direct			
RS → OMCI	0.331	(0.033)	<0.001
RS → Mat dep	0.023	(0.031)	0.465
RS → HAZ (2 years)	−0.107	(0.039)	0.006
RS → Diar ill	0.019	(0.036)	0.596
EN → OMCI	0.110	(0.035)	0.001
EN → Mat dep	−0.091	(0.032)	0.005
EN → HAZ (2 years)	−0.002	(0.039)	0.954
EN → Diar ill	0.074	(0.037)	0.047
Mat dep → OMCI	0.003	(0.026)	0.896
Mat dep → HAZ (2 years)	−0.032	(0.028)	0.250
Mat dep → Diar ill	0.167	(0.029)	<0.001
OMCI → HAZ (2 years)	0.196	(0.031)	<0.001
Diar ill → HAZ (2 years)	−0.059	(0.023)	0.011
HAZ (2 years) → HAZ (4 years)	0.736	(0.014)	<0.001
Indirect			
RS → HAZ (4 years)	−0.033	(0.030)	0.279
RS → HAZ (2 years) → HAZ (4 years)	−0.079	(0.029)	0.006
RS → Diar ill → HAZ (2 years) → HAZ (4 years)	−0.001	(0.002)	0.586
RS → OMCI → HAZ (2 years) → HAZ (4 years)	0.048	(0.009)	<0.001
RS → Mat dep → HAZ (2 years) → HAZ (4 years)	−0.001	(0.001)	0.477
RS → Mat dep → Diar ill → HAZ (2 years) → HAZ (4 years)	0.000	(0.000)	0.484
RS → Mat dep → OMCI → HAZ (2 years) → HAZ (4 years)	0.000	(0.000)	0.895
EN → HAZ (4 years)	0.014	(0.030)	0.651
EN → HAZ (2 years) → HAZ (4 years)	−0.002	(0.029)	0.954
EN → Diar ill → HAZ (2 years) → HAZ (4 years)	−0.003	(0.002)	0.086
EN → OMCI → HAZ (2 years) → HAZ (4 years)	0.016	(0.006)	0.005
EN → Mat dep → HAZ (2 years) → HAZ (4 years)	0.002	(0.002)	0.273
EN → Mat dep → Diar ill → HAZ (2 years) → HAZ (4 years)	0.001	(0.000)	0.095
EN → Mat dep → OMCI → HAZ (2 years) → HAZ (4 years)	0.000	(0.000)	0.895
Mat dep → HAZ (4 years)	−0.030	(0.020)	0.134
Mat dep → HAZ (2 years) → HAZ (4 years)	−0.023	(0.020)	0.251
Mat dep → Diar ill → HAZ (2 years) → HAZ (4 years)	−0.007	(0.003)	0.019
Mat dep → OMCI → HAZ (2 years) → HAZ (4 years)	0.000	(0.004)	0.896

Note. RS, responsive stimulation intervention; EN, enhanced nutrition intervention; Mat dep, maternal depression; OMCI, quality of mother–child interaction; Diar ill, diarrhoeal illness; HAZ, height-for-age; SE, standard error.

et al. 2013), responsive care (Eshel *et al.* 2006) and maternal mental health (Surkan *et al.* 2011). A history of maternal depression influences many of these pathways, and a recent analysis of a cohort from four LMICs showed a consistent influence of maternal depression on growth, and psychological and cognitive development at 8 years (Bennett *et al.* 2016). Maternal depression early in a child's life is associated with negative behaviours towards children (Ewell Foster *et al.* 2008; Surkan *et al.* 2014) and can result in a reduction in the quality of breast milk, poorer self-care and a reduced capacity to stimulate her child or be sensitive to early infant cues pertaining to health and nutrition (Patel 2004; Eshel *et al.* 2006; Black *et al.* 2007; Rahman & Creed 2007).

How then can maternal depression be tackled? There is a dearth of literature on perinatal and postnatal depression in LMICs. Mental health services in LMICs are poorly resourced, but there is some evidence from a recent systematic review that community health workers and lay workers can play an effective role in the detection and treatment of maternal depression (Gilmore & McAuliffe 2013). Family relationships might also help, and work in Vietnam showed that the quality of women's relationships with both their partners and mothers protected against post-partum mental illnesses and increased the rate of recovery for mothers who did develop a mental illness (Nguyen *et al.* 2015).

A full discussion on the interventions tested to date is beyond the scope of this paper, and the literature is mixed in terms of effectiveness. However, there is evidence that group problem-solving therapy (Chibanda *et al.* 2014) and cognitive behavioural therapy delivered by lay workers (Sikander *et al.* 2015) can be effective in low-resource settings. Whether universal screening for depression is of
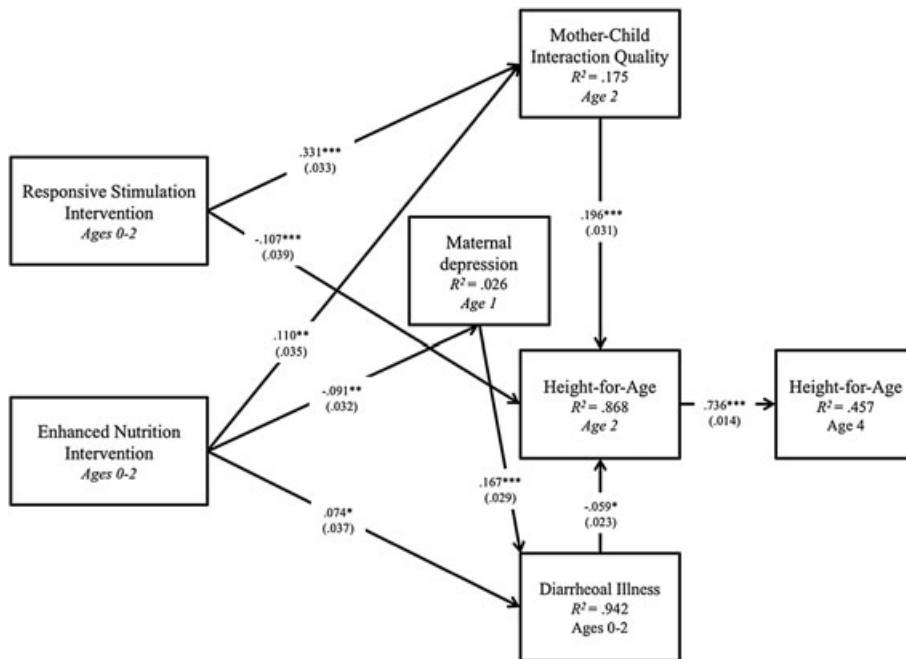
Figure 2. Final path analysis (model 2). All pathways control for household socio-economic status and maternal education.

benefit is, however, controversial, and it is not known to what extent combined maternal nutrition and maternal depression interventions are synergistic (Thombs *et al.* 2014).

Further, diarrhoeal illness mediated the effect of maternal depressive symptoms on height-for-age at 2 years, which was then linked to height-for-age at 4 years. Diarrhoeal illness is known to alter both growth and developmental trajectories through several pathways: (1) direct depletion of nutrients important for both tissue accretion and neurodevelopment during a sensitive period of child growth and development; (2) a direct toxic effect of enteric organisms on early brain development (Guerrant *et al.* 1999); and (3) the effect it has on quality of care that caregivers are able to offer a child and the extent to which the affected child is able to respond (Black *et al.* 2007; Hamadani *et al.* 2012; Aboud & Yousafzai 2016).

Another part of the complex story is the powerful mediating role played by maternal responsive behaviours. In this study, both interventions predicted better quality mother–child interactions, particularly the responsive stimulation intervention, perhaps because responsive caregiving advice is relevant to all forms of contact whereas responsive feeding guidance relates to one context. This finding adds to previous evidence showing that interventions promoting responsive care can support early growth even in a context of high levels of maternal depressive symptoms.

We have demonstrated in a previous paper (Yousafzai *et al.* 2014) that responsive stimulation enhances child development at 2 years. In this analysis, the quality of mother–child interaction then mediates the effect of responsive stimulation on child growth. Mother–child interaction quality might, in part, be a marker for closer maternal attention to needs including feeding (in particular, responsive feeding), but there are likely to be additional factors on the causal pathway related to emotional expressivity (Laucht *et al.* 2001; Bentley *et al.* 2011).

Strengths and limitations

Strengths of the study include minimal attrition and therefore a low risk of participation bias, rigorous assessment of the responsive stimulation and enhanced nutrition interventions and measures, several informative covariates and mediators, and standardized measurements of outcomes. We acknowledge several limitations. The population is fairly homogeneous with a high prevalence of risk for maternal depression. This, however, suggests that our estimates are conservative, so the strength of associations we found may well be an underestimate. Future work could explore how paternal depression is linked to children's height-for-age and early childhood experiences, which may also influence child outcomes. Finally, illness burden was assessed by maternal reporting alone; although this approach is imperfect, it is a standard one (Lee *et al.* 2014). Despite these limitations, we

believe we have elucidated several pathways through which the interventions had an impact upon growth.

Conclusion

The beginning of the Sustainable Development Goals era is a good time to question several beliefs and to raise the profile of maternal mental health and responsive caregiving behaviours given their unequivocal role in determining both short and intergenerational child health (Beattie *et al.* 2015; Requejo & Bhutta 2015). Maternal depression predicts height-for-age through its effects on diarrhoeal illness. Both responsive stimulation and enhanced nutrition interventions improve the quality of maternal–child interactions, which augments children's height-for-age. Intervention packages that promote responsive behaviours for stimulation and feeding and address maternal mental health are likely to be more effective than those promoting nutritional supplementation alone.

Key messages

- The quality of mother–child interactions mediated the effects of both nutrition and responsive stimulation interventions on children's height-for-age at 4 years through the longitudinal stability of height-for-age from the age of 2 years.
- The effect of maternal depressive symptoms on child height-for-age at 4 years is mediated by diarrhoeal illness burden.
- Programmatic approaches to child growth in low-income and middle-income countries must incorporate strategies to prevent, detect and treat maternal depression as well as promote high-quality mother–child interactions.

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