



# Maternal depressive symptoms and early childhood development: the role of mother–child interactions among mother–child dyads in rural areas of Central and Western China

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## ABSTRACT

**Background.** The associations among maternal depressive symptoms (MDS), mother–child interactions and early child development are poorly understood. This study aimed to explore the role of mother–child interactions on the associations between MDS and child development.

**Methods.** A cross-sectional study with a multistage sampling method was conducted in rural areas of Central and Western China. MDS, child development outcomes (communication, gross motor function, fine motor function, problem solving and personal social skills) and mother–child interactions were assessed by The Edinburgh Postpartum Depression Scale, the Chinese version of the Ages and Stages Questionnaires and the Multiple Indicator Cluster Surveys, respectively. Regression-based statistical mediation and moderation were conducted using the PROCESS macro for SPSS.

**Results.** A total of 2,548 participants (mothers: 1,274; children: 1,274) were included in our analyses. MDS was negatively associated with child development outcomes and mother–child interactions partly mediated these associations. The proportion of the mediating effect of mother–child interactions was 7.7% for communication, 8.2% for gross motor, 10.3% for fine motor, 10.1% for problem-solving and 9.5% for personal social domains. In addition, the interaction effects of MDS and mother–child interactions on the communication domain were significant ( $\beta = 0.070$ , 95% CI 0.016, 0.124;  $p = 0.011$ ). The associations between MDS and child communication abilities were weaker at the high level (simple slope =  $-0.019$ ,  $t = -0.458$ ,  $p = 0.647$ ) of mother–child interactions than at the mean level (simple slope =  $-0.089$ ,  $t = -3.190$ ,  $p = 0.002$ ) and the low level (simple slope =  $-0.158$ ,  $t = -4.231$ ,  $p < 0.001$ ). Similar moderating effects were not observed in the other child development outcomes.

**Conclusion.** Our results suggest the important role of mother–child interactions on the associations between MDS and early childhood development. Due to the cross-sectional design of this study, these associations require further investigation in prospective studies.

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## INTRODUCTION

The early years of life are a critical period for child brain growth and development, with the potential to later impact social, economic and health-related quality of life (*Peacock-Chambers, Ivy & Bair-Merritt, 2017*). One research study indicates that 250 million children (43%) younger than 5 years in low-income and middle-income countries are at risk of not reaching their developmental potential (*Black et al., 2017*). A large number of studies have confirmed maternal depressive symptoms (MDS) as a predictor of various negative child development outcomes, such as poor physical and cognitive development, increased behavioural problems and later common mental disorders (*Aoyagi et al., 2019; Gelaye et al., 2016; Liu et al., 2017; Netsi et al., 2018; Tuovinen et al., 2018*). However, most of these studies have been performed in high-income countries and have samples consisting of participants only representing Western, educated, industrialized, rich, and democratic societies (*Rogers et al., 2020*). Studies with more diverse samples are needed. Also, in low-to-middle income countries, MDS is more highly prevalent than in high-income countries (*Gelaye et al., 2016*), and the negative factors that impact both MDS and early childhood development are also more common than in high-income countries (*Herba et al., 2016*).

Understanding the pathways that link MDS and child development outcomes is a critical step in early intervention. MDS has considerable impact on mother–child interactions because depressed mothers tend to fail to bond well with their babies (*O'Higgins et al., 2013*). In addition, depressed mothers have increased self-focus and psychological distancing as well as decreased mother–child involvement, warmth, sensitivity and contingent responsiveness (*Hakanen et al., 2019; Humphreys et al., 2018; Ierardi et al., 2019; Lanzi, Bert & Jacobs, 2009*). A lack of mother–child interactions is associated with high rates of developmental delays in children (*Yang et al., 2019; Yue et al., 2019*). Taken together, mother–child interactions may play a mediating role in the association between MDS and child development. That is to say, MDS affects mother–child interactions and thereby child development. Furthermore, the interactive effects of MDS and mother–child interactions is also a point of concern. MDS and child development vary as a function of other aspects of the caregiving environment, and the negative or positive parenting behaviours may serve as environmental contexts that exacerbate or attenuate the influence of parental depression on children (*Brett et al., 2020; Olino et al., 2016*). Therefore, mother–child interactions may play a moderating role in the association between MDS and child development, which means that different levels of mother–child interactions may ameliorate or worsen the negative impact of MDS. However, there has been little discussion about both mediating and moderating effects of mother–child interactions in the association between MDS and child development.

Over the past few decades, there has been a tremendous amount of economic development in China. However, the economic development has not been uniform throughout the country, and the resulting regional economic development gaps are still of great concern to society because there are increased health risks in less developed regions. A meta-analysis reported that the prevalence of maternal postpartum depression in China is lower in the more developed Eastern China compared with the less developed Central China and Western China (*Qian & Yan, 2013*). Furthermore, children in more economically disadvantaged regions, such as rural areas, may be more affected by problems associated with MDS (*Meaney, 2018*). Therefore, MDS and the associated negative impacts may be more prevalent among mother–child dyads in rural areas of Central and Western China. However, although some studies have reported the negative impacts of MDS on child development in China (*Ip et al., 2018; Li et al., 2018; Lin et al., 2017; Wang et al., 2018; Wei et al., 2018; Yue et al., 2018*), most of these studies have been conducted in urban areas. The similar studies in rural China start quite late. In addition, only a few of them have taken mother–child interactions into consideration at the same time.

Therefore, the objective of the current study was to examine the associations among MDS, mother–child interactions and child development in rural areas of Central and Western China. We hypothesised that MDS impacts child development and that mother–child interactions function as mediators and/or moderators of the associations between MDS and child development. The hypothesis models are illustrated in [Fig. 1](#).

## MATERIALS & METHODS

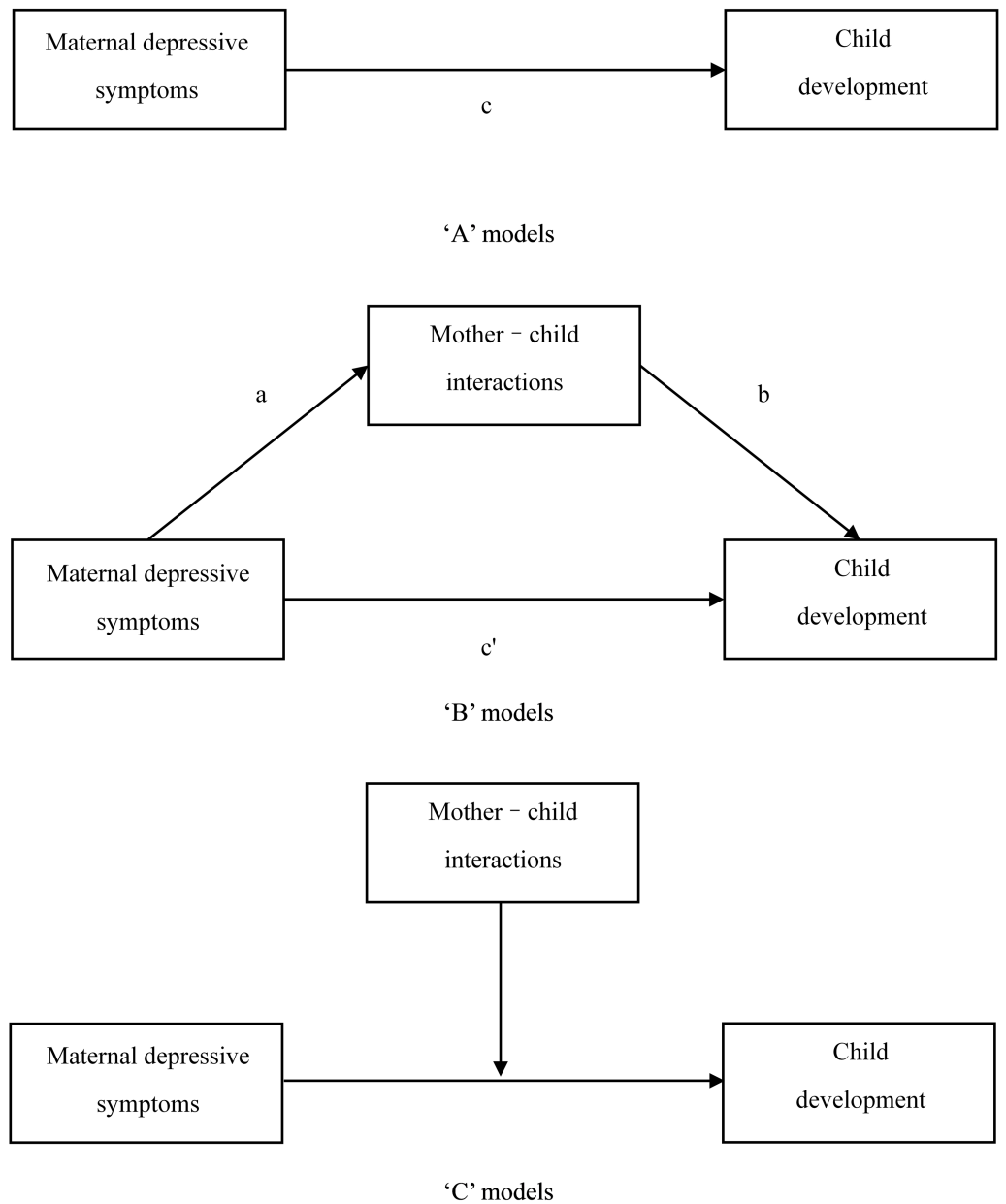
### Participants

This study was based on a subset of data from a cross-sectional survey in eight rural counties of four provinces in Central and Western China in the year of 2016 to 2017, namely Xinjiang, Qinghai, Jiangxi and Ningxia. Research teams from the United Nations International Children’s Emergency Fund (UNICEF), Peking University, Lanzhou University and Capital Medical University as well as government officials and field staff worked together on this survey. In China, there are many administrative villages in each county, and each administrative village can be composed of one or more natural villages. Natural villages are naturally formed and have natural boundaries. A three-stage cluster sampling method was applied in each county. First, 15 administrative villages per county were selected and then two natural villages per administrative village were selected at random with population proportional to size (PPS) (*WHO, 2015*). Third, within each selected natural village, a simple random sampling method was used to select eight families that had at least one child under five years. Inclusion and exclusion criteria for the study were provided in detail elsewhere (*Yang et al., 2019*). Mothers that were the primary caregivers were evaluated for depressive symptoms.

### Measures

#### MDS

The Edinburgh Postpartum Depression Scale (EPDS) was used to identify MDS. EPDS has been validated in Chinese mothers (*Lau et al., 2010*). The EPDS questionnaire has 10



**Figure 1** The hypothesis models in this study.

Full-size  DOI: [10.7717/peerj.11060/fig-1](https://doi.org/10.7717/peerj.11060/fig-1)

items that each have four possible answers. For each question, the mother was instructed to choose one of four possible answers that best described what she had experienced in the previous seven days. Each answer was converted to a score on a scale of 0 to 3. The total score ranged from 0 to 30 with higher scores representing a higher severity of depressive symptoms.

### ***Mother–child interactions***

UNICEF’s Multiple Indicator Cluster Surveys (MICS) questionnaire was used to assess mother–child interactions based on the activities that a mother engaged in with her child in the last three days (*Bornstein & Putnick, 2012; UNICEF, 2013; Zhang et al., 2018a*). The total number of these behaviours engaged in by the mother was equivalent to the score that was given. For example, if the mother engaged in one type of behaviour, the score would be 1. The total score ranged from 0 to 6. A higher score represents more mother–child interactions.

### ***Child development outcomes***

The Chinese version of the Ages & Stages Questionnaires, Third Edition (ASQ-C), was used to evaluate child development outcomes in our study. The ASQ-C is a series of parent–completed questionnaires designed to screen and monitor the development of children aged 1–66 months, which has been found to be a reliable and valid screening instrument for development outcomes in Chinese children (*Squires & Bricker, 2009; Wei et al., 2015*). The sensitivity of the ASQ-C was 87.50% and the specificity of the ASQ-C was 84.48% (*Wei et al., 2015*). The ASQ-C consists of 21 questionnaires with each questionnaire for a different age range of children. The ASQ-C contains five major developmental domains (communication, gross motor function, fine motor function, problem solving and personal social skills) and each domain consists of six questions. The mother was asked to answer questions about some things that her child could and could not do. For each question, an answer of ‘yes’ was scored 10 points, an answer of ‘sometimes’ was scored 5 points and an answer of ‘not yet’ was scored 0 points. The score on each of the six questions was summed to obtain a domain score, with lower scores representing lower levels of development outcomes.

### ***Covariates***

#### ***Child malnutrition***

Each child’s length/height and weight were measured. Children’s malnutrition status was defined based on their anthropometry along three dimensions: weight-for-age, height-for-age, and weight-for-height (*WHO, 2006*).

#### ***Other covariates***

Basic characteristics of the children were collected, including sex (male or female), ethnicity (Han and minorities), age (1–11, 12–23, 24–35, 36–47 or 48–59 months), preterm (yes or no), birth order (1 or 2 or more), maternal education (primary school or below, middle school or high school, above high school) and family economic status (poorest, poor, middle, richer and richest). Family economic status was categorised based on the quintiles in the distribution of annual net income. The annual net income was equal to the total family income for the last year minus the total production and operating expenses (*Liu et al., 2018; Yang et al., 2019*).

#### ***Statistical analyses***

The statistical analyses were conducted in SPSS v.25.0 with the addition of the PROCESS plug-in for mediation and moderation analyses. First, a Pearson’s correlation was used

to evaluate the bivariate associations among MDS, mother–child interactions and child development outcomes, and all of these variables were conducted as continuous variables. Second, multiple linear regression analyses were used to determine the associations between MDS and child development outcomes ('A' models in Fig. 1). The letter  $c$  represents path coefficients. The ASQ-C score was the dependent variable, the EPDS score was the independent variable and other basic characteristics were covariates in the multiple linear regression analyses. Third, the mediating and moderating analyses were conducted in PROCESS using least squares regression, and the mother–child interactions score was entered as mediator ('B' models in Fig. 1, the letters  $a$ ,  $b$  and  $c'$  represent path coefficients) and moderator ('C' models in Fig. 1). The variables were standardised before analyses. The significance of mediating and moderating effects of mother–child interactions was tested by the bootstrap method. The 95% confidence intervals (CI) were estimated by the bias-corrected bootstrapping procedure with the number of iterations set to 5,000. If the 95% CI of the indirect effects and interaction terms did not include zero, the mother–child interactions significantly mediated and moderated the associations (Hayes, 2013).

### Human ethics

The Medical Ethics Research Board of Peking University Health Science Centre approved this study (IRB00001052-16041). All participating mothers provided consent via written permission or fingerprint for both their own and their children's involvement.

## RESULTS

### Basic characteristics

A total of 2,548 participants (mothers: 1,274; children: 1,274) were included in our analyses. The basic characteristics are shown in Table 1. Most of the children were male (52.3%) and 62.2% of the children were ethnic minorities. Nearly half of the children were aged 1–23 months. The percentage of preterm births was 4.8%. In addition, about a third of the children were the first child of their parents. Our analysis found that 5.7% of the children were considered malnourished. Nearly half of the mothers in this study had a middle school education level.

### Correlations among the target variables

Table 2 presents the bivariate correlations. We found that MDS was negatively correlated to mother–child interactions as well as positive child development outcomes in the five developmental domains (all  $p < 0.05$ ). Conversely, mother–child interactions were positively correlated to positive child development outcomes in the five developmental domains (all  $p < 0.01$ ).

### MDS and child development outcomes

The associations between MDS and child development outcomes are shown in Table 3. After adjusting for confounding covariates, the scores of MDS had significant negative associations with the scores of communication ( $\beta = -0.102$ ), gross motor function ( $\beta = -0.109$ ), fine motor function ( $\beta = -0.095$ ), problem solving ( $\beta = -0.098$ ) and personal social domains ( $\beta = -0.090$ ) ( $p < 0.01$ ).

**Table 1** Basic characteristics of the participants this study.

Characteristics		n	%
Sex of child	Male	666	52.3
	Female	608	47.7
Ethnicity	Han	481	37.8
	Minorities	793	62.2
Age (months)	1–11	306	24.0
	12–23	338	26.5
	24–35	262	20.6
	36–47	209	16.4
	48–59	159	12.5
Preterm <sup>a</sup>	No	1,182	95.2
	Yes	60	4.8
Birth order of child	1	438	34.4
	2 or more	836	65.6
Malnutrition <sup>b</sup>	No	1,184	94.3
	Yes	72	5.7
Maternal education	Primary school or below	314	24.6
	Middle school	667	52.4
	High school or above	293	23.9
Family economic status	Poorest	268	21.0
	Poor	284	22.3
	Middle	212	16.6
	Richer	303	23.8
	Richest	207	16.2

**Notes.**<sup>a</sup>32 missing.<sup>b</sup>18 missing.**Table 2** Bivariate correlation among target variables.

	1	2	3	4	5	6	7
1. MDS	1						
2. mother–child interactions	−0.066 <sup>*</sup>	1					
3. communication	−0.076 <sup>**</sup>	0.154 <sup>**</sup>	1				
4. gross motor function	−0.108 <sup>**</sup>	0.163 <sup>**</sup>	0.383 <sup>**</sup>	1			
5. fine motor function	−0.118 <sup>**</sup>	0.155 <sup>**</sup>	0.370 <sup>**</sup>	0.363 <sup>**</sup>	1		
6. problem solving	−0.110 <sup>**</sup>	0.164 <sup>**</sup>	0.369 <sup>**</sup>	0.379 <sup>**</sup>	0.505 <sup>**</sup>	1	
7. personal social	−0.087 <sup>**</sup>	0.171 <sup>**</sup>	0.453 <sup>**</sup>	0.418 <sup>**</sup>	0.380 <sup>**</sup>	0.435 <sup>**</sup>	1

**Notes.**<sup>\*</sup> $p < 0.05$ .<sup>\*\*</sup> $p < 0.01$ .**Mediation analyses**

In the mediating models (Table 3), the score of MDS was entered as the independent variable and the score of mother-child interactions was entered as the mediator. After adjusting for confounding covariates, the mediation analysis found that MDS was negatively associated

**Table 3** Mediating role of mother–child interactions on the associations between maternal depressive symptoms and child development outcomes in five models.

Outcomes	Path coefficients				indirect effect ( $a * b$ )	95% CI ( $a * b$ )
	<i>c</i>	<i>a</i>	<i>b</i>	<i>c'</i>		
communication	−0.102 <sup>***</sup>	−0.074 <sup>*</sup>	0.107 <sup>***</sup>	−0.094 <sup>**</sup>	−0.008	−0.018, −0.002
gross motor function	−0.109 <sup>***</sup>	−0.074 <sup>*</sup>	0.121 <sup>***</sup>	−0.100 <sup>***</sup>	−0.009	−0.019, −0.003
fine motor function	−0.095 <sup>**</sup>	−0.074 <sup>*</sup>	0.132 <sup>***</sup>	−0.085 <sup>**</sup>	−0.010	−0.021, −0.003
problem solving	−0.098 <sup>***</sup>	−0.074 <sup>*</sup>	0.134 <sup>***</sup>	−0.088 <sup>**</sup>	−0.010	−0.021, −0.003
personal social	−0.090 <sup>**</sup>	−0.074 <sup>*</sup>	0.116 <sup>***</sup>	−0.082 <sup>**</sup>	−0.009	−0.019, −0.002

**Notes.**

Controlling for sex of child, ethnicity, age, preterm, birth order of child, malnutrition, maternal education and family economic status. The letter *c* represented path coefficients of associations between maternal depressive symptoms and child development outcomes without any mediator; the letter *a* represented path coefficients of associations between maternal depressive symptoms and mother–child interactions in mediating models; the letter *b* represented path coefficients of associations between mother–child interactions and child development outcomes in mediating models; the letter *c'* represented path coefficients of associations between maternal depressive symptoms and child development outcomes in mediating models.

<sup>\*</sup> $p < 0.05$ .

<sup>\*\*</sup> $p < 0.01$ .

<sup>\*\*\*</sup> $p < 0.001$ .

with mother–child interactions ( $p < 0.05$ ). However, mother–child interactions were positively associated with child development outcomes in the five developmental domains ( $p < 0.001$ ). Through the bootstrap method, the 95% CI of indirect effects in the mediating models did not contain zero, which indicates significant mediation effects of mother–child interactions on the associations between MDS and child development outcomes. In addition, the associations between MDS and child development outcomes were still significant, which indicated the partially mediating roles of mother–child interactions in these associations ( $p < 0.01$ ). Coefficients ( $a * b/c$ ) were used to assess the proportion of mediation. The proportion of the mediating effect of mother–child interactions was 7.7% for communication, 8.2% for gross motor, 10.3% for fine motor, 10.1% for problem solving and 9.5% for personal social domains.

**Moderation analyses**

In the moderating models (Table 4), the score of MDS was entered as the independent variable and the score of mother–child interactions was entered as the moderator. After adjusting for confounding covariates, the interaction effects of MDS and mother–child interactions on the communication domain was significant ( $\beta = 0.070$ , 95% CI 0.016, 0.124;  $p = 0.011$ ). As depicted in Fig. 2, mother–child interactions were divided into low (the mean minus one standard deviation [SD]), mean (the mean) and high (the mean plus one SD). The associations between MDS and child communication abilities were weaker at the high level (simple slope =  $-0.019$ ,  $t = -0.458$ ,  $p = 0.647$ ) of mother–child interactions than at the mean level (simple slope =  $-0.089$ ,  $t = -3.190$ ,  $p = 0.002$ ) and the low level (simple slope =  $-0.158$ ,  $t = -4.231$ ,  $p < 0.001$ ).

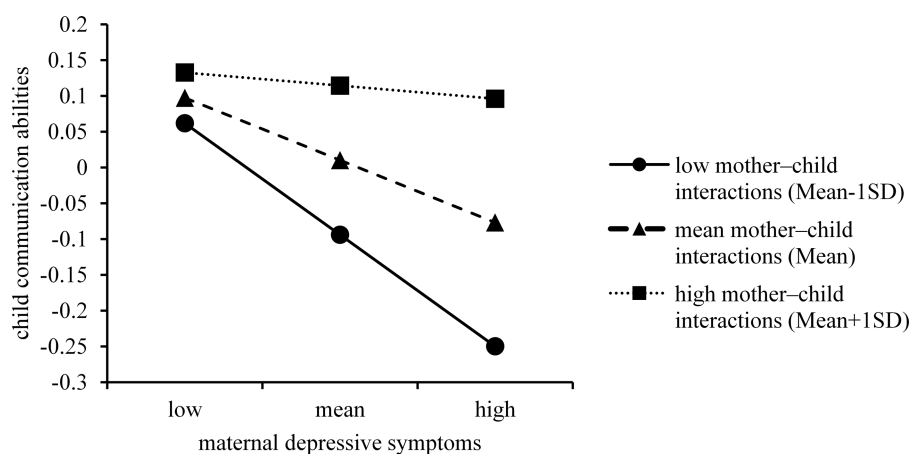


**Table 4** Moderating role of mother–child interactions on the associations between maternal depressive symptoms and child development outcomes in five models.

Independent variables	Outcomes	$\beta$	SE	$p$	95% CI
Maternal depressive symptoms*mother–child interactions	communication	0.070	0.028	0.011	0.016, 0.124
	gross motor function	−0.009	0.028	0.734	−0.064, 0.045
	fine motor function	0.025	0.029	0.395	−0.032, 0.081
	problem solving	−0.004	0.029	0.877	−0.061, 0.052
	personal social	0.012	0.028	0.660	−0.042, 0.067

**Notes.**

Controlling for sex of child, ethnicity, age, preterm, birth order of child, malnutrition, maternal education and family economic status.

**Figure 2** Simple regression lines of maternal depressive symptoms on child communication abilities under different levels of mother–child interactions.

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## DISCUSSION

Our results revealed the negative impact of MDS on child development outcomes in rural areas of Central and Western China. Furthermore, mother–child interactions partly mediated the associations of MDS with child development in communication, gross motor function, fine motor function, problem solving and personal social skills. In addition, mother–child interactions moderated the associations of MDS with child development in communication.

The wellbeing of the children is tied to the wellbeing of their mothers and the home environment. Consistent with prior research (Yue *et al.*, 2018; Zhang *et al.*, 2018a), our models found negative impacts of MDS on child development, which suggests that future intervention programmes should focus on the depressed mother and her child. The pathways between MDS and child development have received considerable attention because it is critical that interventions are appropriate (Kuckertz, Mitchell & Wiggins, 2018; Wang & Dix, 2015). One potential characteristic of depressed mothers that may be

responsible for the negative associations with child development outcomes is disinterest or a lack of engagement. Depressed mothers are less likely to engage in face-to-face play behaviour and interactions with the child, such as vocalising, smiling, imitation and game playing. In addition, depressed mothers are more likely to be more disengaged, irritable and hostile to their children compared to non-depressed mothers (*Field, 2010; Ierardi et al., 2019a; Yue et al., 2018; Zhang et al., 2018b*). In the current study, we also found that higher MDS was a predictor of decreased mother–child interactions. Furthermore, the absence of mother–child interactions is significantly correlated with child developmental delays in many domains, which is similar to the results of the current study (*Weisleder et al., 2018; Yue et al., 2019*). We used mediation analyses and found evidence supporting the mediating role of mother–child interactions between MDS and child development in rural China, which is consistent with prior research in other countries (*Murray et al., 2010; Stein et al., 2008*). Our findings suggest that MDS can indirectly affect child development by influencing mother–child interactions. Thus, identifying and implementing effective assessments and interventions targeted at improving mother–child interactions could help reduce the risk of poor child development caused by MDS.

Previous research has shown that the influence of MDS on child development is moderated by some factors, such as level of financial support, socioeconomic status, suboptimum maternal care, family disharmony and negative emotions of the child (*Sacchi et al., 2018; Stein et al., 2014*). Whether mother–child interactions could moderate the association between MDS and child development has not previously been examined. Here, we observed a moderating role of mother–child interactions in the child communication domain. In our analysis, a lower level of mother–child interactions strengthened the associations between MDS and lower child communication abilities. Maternal behaviours, such as speech and affect, can be modelled by or transmitted to the child, and the child of a depressed mother may look ‘depressed’ (e.g., less talking, less touching and more negative facial expressions) (*Stein et al., 2014; Tronick & Reck, 2009*). Importantly, a child’s communication efforts may be ignored by a depressed mother (*Valla et al., 2016*), and decreased mother–child interactions means that the child loses opportunities to practice and improve communication abilities. Therefore, children exposed to MDS and lower mother–child interactions have a greater chance of poor performance in communication domains.

Despite the moderating effect of mother–child interaction on the communication abilities of the child, we did not observe similar moderating effects in other developmental domains. Therefore, mother–child interactions are more likely to play a mediating role rather than a moderating role on the negative influences of MDS on child development outcomes involving gross motor function, fine motor function, problem solving and personal social abilities. However, mother–child interactions play both mediating and moderating roles on the negative influences of MDS on the communication abilities of the child. A possible explanation for mother–child interactions having both these mediating and moderating effects on communication abilities of the child is that compared with other measured child development domains, communication abilities are developed during interactions, and the most frequent person a child interacts with is the mother.

Thus, poor communication abilities of the child are a result of the combined lack of mother–child interactions and MDS which have a significant interactive effect. Because moderating effects of mother–child interactions have not been routinely examined in the literature, additional studies are needed to confirm our findings.

Although the current study improves a broader understanding of the role of mother–child interactions in the associations between MDS and child development outcomes, several limitations should be considered. First, as the analyses were carried out using cross-sectional data, no causal interpretations can be made. Our study design did not allow us to determine whether MDS caused poor mother–child interactions and poor child development rather than the reverse or a more cyclic causal relationship. Our study design also limited our ability to test the mediating effects, so we must be careful not to overstate conclusions about mediation from cross-sectional analyses. Future longitudinal data with more appropriate statistical methods, such as latent variable models, is needed for further verification. Second, this data was obtained through maternal self-reporting. It's inevitable for information bias to occur because of overreporting and underreporting. MDS may influence how a mother perceives her child development outcomes, which could confound the association (*Foster, Garber & Durlak, 2008*). Third, our study used secondary data not specifically designed for our research objectives. Although we adjusted for potential confounding covariates, we cannot rule out the possibility of residual confounding because there are a significant number of factors that influence early childhood development. Besides, the covariates we mainly adjusted were from the characteristics of the child rather than of the mother. Some critical factors of the mother, such as marital satisfaction, social support and other mental disorders, were not available for our study.

## CONCLUSIONS

The current study confirms the negative associations between MDS and child communication, gross motor function, fine motor function, problem solving and personal social abilities. Mother–child interactions partly mediated these associations. Furthermore, mother–child interactions moderated the negative associations between MDS and communication abilities of the child. Due to the cross-sectional design of this study, these associations require further investigation in prospective studies.

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## ADDITIONAL INFORMATION AND DECLARATIONS

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### Competing Interests

Yuning Yang and Xiaona Huang are employed by UNICEF China.

### Author Contributions

- Xiaoli Liu and Chenlu Yang performed the experiments, analyzed the data, prepared figures and/or tables, authored or reviewed drafts of the paper, and approved the final draft.
- Yuning Yang and Xiaona Huang conceived and designed the experiments, authored or reviewed drafts of the paper, and approved the final draft.
- Yinping Wang, Yaqing Gao and Qiyang Song performed the experiments, prepared figures and/or tables, and approved the final draft.
- Yan Wang and Hong Zhou conceived and designed the experiments, performed the experiments, authored or reviewed drafts of the paper, and approved the final draft.

### Human Ethics

The following information was supplied relating to ethical approvals (i.e., approving body and any reference numbers):

The Medical Ethics Research Board of Peking University Health Science Center approved this study (IRB00001052-16041).

### Data Availability

The following information was supplied regarding data availability:

Raw measurements are available as a [Supplementary File](#).

### Supplemental Information

Supplemental information for this article can be found online at <http://dx.doi.org/10.7717/peerj.11060#supplemental-information>.

## REFERENCES

- Aoyagi SS, Takei N, Nishimura T, Nomura Y, Tsuchiya KJ. 2019. Association of late-onset postpartum depression of mothers with expressive language development during infancy and early childhood: the HBC study. *PeerJ* 7:e6566 DOI 10.7717/peerj.6566.
- Black MM, Walker SP, Fernald LCH, Andersen CT, DiGirolamo AM, Lu C, McCoy DC, Fink G, Shawar YR, Shiffman J, Devercelli AE, Wodon QT, Vargas-Barón E, Grantham-McGregor S. 2017. Early childhood development coming of age: science through the life course. *Lancet* 389:77–90 DOI 10.1016/s0140-6736(16)31389-7.

- Bornstein MH, Putnick DL. 2012.** Cognitive and socioemotional caregiving in developing countries. *Child Development* **83**:46–61 DOI [10.1111/j.1467-8624.2011.01673.x](https://doi.org/10.1111/j.1467-8624.2011.01673.x).
- Brett BE, Stern JA, Gross JT, Cassidy J. 2020.** Maternal depressive symptoms and preschoolers' helping, sharing, and comforting: the moderating role of child attachment. *Journal of Clinical Child & Adolescent Psychology*. Epub ahead of print Mar 31 2020 DOI [10.1080/15374416.2020.1738235](https://doi.org/10.1080/15374416.2020.1738235).
- Field T. 2010.** Postpartum depression effects on early interactions, parenting, and safety practices: a review. *Infant Behavior and Development* **33**:1–6 DOI [10.1016/j.infbeh.2009.10.005](https://doi.org/10.1016/j.infbeh.2009.10.005).
- Foster CJ, Garber J, Durlak JA. 2008.** Current and past maternal depression, maternal interaction behaviors, and children's externalizing and internalizing symptoms. *Journal of Abnormal Child Psychology* **36**:527–537 DOI [10.1007/s10802-007-9197-1](https://doi.org/10.1007/s10802-007-9197-1).
- Gelaye B, Rondon MB, Araya R, Williams MA. 2016.** Epidemiology of maternal depression, risk factors, and child outcomes in low-income and middle-income countries. *The Lancet Psychiatry* **3**:973–982 DOI [10.1016/s2215-0366\(16\)30284-x](https://doi.org/10.1016/s2215-0366(16)30284-x).
- Hakanen H, Flykt M, Sinervä E, Nolvi S, Kataja EL, Pelto J, Karlsson H, Karlsson L, Korja R. 2019.** How maternal pre- and postnatal symptoms of depression and anxiety affect early mother-infant interaction? *Journal of Affective Disorders* **257**:83–90 DOI [10.1016/j.jad.2019.06.048](https://doi.org/10.1016/j.jad.2019.06.048).
- Hayes A. 2013.** Introduction to mediation, moderation, and conditional process analysis. *Journal of Educational Measurement* **51**:335–337.
- Herba CM, Glover V, Ramchandani PG, Rondon MB. 2016.** Maternal depression and mental health in early childhood: an examination of underlying mechanisms in low-income and middle-income countries. *Lancet Psychiatry* **3**:983–992 DOI [10.1016/s2215-0366\(16\)30148-1](https://doi.org/10.1016/s2215-0366(16)30148-1).
- Humphreys KL, King LS, Choi P, Gotlib IH. 2018.** Maternal depressive symptoms, self-focus, and caregiving behavior. *Journal of Affective Disorders* **238**:465–471 DOI [10.1016/j.jad.2018.05.072](https://doi.org/10.1016/j.jad.2018.05.072).
- Ierardi E, Ferro V, Trovato A, Tambelli R, Riva Crugnola C. 2019.** Maternal and paternal depression and anxiety: their relationship with mother-infant interactions at 3 months. *Archives of Women's Mental Health* **22**:527–533 DOI [10.1007/s00737-018-0919-x](https://doi.org/10.1007/s00737-018-0919-x).
- Ip P, Li TMH, Chan KL, Ting AYY, Chan CY, Koh YW, Ho FKW, Lee A. 2018.** Associations of paternal postpartum depressive symptoms and infant development in a Chinese longitudinal study. *Infant Behavior and Development* **53**:81–89 DOI [10.1016/j.infbeh.2018.08.002](https://doi.org/10.1016/j.infbeh.2018.08.002).
- Kuckertz JM, Mitchell C, Wiggins JL. 2018.** Parenting mediates the impact of maternal depression on child internalizing symptoms. *Depression and Anxiety* **35**:89–97 DOI [10.1002/da.22688](https://doi.org/10.1002/da.22688).
- Lanzi RG, Bert SC, Jacobs BK. 2009.** Depression among a sample of first-time adolescent and adult mothers. *Journal of Child & Adolescent Psychiatric Nursing* **22**:194–202 DOI [10.1111/j.1744-6171.2009.00199.x](https://doi.org/10.1111/j.1744-6171.2009.00199.x).

- Lau Y, Wang Y, Yin L, Chan KS, Guo X. 2010. Validation of the Mainland Chinese version of the Edinburgh Postnatal Depression scale in Chengdu mothers. *International Journal of Nursing Studies* 47:1139–1151 DOI 10.1016/j.ijnurstu.2010.02.005.
- Li F, Tian YP, Liu XM, Xia RL, Jin LM, Sun XW, Song XX, Yuan W, Liang H. 2018. A prospective cohort study on the relationship between maternal prenatal depressive symptoms and children's behavioral problems at 2 years old. *Zhonghua Liu Xing Bing Xue Za Zhi* 39:455–459 DOI 10.3760/cma.j.issn.0254-6450.2018.04.013.
- Lin Y, Xu J, Huang J, Jia Y, Zhang J, Yan C, Zhang J. 2017. Effects of prenatal and postnatal maternal emotional stress on toddlers' cognitive and temperamental development. *Journal of Affective Disorders* 207:9–17 DOI 10.1016/j.jad.2016.09.010.
- Liu Y, Kaaya S, Chai J, McCoy DC, Surkan PJ, Black MM, Sutter-Dallay AL, Verdoux H, Smith-Fawzi MC. 2017. Maternal depressive symptoms and early childhood cognitive development: a meta-analysis. *Psychological Medicine* 47:680–689 DOI 10.1017/s003329171600283x.
- Liu X, Yang C, Zhong Q, Song Q, Huang X, Yang Y, Huang Y, Wang Y, Zhou H. 2018. Improved timely birth dose coverage of hepatitis B vaccine narrows the socio-economic inequality in western China in 2011–2016. *Vaccine* 36:3901–3907 DOI 10.1016/j.vaccine.2018.05.085.
- Meaney MJ. 2018. Perinatal maternal depressive symptoms as an issue for population health. *American Journal of Psychiatry* 175:1084–1093 DOI 10.1176/appi.ajp.2018.17091031.
- Murray L, Arteché A, Fearon P, Halligan S, Croudace T, Cooper P. 2010. The effects of maternal postnatal depression and child sex on academic performance at age 16 years: a developmental approach. *Journal of Child Psychology and Psychiatry and Allied Disciplines* 51:1150–1159 DOI 10.1111/j.1469-7610.2010.02259.x.
- Netsi E, Pearson RM, Murray L, Cooper P, Craske MG, Stein A. 2018. Association of persistent and severe postnatal depression with child outcomes. *JAMA Psychiatry* 75:247–253 DOI 10.1001/jamapsychiatry.2017.4363.
- O'Higgins M, Roberts IS, Glover V, Taylor A. 2013. Mother-child bonding at 1 year; associations with symptoms of postnatal depression and bonding in the first few weeks. *Archives of Women's Mental Health* 16:381–389 DOI 10.1007/s00737-013-0354-y.
- Olino TM, McMakin DL, Nicely TA, Forbes EE, Dahl RE, Silk JS. 2016. Maternal depression, parenting, and youth depressive symptoms: mediation and moderation in a short-term longitudinal study. *Journal of Clinical Child & Adolescent Psychology* 45:279–290 DOI 10.1080/15374416.2014.971456.
- Peacock-Chambers E, Ivy K, Bair-Merritt M. 2017. Primary care interventions for early childhood development: a systematic review. *Pediatrics* 140:e20171661 DOI 10.1542/peds.2017-1661.
- Qian YR, Yan XY. 2013. Meta analysis of the prevalence rate of post depressive depression in China. *Chinese Journal of Practical Nursing* 29:1–3 DOI 10.3760/cma.j.issn.1672-7088.2013.12.001.
- Rogers A, Obst S, Teague SJ, Rossen L, Spry EA, Macdonald JA, Sunderland M, Olsson CA, Youssef G, Hutchinson D. 2020. Association between maternal perinatal

- depression and anxiety and child and adolescent development: a meta-analysis. *JAMA Pediatrics* **174**:1–11 DOI [10.1001/jamapediatrics.2020.2910](https://doi.org/10.1001/jamapediatrics.2020.2910).
- Sacchi C, De Carli P, Vieno A, Piallini G, Zoia S, Simonelli A. 2018.** Does infant negative emotionality moderate the effect of maternal depression on motor development? *Early Human Development* **119**:56–61 DOI [10.1016/j.earlhumdev.2018.03.006](https://doi.org/10.1016/j.earlhumdev.2018.03.006).
- Squires J, Bricker D. 2009.** *Ages & Stages Questionnaires[R], Third Edition (ASQ-3[TM]): a parent-completed child-monitoring system*. Baltimore: Brookes Publishing Company.
- Stein A, Malmberg LE, Sylva K, Barnes J, Leach P. 2008.** The influence of maternal depression, caregiving, and socioeconomic status in the post-natal year on children's language development. *Child Care Health and Development* **34**:603–612 DOI [10.1111/j.1365-2214.2008.00837.x](https://doi.org/10.1111/j.1365-2214.2008.00837.x).
- Stein A, Pearson RM, Goodman SH, Rapa E, Rahman A, McCallum M, Howard LM, Pariante CM. 2014.** Effects of perinatal mental disorders on the fetus and child. *Lancet* **384**:1800–1819 DOI [10.1016/s0140-6736\(14\)61277-0](https://doi.org/10.1016/s0140-6736(14)61277-0).
- Tronick E, Reck C. 2009.** Infants of depressed mothers. *Harvard Review of Psychiatry* **17**:147–156 DOI [10.1080/10673220902899714](https://doi.org/10.1080/10673220902899714).
- Tuovinen S, Lahti-Pulkkinen M, Girchenko P, Lipsanen J, Lahti J, Heinonen K, Reynolds RM, Hämäläinen E, Kajantie E, Laivuori H, Pesonen AK, Villa PM, Räikkönen K. 2018.** Maternal depressive symptoms during and after pregnancy and child developmental milestones. *Depression and Anxiety* **35**:732–741 DOI [10.1002/da.22756](https://doi.org/10.1002/da.22756).
- UNICEF. 2013.** MICS5 TOOLS. Available at <http://mics.unicef.org/tools?round=mics5> (accessed on 11 November 2020).
- Valla L, Wentzel-Larsen T, Smith L, Birkeland MS, Slinning K. 2016.** Association between maternal postnatal depressive symptoms and infants' communication skills: a longitudinal study. *Infant Behavior and Development* **45**:83–90 DOI [10.1016/j.infbeh.2016.10.001](https://doi.org/10.1016/j.infbeh.2016.10.001).
- Wang Y, Dix T. 2015.** Mothers' early depressive symptoms predict children's low social competence in first grade: mediation by children's social cognition. *Journal of Child Psychology and Psychiatry and Allied Disciplines* **56**:183–192 DOI [10.1111/jcpp.12297](https://doi.org/10.1111/jcpp.12297).
- Wang H, Zhou H, Zhang Y, Wang Y, Sun J. 2018.** Association of maternal depression with dietary intake, growth, and development of preterm infants: a cohort study in Beijing, China. *Frontiers in Medicine* **12**:533–541 DOI [10.1007/s11684-017-0591-y](https://doi.org/10.1007/s11684-017-0591-y).
- Wei M, Bian X, Squires J, Yao G, Wang X, Xie H, Song W, Lu J, Zhu C, Yue H, Zhu G, Wang Q, Xu R, Wan C, Sun S, Chen J. 2015.** Studies of the norm and psychometrical properties of the ages and stages questionnaires, third edition, with a Chinese national sample. *Zhonghua Er Ke Za Zhi* **53**:913–918.
- Wei Q, Zhang C, Zhang J, Luo S, Wang X. 2018.** Caregiver's depressive symptoms and young children's socioemotional development delays: a cross-sectional study in poor rural areas of China. *Infant Mental Health Journal* **39**:209–219 DOI [10.1002/imhj.21699](https://doi.org/10.1002/imhj.21699).

- Weisleder A, Mazzuchelli DSR, Lopez AS, Neto WD, Cates CB, Goncalves HA, Fonseca RP, Oliveira J, Mendelsohn AL. 2018. Reading aloud and child development: a cluster-randomized trial in Brazil. *Pediatrics* 141:e20170723 DOI 10.1542/peds.2017-0723.
- WHO. 2006. *WHO child growth standards: length/height-for-age, weight-for-age, weight-for-length, weight-for-height and body mass index-for-age: methods and development*. Geneva: WHO Press.
- WHO. 2015. Steps in applying Probability Proportional to Size (PPS) and calculating basic probability weights. Available at [http://www.who.int/tb/advisory\\_bodies/impact\\_measurement\\_taskforce/meetings/prevalence\\_survey/psws\\_probability\\_prop\\_size\\_bierrenbach.pdf](http://www.who.int/tb/advisory_bodies/impact_measurement_taskforce/meetings/prevalence_survey/psws_probability_prop_size_bierrenbach.pdf) (accessed on 11 November 2020).
- Yang C, Liu X, Yang Y, Huang X, Song Q, Wang Y, Zhou H. 2019. Quality of care and suspected developmental delay among children aged 1-59 months: a cross-sectional study in 8 counties of rural China. *BMC Pediatrics* 19:41 DOI 10.1186/s12887-019-1406-x.
- Yue A, Gao J, Yang M, Swinnen L, Medina A, Rozelle S. 2018. Caregiver depression and early child development: a mixed-methods study from rural China. *Frontiers in Psychology* 9:2500 DOI 10.3389/fpsyg.2018.02500.
- Yue A, Shi Y, Luo R, Wang B, Weber A, Medina A, Kotb S, Rozelle S. 2019. Stimulation and early child development in China: caregiving at arm's length. *Journal of Developmental and Behavioral Pediatrics* 40:458–467 DOI 10.1097/dbp.0000000000000678.
- Zhang S, Dang R, Yang N, Bai Y, Wang L, Abbey C, Rozelle S. 2018b. Effect of Caregiver's Mental Health on Early Childhood Development across Different Rural Communities in China. *International Journal of Environmental Research and Public Health* 15:2341 DOI 10.3390/ijerph15112341.
- Zhang J, Guo S, Li Y, Wei Q, Zhang C, Wang X, Luo S, Zhao C, Scherpbier RW. 2018a. Factors influencing developmental delay among young children in poor rural China: a latent variable approach. *BMJ Open* 8:e021628 DOI 10.1136/bmjopen-2018-021628.