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Factors influencing developmental delay among young children in poor rural China: a latent variable approach

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Manuscripts

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4 **1 Title Page**
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8 **2 Title:** Factors influencing developmental delay among young
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11 **3 children in poor rural China: a latent variable approach**
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4 **23 Abstract**

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7 24 **OBJECTIVES:** The aims of the study were to determine the prevalence of suspicious
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9 25 developmental delay in children living in poor rural China and to investigate factors
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12 26 influencing child developmental delay.

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15 27 **DESIGN:** A community-based, cross-sectional survey was conducted.

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18 28 **SERRING:** 83 villages in Shangxi and Guizhou Provinces, China.

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20
21 29 **PARTICIPANTS:** 2,514 children aged 6-35 months and their first caretakers.

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24 30 **OUTCOMES MEASURES:** Child suspicious developmental delay using the Ages & Stages
25
26 31 Questionnaires -Chinese version. Caregivers' education and age, wealth index Infants, child
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28
29 32 feeding index, parent-child interaction, number of books and Zung self-rating depression
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32 33 scale were all parent reported. Haemoglobin value measured using a calibrated, automated
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35 34 analyzer. Birth weight obtained from medical record.

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37
38 35 **RESULTS:** Overall, 35.7% of the surveyed children aged 6-35 months demonstrated
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40
41 36 suspicious developmental delay. The prevalence of suspicious developmental delay was
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43
44 37 inversely associated with age, with the prevalence among young children aged 6-11 months
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46
47 38 nearly doubling that of children aged 30-35 months (48.9% and 22.8%, respectively). Using a
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49
50 39 structural equation model, it was demonstrated that caregiver's care and stimulus factors and
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53 40 child's hemoglobin level were directly correlated, while caregiver's socio-demographic
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56 41 factors were indirectly associated with suspicious developmental delay.

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4 42 CONCLUSIONS: The prevalence of suspicious developmental delay is high in poor rural
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6 43 areas of China. Interventions to improve child development are needed in poor rural area of
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9 44 China.

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11
12 45 Key words: Suspicious Developmental Delay; Infants and young children; Structural
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15 46 equation model; Rural China
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21 48 **Strengths and limitations of this study**

- 22
23 49 • This pilot study includes suspicious developmental delay among children under 3 years
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25
26 50 of age in poor rural areas of China.
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29 51 • A structural equation model is a good approach to examine the influencing factors on
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32 52 suspicious developmental delay.
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35 53 • A few binary variables were not incorporated in the structural equation model because of
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38 54 methodological limitation.
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56 INTRODUCTION

57 Developmental delay encompasses a wide spectrum of impairments or lack of developmental
58 features that are appropriate to the child's age. It may manifest in various aspects, including
59 physical, mental, language, and social domains[1,2]. Worldwide, developmental delay
60 accounts for more morbidity across the lifespan than any other chronic conditions[3]. A
61 conservative estimate is that across the world more than 200 million children under 5 years
62 old failed to reach their potential in cognitive and social-emotional development. As a
63 number of social factors such as poverty, malnutrition, lack of appropriate care, and child
64 abuse and neglect, have been identified as potential contributing factors to developmental
65 delay [4], developmental delay has been a major issue in low and middle-income countries.
66 Moreover, national statistics on young children's cognitive or social emotional development
67 are not available for most developing countries. This gap contributes to the invisibility of the
68 issue of development delay. With a total of 15 million disadvantaged children (defined as
69 stunted, living in poverty, or both), China has the third largest number of disadvantaged
70 children globally, following India (65 million) and Nigeria (16 million)[4]. It is clear that
71 interventions and policies designed to promote child development and prevent or ameliorate
72 developmental delay are urgently needed as China moves forward.

73 The pathway between poverty and poor development described by Walker et al is built on the
74 fact that poverty is associated with inadequate food, and poor access to water, sanitation and

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4 75 hygiene [5]. Poverty is also related to poor maternal education, increasing maternal stress,
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7 76 depression, and inadequate stimulation at home. All these factors detrimentally affect child
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10 77 development, and this deprived development may lead to poor school performance and
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12 78 achievement. In addition, poverty and socio-cultural context risk factors may increase young
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15 79 children's exposure to biological and psychosocial risks, and the accumulation in risks often
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18 80 significantly harm child development. Children in developing countries are frequently
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21 81 exposed to multiple and cumulative risks negatively affecting their development, especially
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24 82 through changes in their brain structure and function, and behavioral changes[6].

25
26 83 Biological risk factors related to young children's developmental delay include infectious
27
28
29 84 disease, chronic malnutrition, iodine deficiency, iron deficiency, anemia, malaria, low birth
30
31
32 85 weight, preterm birth, and exposure to lead or arsenic, etc.[5,7-10].

33
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35 86 Psychological risk factors associated with developmental delay are mainly related to
36
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38 87 parenting, more specifically, cognitive stimulation, caregiver sensitivity and responsiveness
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41 88 to the child, and caregiver affect in terms of emotional warmth or rejection of the child[5].

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43 89 Parents and caregivers can play an important role in providing the child with a healthy, safe
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46 90 and caring environment[11].

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49 91 The effects of these biological and psychological risk factors are sensitive to contextual
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52 92 factors such as poverty and maternal depression[5]. Common mental disorders, including
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55 93 depression and anxiety among women during pregnancy, or in the first post-partum year, are

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4 94 recognized as a public health issue globally. There are emerging evidence show that maternal
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6 95 mental disorders have adverse impacts on physical and psychological development of fetuses
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9 96 and infants[12-18].
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12 97 To sum up, various social, biological and psychological factors may contribute to child
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15 98 developmental delay. The existing evidence indicated that four major risk factors affect at
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18 99 least 20–25% of children in developing countries[5]: inadequate cognitive stimulation,
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21 100 stunting, iron deficiency, and iodine deficiency. There is a paucity of data on the prevalence
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24 101 and risk factors for developmental delay in China, especially in poor rural areas where
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27 102 children are at high risk for developmental delay due to the economic and social restraints. In
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30 103 addition, although the influencing factors for child developmental delay have been widely
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33 104 studied, the relationships among these factors and their direct and indirect associations with
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36 105 the development outcome were seldom examined in the existing literature. The goals of this
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39 106 study were to determine the prevalence of developmental delay in young children in rural
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42 107 China and compare the prevalence of developmental delay in rural China to other developing
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45 108 countries, and to explore factors contributing to child developmental delay.

109 **METHOD**

110 **Participants and Design**

111 A community-based cross-sectional survey on child health, nutrition and development was
112 conducted between July and September 2013 in remote mountainous areas of Shanxi and

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4 113 Guizhou provinces, located in the central and south-west regions of China respectively. The
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7 114 survey sites were the project sites of the Integrated Early Childhood Development (IECD)
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10 115 Project funded by UNICEF. A total of 83 villages were selected from six counties of the two
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12 116 provinces based on the following criteria: 1) having at least 50 children under 3 years old; 2)
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14
15 117 having a township health center staffed with maternal and child health professionals; 3)
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17
18 118 reachable by vehicles. All the children under 3 years and their primary caregivers (defined as
19
20
21 119 person(s) who take primary responsibility for taking care of child in the family) in the chosen
22
23
24 120 villages were eligible for the study. Altogether, 2,953 children out of the 4,288 children in the
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26
27 121 83 villages participated in the study and their primary caregivers finished the survey. The
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30 122 response rate was 68.9%. All caretakers provided their written informed consent to
31
32
33 123 participate in this study. The study was reviewed and approved by Peking University
34
35
36 124 Biomedical Ethics Committee.
37
38
39 125 For this analysis, children with hearing disabilities (e.g., deaf children) (n=16) were excluded
40
41
42 126 because the disabilities may directly affect their performance. In addition, we excluded
43
44
45 127 children aged 1-5 months (n=326) because their hemoglobin values were not tested; children
46
47
48 128 with implausible hemoglobin values (n =1, Hb =225 g/L); and respondents who were not
49
50
51 129 primary caregivers (n =96). Therefore, the final sample size for this analysis was 2,514
52
53
54 130 children.

131 **Study Instruments**

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4 132 *Outcome measure : Child developmental delay measurement*

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6 133 The Ages & Stages Questionnaires -Chinese version (ASQ-C), which was validated recently
7
8
9 134 in Chinese, was used to assess children's development status. ASQ-C includes various
10
11
12 135 dimensions, including communication, gross motor (GM), fine motor (FM), problem solving
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14
15 136 (CG) and social emotional (SE) (Bian, Yao, Squires, Wei, Chen & Fang, 2010). Each of the
16
17
18 137 domains contains six sub-items. The responses of 'yes', 'sometimes', or 'not yet' were given
19
20
21 138 scores of 10, 5, and 0 points, respectively. Development delay in a certain domain was
22
23
24 139 defined as if domain score was lower than 2SD (Standard Deviation) of the cutoff point in the
25
26
27 140 normative norm in that domain. Overall suspicious development delay was defined as if there
28
29
30 141 was delay in any one of five domains of ASQ, including communication, gross motor, fine
31
32 142 motor, problem solving, and personal-social domain.

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35 143 *Social, biological and psychological factors*

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37 144 Household survey questionnaire

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40 145 A face-to-face interview was conducted with the child caregivers using a structured
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43 146 questionnaire developed based on UNICEF's 5th Multiple Indicator Cluster Survey (MICS5).
44
45
46 147 The questionnaire contained questions on the household socioeconomic status, family
47
48
49 148 structure, health and development of children under five years old and their mother in the
50
51
52 149 household. Wealth index was developed based on the number of household appliances
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55 150 (telephone, TV, washing machine, refrigerator, and internet connection).

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4 151 Zung self-rating depression scale (ZSDS)
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6 152 The Zung Self-rating Depression Scale (ZSDS), validated and widely utilized in China[19-
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9 153 21], was used to assess caregivers' mental health status. The scale comprises 20 items and
10
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12 154 each question is scored on a scale of 1-4 based on the following responses: never or rarely,
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15 155 sometimes, most of the time, or always. A score between 50 and 69 indicates depression, and
16
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18 156 a score of 70 or above indicates severe depression. In this study, caregivers with a score of 50
19
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21 157 or more were identified as positive for depression [22]

22
23 158 Infants and child feeding index (ICFI)
24

25
26 159 The Infant and child feeding index (ICFI), based on a dietary recall of the past 24 hours from
27
28
29 160 a questionnaire, was used to gather information on current feeding practices of children. This
30
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32 161 index includes practices related to breastfeeding, bottle feeding, feeding frequency and food
33
34
35 162 diversity given to the children prior to the survey being conducted. The ICFI was developed
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38 163 on the basis of current feeding practices for infants and young children recommended by
39
40
41 164 WHO[23] and proposed by Ruel and Menon[24]. To take into account the age specific
42
43
44 165 feeding recommendations, the ICFI was compiled separately for three age groups: 6-8
45
46 166 months, 9-11 months and 12-35 months. A score of 2 was added if the child was breastfed; 1
47
48
49 167 point added if the child had never been bottle-fed; 2 points added if the child's feeding
50
51
52 168 frequency met the recommendation; and 1 point if the feeding frequency was below the
53
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55 169 recommendation but above zero. Dietary diversity of food groups refers to the number of
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4 170 different food groups provided to the child. Altogether 7 food groups were counted, and a
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6 171 score of +2 was added if 4 or more food groups were consumed, and a score of +1 was added
7
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9 172 if 1 to 3 food groups were consumed.

173 Parent-child interaction

174 The level of parent-child interaction was assessed based on the following six activities that
175 caregivers did with their child: 1) reading books to the child, 2) telling stories to the child, 3)
176 singing songs to or with the child, 4) taking the child outdoor, 5) playing toys with the child,
177 and 6) naming, counting or drawing things to promote learning with the child. If one of the
178 above mentioned behaviors were reported by the caregivers, +1 score was given, with the
179 highest possible score of +6.

180 Haemoglobin value

181 Trained staff collected capillary blood sample from the child and measured their hemoglobin
182 (Hb) concentration using a calibrated, automated analyzer (HemoCue 201 [HemoCue,
183 Angelholm, Sweden]). Anemia is defined as a hemoglobin concentration <110 g/L, based on
184 the global definition for preschool children and adjusted for altitude[25]. Children with
185 anemia were referred to an appropriate health facility for treatment.

186 Anthropometric measurements

187 Birth weight was obtained from medical record.

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189 **Data Analysis**

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4 190 Data analysis was performed using SPSS for Windows (version 16.0, SPSS Inc., Chicago, IL,
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6
7 191 USA). Descriptive statistics were provided as median, range and interquartile range for
8
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10 192 continuous variables and count and percentage for categorical variables. A structural
11
12 193 equation model (Amos 20 for Windows, IBM, Armonk, NY, USA) was used to test if the
13
14
15 194 hypothetical explanatory model fits the observed data and to apply the asymptotically
16
17
18 195 distribution-free estimate. The hypothetical explanatory model was derived from literature
19
20
21 196 [4,5]and the univariate regression result. The assignment rules and explanation of variables in
22
23
24 197 the structural equation model are described in Table 1. The model was modified according to
25
26
27 198 statistics suggested by the modification index in Amos. An absolute value of ≥ 1.96 ($p \leq 0.05$)
28
29
30 199 for the standardized β -coefficient T was considered significant. Goodness of fit index (GFI),
31
32
33 200 normal fit index (NFI), comparative fit index (CFI) and root mean squared error of
34
35
36 201 approximation (RMSEA) were used to test model fit. For GFI, CFI and NFI, 1 means a
37
38
39 202 perfect fit while >0.9 indicates an adequate fit. For RMSEA, <0.05 indicates a good model.
40
41
42 203 Chi-square statistic to test the null hypothesis was not required as the sample size
43
44
45 204 was >1000 [26].

46 205 Table 1. Assignment rules and explanation of variables in structural equation model

Variables	assignment rules or explanation
caregiver's education	illiteracy,+1
	primary school,+2
	junior high school,+3

1		
2		
3		senior high school and above,+4
4		
5	caregiver's age	caregiver's integer age
6		
7		
8	wealth index	numbers of accessories including phone(telephone or mobile),washing machine, refrigerator, TV set, access to Internet
9		
10		
11		
12		
13		
14	parent-child interaction	6 behaviors including read books to child, told stories, sang songs, took child outside the home, played with child, and named, counted or drew things to promote learning would form stimulus signals
15		
16		
17		
18		
19	numbers of books	numbers of books children owned presently
20		
21		
22	score of ZSDS	reversed score of caregiver's depression assessed by the Zung Self-rating Depression Scale
23		
24		
25		
26		Breastfeeding:
27		
28		6-9 mo: No=0; Yes= +2;
29		
30		9-11 mo: No=0; Yes=+2;
31		
32		12-35 mo: No=0; Yes=+1.
33		
34		Bottle feeding: Yes=0; No=+1;
35	ICFI	
36		Feeding frequency:
37		
38		6-9 mo: 0 meal = 0; 1 meal = +1; 2 meals or more = +2;
39		
40		9-11 mo: 0 meal = 0; 1-2 meals = +1; 3 meals or more = +2;
41		
42		12-35 mo: 0-1 meals = 0; 2-3 meals = +1; 4 meals or more = +2;
43		
44		Dietary diversity: 0 group = 0; 1-3 groups = +1; 4 or more groups = +2
45		
46	birth weight	birth weight of child (medical records or parental report)
47		
48	haemoglobin value for children	haemoglobin value we tested
49		
50	Communication	score of communication assessed by ASQ
51		
52	gross motor	score of gross motor assessed by ASQ
53		
54	fine motor	score of fine motor assessed by ASQ
55		

problem solving score of problem solving assessed by ASQ

social emotional score of social emotional assessed by ASQ

206 Note: ZSDS: Zung Self-rating Depression Scale; ICFI: infant and young child feeding index

207

208 RESULTS

209 Demographic, Socio-economic Characteristics of Participants

210 About 21.0% of children surveyed were 6-11 months, while 41.1% were 12-23 months, and
 211 37.9% were 24-35 months. Slightly more boys were included in the survey than girls (56.8%
 212 versus 43.2%, respectively) (Table 2). About half (47.9%) were the firstborn children and
 213 11.4% were left-behind children (i.e. their parents are migrant workers who leave rural areas
 214 for the cities while leaving children behind in their hometowns). More than one-third (35.5%)
 215 were ethnic minority children. Most of the caregivers interviewed (79.6%) were mothers. The
 216 average age of caregivers was 30.19 years with a standard deviation (SD) of 9.71 years; a
 217 majority (62.1%) of caregivers interviewed aged 20-29 years. Most (63.5%) had completed
 218 at least 9 years of education (i.e. secondary education). Among the surveyed households,
 219 51% lived under the national poverty line of US\$1 per day and 45% lived more than 5
 220 kilometers to the nearest health facilities.

221 Table 2. Sociodemographic and clinical characteristics of sampled child-caregiver pairs (N=2514)

	N	%		N	%
--	---	---	--	---	---

1						
2						
3	Child age			Caregivers interviewed		
4						
5	6-11	528	21.0	Mother	2002	79.6
6						
7						
8	12-23	1034	41.1	Father	189	7.5
9						
10						
11	24-35	952	37.9	Grandparents	320	12.7
12						
13						
14	Child gender			Others	3	0.1
15						
16						
17	Male	1427	56.8	Caregivers' age		
18						
19						
20	Female	1087	43.2	<20	42	1.7
21						
22						
23	Having elder sibling			20-	1561	62.1
24						
25						
26	Yes	1277	50.8	30-	539	21.4
27						
28						
29	No	1203	47.9	40-	349	13.9
30						
31						
32	Unknown	34	1.4	Unknown	23	0.9
33						
34						
35	Left-behind children			Caregivers' education		
36						
37	Yes	286	11.4	Illiteracy	256	10.2
38						
39						
40	No	2228	88.6	Primary education	661	26.3
41						
42						
43	Ethnicity			Secondary	1277	50.8
44						
45						
46	Han	1621	64.5	Above secondary	320	12.7
47						
48						
49	Minority	893	35.5	Distance to health facility		
50						
51						
52				<5km	1345	53.5
53						
54						
55						
56						
57						
58						
59						
60						

≥5km	1131	45.0
Unknown	38	1.5

222

223 Suspicious Developmental Delay among Children under 3 Years Old

224 Overall, 35.7% of the surveyed children under 3 years of age had suspicious developmental
 225 delay (Table 3). Across all age groups, prevalence of suspicious developmental delay was
 226 inversely associated to the child's age, with the highest rate (48.9%) among children aged 6-
 227 11 months and lowest (22.8%) among children aged 30-35 months. Across all domains, delay
 228 in communication was the lowest (8.9%) and delay in fine motor was the highest (20.6%),
 229 while other domains ranged from 15.1% to 16.7%.

230 Table 3. Prevalence of child suspicious development delay

	6-months	12-months	18-months	24-months	30-months	Total
	n(%)	n(%)	n(%)	n(%)	n(%)	n(%)
	N=538	N=473	N=561	N=517	N=435	N=2514
suspicious Developmental delay	258(48.0)	210(44.4)	207(36.9)	123(23.8)	99(22.8)	897(35.7)
Delay in subscales:						
Communication	92(17.4)	46(9.7)	46(8.2)	22(4.3)	18(4.1)	224(8.9)
Gross motor	107(20.3)	85(18.0)	83(14.8)	61(11.8)	44(10.1)	380(15.1)
Fine motor	157(29.7)	145(30.7)	144(25.7)	50(9.7)	23(5.3)	519(20.6)

Problem solving	98(18.6)	131(27.7)	84(15.0)	50(9.7)	56(12.9)	419(16.7)
Social emotional	102(19.3)	92(19.5)	96(17.1)	63(12.2)	52(12.0)	405(16.1)

231

232 **Social, biological and psychological factors**

233 The wealth index in the surveyed families ranged from 0 to 5, with a median of 4, indicating
 234 that most of the families owned major appliances. The parent-child interaction scores ranged
 235 from 0 to 6, with a median score of 6. On average, the surveyed children owned only 1 book
 236 (median=1, IQR=3). Caregivers' ZSDS in this survey ranged from 38 to 80, with a median
 237 score of 63.76. Nearly two-fifths of caregivers (38.5%) had symptoms of depression. The
 238 ICFI ranged from 0 to 7, with a median score of 2. The hemoglobin values for the surveyed
 239 children were 51 to 178 g/L, with a median of 110 g/L. Anemia prevalence was high at
 240 43.8%. Birth weight of the surveyed children ranged from 1.40 to 6.00 kilograms, with a
 241 median of 3.30 kilograms; 2.9% had low birth weight (i.e. birth weight less than 2.5 kg) .

242

243 **Structural Equation Model for Children's Developmental Delay**

244 About half of the squared multiple correlation of variables were more than 0.50 (Table S1),
 245 which indicated that the variables had a good reliability. In the final structural equation
 246 model (shown in Table 4), ICFI and birth weight were excluded from the model, because of
 247 lack of statistically significant relationships with other variables. Figure 1 shows the
 248 estimated covariance and paths for this model. Three factors influencing children's

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2
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4 249 developmental status were identified: 1) caregiver sociodemographic factors such as
5
6
7 250 caregiver's education, age, and wealth index (total effect =0.23 on child developmental
8
9
10 251 status); 2) care and stimulus factors measured by parent-child interaction, number of books
11
12 252 and ZSDS score (direct effect= 0.57); and 3) child's hemoglobin level (direct effect= 0.07).
13
14
15 253 Younger caregivers were more likely to interact with children than older caregivers
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18 254 (covariance of residuals =-0.18) and the latent variable- caregiver's sociodemographic
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21 255 factors-had a direct positive effect on 'care and stimulus factors' (path coefficient=0.40) and
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24 256 an indirect positive effect on children's developmental status. The overall model fit was good
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27 257 as reflected by the goodness of fit index of 0.977 and the comparative fit index of 0.884.
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Table 4. Regression weights of structural equation model

Equation	Estimates (unstandardized)	Estimates (Standardized)	Standard Error	Critical ratio	P value
Regression weights					
Care and stimulus ← caregiver factors	0.402	0.401	0.047	8.497	<0.001
Children's developmental status ← care and stimulus	9.608	0.573	0.913	10.525	<0.001
Children's developmental status ← haemoglobin value for children	0.593	0.071	0.178	3.331	0.001
Caregivers' education ← caregiver factors	1.000	0.794			
Caregivers' age ← caregiver factors	-8.358	-0.576	0.543	-15.380	<0.001
Wealth index ← caregiver factors	0.775	0.461	0.055	14.163	<0.001
parent-child interaction ← care and stimulus	1.000	0.456			
Numbers of books ← care and stimulus	1.687	0.303	0.220	7.678	<0.001
Score of ZSDS ← care and stimulus	4.856	0.415	0.488	9.944	<0.001
Communication ← Children's developmental status	0.863	0.622	0.029	30.054	<0.001
Gross motor ← Children's developmental status	0.970	0.726	0.030	32.608	<0.001
Fine motor ← Children's developmental status	1.132	0.778	0.028	40.216	<0.001

Problem solving ← Children's developmental status	1.188	0.848	0.030	40.212	<0.001
Social emotional ← Children's developmental status	1.000	0.752			
Covariance					
e8 ↔ e10	-19.912	-0.248	2.961	-6.725	<0.001
e3 ↔ e5	0.620	0.188	0.064	9.708	<0.001
e2 ↔ e4	-1.695	-0.175	0.270	-6.290	<0.001
e1 ↔ e5	0.364	0.215	0.051	7.136	<0.001
e5 ↔ e7	3.079	0.076	0.680	4.527	<0.001
e5 ↔ e6	-2.709	-0.115	0.575	-4.712	<0.001
e2 ↔ e6	-5.270	-0.100	1.247	-4.228	<0.001

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Note: ZSDS: Zung Self-rating Depression Scale

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4 263 **DISCUSSION**

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6 264 Our results showed that the prevalence of suspicious developmental delay among children
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9 265 aged 6-35 months was high and inversely associated with children's age in poor rural China.
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12 266 Furthermore, by using the structural equation model, some risk factors for children's
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15 267 suspicious development delay and their relationship were identified. So far only one study
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18 268 examined developmental delay in rural China and reported a prevalence of 20.0% in
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21 269 cognitive development and 32.3% in psychomotor development among children aged 6-12
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24 270 months[27]. Our study revealed that 35.7% of rural children under 3 years of age had
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27 271 suspicious developmental delay and that among children aged 6-12 months, 17-20% of them
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30 272 had delay in communication, problem solving, social emotional and gross motor, and nearly
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33 273 30% had delay in fine motor development. Overall the prevalence observed in our study was
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36 274 comparable to the results from the previous study. According to the very limited data from
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39 275 the WHO report[28], the reported prevalence of developmental delay in young children was
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42 276 17% in Senegal, 15% in Nigeria, 13% in India, and 24% in Brazil. The lower prevalence
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45 277 reported by other developing countries may reflect the underestimated rates and inaccurate
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48 278 measurement of developmental delay. Promoting early childhood development (ECD) is a
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51 279 critical issue. It is recommended that government and healthcare providers should pay more
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54 280 attention to early diagnosis and intervention of developmental delay. Among the five
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4 281 domains of ASQ, suspicious developmental delay of fine motor had the highest prevalence.
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7 282 This is a key finding that requires further intervention in poor rural areas of China.
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10 283 It was found in the structural equation model that caregiver's sociodemographic factors, care
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12 284 and stimulus factors and hemoglobin values of children were directly or indirectly associated
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15 285 with suspicious developmental delay. These findings indicate potential areas that future
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18 286 intervention programs should focus on, including improving child's feeding and nutrition,
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21 287 raising public awareness of the issue of developmental delay, and improving parenting skills
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24 288 to increase interaction with children.
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27 28 290 **Relations between caregiver factors and child development**

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30 291 Our results showed that younger caregivers with higher education level and wealth index had
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33 292 an indirect, positive effect on their child's development. Previous studies have investigated
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36 293 the relations between caregivers' socio-demographic factors and child development. In a
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39 294 population-based study in Argentina and a cohort study in Brazil, it was found that poverty
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42 295 and maternal education were associated with early attainment of selected developmental
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45 296 milestones or cognitive and motor development [29,30]. Another report also indicated that
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48 297 parenting cognitive stimulation, caregiver's responsiveness, and caregiver's affect are
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51 298 sensitive to contextual factors such as poverty, cultural values and practices[5]. The findings
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54 299 from our study are consistent with these previous results. In addition, our study revealed that
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56 300 caregiver factors were indirect predictors of their child's development delay. Although

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4 301 caregiver factors had no direct effect on their child's developmental status, these factors such
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6 302 as caregivers' education, age and poverty level may impact other factors therefore indirectly
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9 303 affecting developmental delay. More attention should be paid to change these contextual
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12 304 factors when designing future interventions to improve children's development and health.

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16 306 **Relations between care and stimulus factors and child development**

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19 307 The current study revealed that the most important predictor on child's suspicious
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22 308 developmental delay was care and stimulus factors (path coefficient=0.57). Better parent-
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25 309 child interaction, more books and less maternal depression had positive effect on child
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28 310 development. Children who had one score point increase on care and stimulus factors had
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31 311 0.57 score increase on child development. The findings of the current study were consistent
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34 312 with previous studies showing the protective effect of parent-child interaction, children's
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37 313 books and optimistic caregivers on child development[31]. Thus, it is necessary to promote
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40 314 parent-child interactions, through encouraging activities such as reading books to their child,
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43 315 telling stories to their child, singing songs to and with their child, bringing their child to play
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46 316 outdoors, playing toys with their child, and naming, counting or drawing things to promote
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49 317 learning that would form stimulus signals[5,32,33]. Depression among caregivers was also
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52 318 alarmingly high in our study sample, confirming findings from previously published studies
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55 319 [34,35]. Our results also found caregivers with depression had increased risk on adverse
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58 320 effects on child development[17,36]. The previously published studies have shown

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4 321 depression among caregivers not only impact children's physical health, but also place
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6 322 children at a higher risk of developmental delay[37,38]. It is well-established that maternal
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9 323 depression during the period that the mother–infant interaction was observed (concurrent or
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12 324 recent maternal depression) was associated with reduced maternal responsiveness, which was
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15 325 positively associated with later emotional, cognitive and physical development of the
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18 326 infant[39,40]. Our study revealed a latent variable, care and stimulus factors that include
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21 327 caregiver depression scores and parent-child interaction scores, had a comprehensive impact
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24 328 on child development. Accordingly, these findings suggest an urgent need for child
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27 329 development interventions on children's care and stimulus factors in poor rural China.

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30 331 **Relations between Hb values and child development**

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33 332 Our study found hemoglobin values of children had a positive effect on child development.
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36 333 Other biological factors, such as birth weight of children and ICFI did not predict child
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39 334 development, which was not consistent with previous research[5]. A possible explanation
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42 335 might be that in our structural equation model, only continuous variables were involved and
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45 336 three variables in our study could not be converged as one latent variable, and each variable
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48 337 had poor correlations with the other two variables. Anemia among children was alarmingly
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51 338 high in our sample, confirming findings from a previous published study[41]. These findings
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54 339 point to a severe public health problem[42], and provide further evidence on anemia's
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57 340 negative impact on child growth and development[4,5,43]. Our survey found that the

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4 341 hemoglobin value of children had a positive effect on child development. On the positive side,
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6 342 the Chinese government has realized this public health issue and has started providing
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9 343 micronutrient supplements named “Ying Yang Bao (YYB)” to 6-35 month old children living
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12 344 in poor rural areas free of charge. It is expected that this nutrition intervention program will
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15 345 decrease child anemia effectively. Although the current study did not find that birth weight
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18 346 and ICFI are associated with child development, it is known that poor maternal nutrition,
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21 347 infections and child feeding practices can impact child nutrition and development. Therefore,
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24 348 these areas still need to be monitored and improved through government interventions in poor
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26 349 rural China.

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30 351 **Limitations**

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33 352 Our study had several limitations that should be discussed and considered. First, as a cross-
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36 353 sectional study, the associations identified in our study do not suggest a causal relationship
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39 354 between these factors and child’s suspicious developmental delay. Although the structured
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42 355 equation model is a powerful statistical technique for simultaneous consideration of the
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45 356 multiple variables measured, further evidence from cohort studies and interventional studies
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48 357 is needed to infer causal relationship. Second, because of the restrictions and limitations on
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51 358 structural equation model methodology and the software, many binary variables were not
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54 359 incorporated in the structural equation model, especially the variables measuring infant and
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56 360 young child infections such as diarrhea and pneumonia. Third, this study was conducted in

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4 361 two provinces located in central and south-west regions of China. These study sites cannot
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6 362 represent all poor rural areas of China. Caution is warranted when generalizing findings from
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9 363 our studies to rural areas in China.
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11 364 **Conclusions**

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15 365 These preliminary findings indicated that the prevalence of suspicious developmental delay is
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17 366 high in poor rural areas of China. More attention needs to be paid to early childhood
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20 367 development (ECD). Interventions should specifically target and support families in poverty
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23 368 and with low education levels, as well as prioritize maternal and children nutrition and mental
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26 369 health, so as to improve fetal and early child development.
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28 29 370 **Acknowledgments**

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35 372 collection, and thank all the participants in this study.
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44 375 **Competing interests**

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48 376 The authors declare that they have no competing interests.
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51 377 **Author's contributions**

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4 378 Ying Li did the data analysis. Jingxu Zhang drafted the article. Sufang Guo, Xiaoli Wang and
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7 379 Robert W. Scherpbier designed the study. Jingxu Zhang, Qianwei Wei, Cuihong Zhang and
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10 380 Shusheng Luo collected the data. Xiaoli Wang and Chunxia Zhao critically revised the
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12 381 manuscript. All authors read and approved the final manuscript.
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15 382 **Data sharing statement**
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18 383 The datasets analyzed during the current study are not publicly available, but are available
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21 384 from the corresponding author on reasonable request.
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24 385 **Consent for publication**
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28 386 Not applicable.
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31 387 **Ethics approval and consent to participate**
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34 388 This study was approved by Peking University's Biomedical Ethics Committee. Consent was
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37 389 obtained from the participants/guardians/parents.
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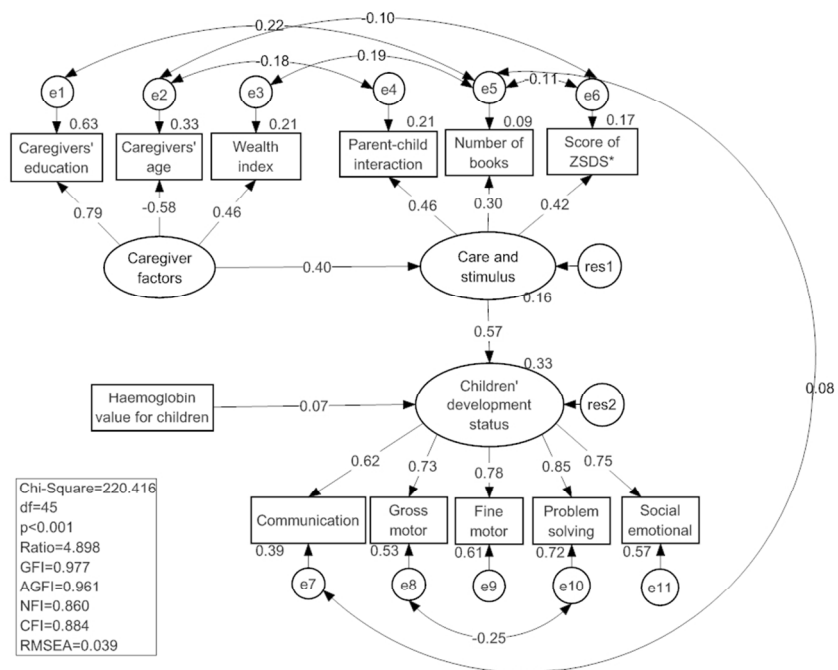
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Figure 1 Structural equation model and standardized coefficient for relationships between factors that theoretically influence children’s suspicious developmental delay

For peer review only



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Supplementary 1

Table S1. The squared multiple correlations of variables

Variables	Squared multiple correlations
Caregivers' education	0.631
Caregivers' age	0.331
Wealth index	0.213
Parent-child interaction	0.208
Number of books	0.092
Score of ZSDS	0.172
Communication	0.387
Gross motor	0.527
Fine motor	0.605
Problem solving	0.719
Social emotional	0.566

Note: ZSDS: Zung Self-rating Depression Scale

STROBE 2007 (v4) Statement—Checklist of items that should be included in reports of *cross-sectional studies*

Section/Topic	Item #	Recommendation	Reported on page #
Title and abstract	1	(a) Indicate the study's design with a commonly used term in the title or the abstract	3
		(b) Provide in the abstract an informative and balanced summary of what was done and what was found	3
Introduction			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	5-7
Objectives	3	State specific objectives, including any prespecified hypotheses	7
Methods			
Study design	4	Present key elements of study design early in the paper	7-8
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	
Participants	6	(a) Give the eligibility criteria, and the sources and methods of selection of participants	7-8
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	9-11
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	
Bias	9	Describe any efforts to address potential sources of bias	
Study size	10	Explain how the study size was arrived at	
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	
Statistical methods	12	(a) Describe all statistical methods, including those used to control for confounding	12
		(b) Describe any methods used to examine subgroups and interactions	
		(c) Explain how missing data were addressed	
		(d) If applicable, describe analytical methods taking account of sampling strategy	
		(e) Describe any sensitivity analyses	
Results			

Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed (b) Give reasons for non-participation at each stage (c) Consider use of a flow diagram	
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders (b) Indicate number of participants with missing data for each variable of interest	14
Outcome data	15*	Report numbers of outcome events or summary measures	
Main results	16	(a) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included (b) Report category boundaries when continuous variables were categorized (c) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	
Discussion			
Key results	18	Summarise key results with reference to study objectives	21-22
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias	25-26
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	22-25
Generalisability	21	Discuss the generalisability (external validity) of the study results	26
Other information			
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	27

*Give information separately for cases and controls in case-control studies and, if applicable, for exposed and unexposed groups in cohort and cross-sectional studies.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at <http://www.plosmedicine.org/>, Annals of Internal Medicine at <http://www.annals.org/>, and Epidemiology at <http://www.epidem.com/>). Information on the STROBE Initiative is available at www.strobe-statement.org.

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Factors influencing developmental delay among young children in poor rural China: a latent variable approach

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4 **1 Title Page**
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8 **2 Title:** Factors influencing developmental delay among young
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11 children in poor rural China: a latent variable approach
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For peer review only

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4 **22 Abstract**

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6 **23 OBJECTIVES:** The aims of the study were to determine the prevalence of suspected
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24 developmental delay in children living in poor rural China and to investigate factors
25 influencing child developmental delay.

26 **DESIGN:** A community-based, cross-sectional survey was conducted.

27 **SERRING:** 83 villages in Shangxi and Guizhou Provinces, China.

28 **PARTICIPANTS:** 2,514 children aged 6-35 months and their first caregivers.

29 **OUTCOMES MEASURES:** Child suspected developmental delay using the Ages & Stages
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30 Questionnaires -Chinese version. Caregivers' education and age, wealth index Infants, child
31 feeding index, parent-child interaction, number of books and Zung self-rating depression
32 scale were all primary caregivers reported. Haemoglobin value measured using a calibrated,
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33 automated analyzer. Birth weight obtained from medical record.

34 **RESULTS:** Overall, 35.7% of the surveyed children aged 6-35 months demonstrated
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35 suspected developmental delay. The prevalence of suspected developmental delay was
36 inversely associated with age, with the prevalence among young children aged 6-11 months
37 nearly doubling that of children aged 30-35 months (48.0% and 22.8%, respectively). Using a
38 structural equation model, it was demonstrated that caregiver's care and stimulus factors and
39 child's hemoglobin level were directly correlated, while caregiver's socio-demographic
40 factors were indirectly associated with suspected developmental delay.

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4 41 CONCLUSIONS: The prevalence of suspected developmental delay is high in poor rural
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6 42 areas of China. Interventions to improve child development are needed in poor rural area of
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9 43 China.

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12 44 Key words: suspected Developmental Delay; Infants and young children; Structural equation
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15 45 model; Rural China
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21 47 **Strengths and limitations of this study**

- 22
23 48 • This cross-sectional study includes suspected developmental delay among children under
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26 49 3 years of age in poor rural areas of China.
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29 50 • A structural equation model is a good approach to examine the influencing factors on
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32 51 suspected developmental delay.
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35 52 • A few binary variables were not incorporated in the structural equation model because of
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38 53 methodological limitation.
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55 INTRODUCTION

56 Developmental delay encompasses a wide spectrum of impairments or lack of developmental
57 features that are appropriate to the child's age. It may manifest in various aspects, including
58 motor, mental, language, and social domains[1,2]. Worldwide, developmental delay accounts
59 for more morbidity across the lifespan than any other chronic conditions[3]. A conservative
60 estimate is that across the world more than 200 million children under 5 years old failed to
61 reach their potential in cognitive and social emotional development. As a number of social
62 factors such as poverty, malnutrition, lack of appropriate care, and child abuse and neglect,
63 have been identified as potential contributing factors to developmental delay [4],
64 developmental delay has been a major issue in low and middle-income countries. Moreover,
65 national statistics on young children's cognitive or social emotional development are not
66 available for most developing countries. This gap contributes to the invisibility of the issue of
67 development delay. With a total of 15 million disadvantaged children (defined as stunted,
68 living in poverty, or both), China has the third largest number of disadvantaged children
69 globally, following India (65 million) and Nigeria (16 million)[4]. It is clear that
70 interventions and policies designed to promote child development and prevent or ameliorate
71 developmental delay are urgently needed as China moves forward.
72 The pathway between poverty and poor development described by Walker et al is built on the
73 fact that poverty is associated with inadequate food, and poor access to water, sanitation and

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4 74 hygiene [5]. Poverty is also related to poor maternal education, increasing maternal stress,
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7 75 depression, and inadequate stimulation at home. All these factors detrimentally affect child
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10 76 development, and this deprived development may lead to poor school performance and
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12 77 achievement. In addition, poverty and socio-cultural context risk factors may increase young
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15 78 children's exposure to biological and psychosocial risks, and the accumulation in risks often
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18 79 significantly harm child development. Children in developing countries are frequently
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21 80 exposed to multiple and cumulative risks negatively affecting their development, especially
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24 81 through changes in their brain structure and function, and behavioral changes[6].

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26 82 Biological risk factors related to young children's developmental delay include infectious
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29 83 disease, chronic malnutrition, iodine deficiency, iron deficiency, anemia, malaria, low birth
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32 84 weight, preterm birth, and exposure to lead or arsenic, etc.[5,7-10].

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35 85 Psychological risk factors associated with developmental delay are mainly related to
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38 86 parenting, more specifically, cognitive stimulation, caregiver sensitivity and responsiveness
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41 87 to the child, and caregiver affect in terms of emotional warmth or rejection of the child[5].

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43 88 Parents and caregivers can play an important role in providing the child with a healthy, safe
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46 89 and caring environment[11].

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49 90 The effects of these biological and psychological risk factors are sensitive to contextual
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52 91 factors such as poverty and maternal depression[5]. Common mental disorders, including
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55 92 depression and anxiety among women during pregnancy, or in the first post-partum year, are

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4 93 recognized as a public health issue globally. There are emerging evidence show that maternal
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6 94 mental disorders have adverse impacts on physical and psychological development of fetuses
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9 95 and infants[12-18].
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12 96 To sum up, various social, biological and psychological factors may contribute to child
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15 97 developmental delay. The existing evidence indicated that four major risk factors affect at
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18 98 least 20–25% of children in developing countries[5]: inadequate cognitive stimulation,
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21 99 stunting, iron deficiency, and iodine deficiency. There is a paucity of data on the prevalence
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24 100 and risk factors for developmental delay in China, especially in poor rural areas where
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27 101 children are at high risk for developmental delay due to the economic and social restraints. In
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30 102 addition, although the influencing factors on child developmental delay have been widely
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33 103 studied, the relationships among these factors and their direct and indirect associations with
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36 104 the development outcome were seldom examined in the existing literature. Comparing to
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39 105 mostly commonly used methods such as linear or logistic regression, a structural equation
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42 106 model could effectively control measurement error [19]. More importantly, structural
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45 107 equation model could tackle multiple dependent variables simultaneously and examine the
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48 108 relationships between dependent variables and independent variables at the same time
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51 109 without adjusting confounders. Especially, the structural equation model can explore the
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54 110 direct, indirect and total effects of multiple factors as mentioned above on child
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57 111 developmental delay, which will provide a latent variable approach. The goals of this study

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4 112 were to determine the prevalence of developmental delay in young children in rural China
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7 113 and to explore factors contributing to child developmental delay.
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9 114 **METHOD**

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12 115 **Participants and Design**

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15 116 A community-based cross-sectional survey on child health, nutrition and development was
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18 117 conducted between July and September 2013 in remote mountainous areas of Shanxi and
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21 118 Guizhou provinces, located in the central and south-west regions of China respectively. The
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24 119 survey sites were the project sites of the Integrated Early Childhood Development (IECD)
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27 120 Project funded by UNICEF. A total of 83 villages were selected from six counties of the two
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30 121 provinces based on the following criteria: 1) having at least 50 children under 3 years old; 2)
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32 122 having a township health center staffed with maternal and child health professionals; 3)
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35 123 reachable by vehicles. All the children under 3 years and their primary caregivers (defined as
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38 124 person(s) who take primary responsibility for taking care of child in the family) in the chosen
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41 125 villages were eligible for the study. Altogether, 2,953 children out of the 4,288 children in the
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44 126 83 villages participated in the study and their primary caregivers finished the survey. The
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47 127 response rate was 68.9%. All caretakers provided their written informed consent to
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50 128 participate in this study. The study was reviewed and approved by Peking University
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52 129 Biomedical Ethics Committee.
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55 130 For this analysis, children with hearing disabilities (e.g., deaf children) (n=16) were excluded
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4 131 because the disabilities may directly affect their performance. In addition, we excluded
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6 132 children aged 1-5 months (n=326) because their hemoglobin values were not tested; children
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9 133 with implausible hemoglobin values (n =1, Hb =225 g/L); and respondents who were not
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12 134 primary caregivers (n =96). Therefore, the final sample size for this analysis was 2,514
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14
15 135 children.

18 136 **Patient and Public Involvement**

20 137 At survey day, children under 3 years old and their caregivers in the village were recruited
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23 138 and conducted. The research questions were interviewed face-to-face and children growth,
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26 139 Haemoglobin value and development were measured after interview. The status of growth,
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29 140 anemia and development were disseminated to the caregivers immediately.

32 141 **Study Instruments**

35 142 *Outcome measure : Child developmental delay measurement*

37 143 The Ages & Stages Questionnaires -Chinese version (ASQ-C), which was validated recently
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40 144 in Chinese, was used to assess children's development status [20].ASQ-C includes various
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43 145 dimensions, including communication, gross motor, fine motor , problem solving and
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46 146 personal-social [21]. Each of the domains contains six sub-items. The responses of 'yes',
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49 147 'sometimes', or 'not yet' were given scores of 10, 5, and 0 points, respectively. Development
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52 148 delay in a certain domain was defined as if domain score was lower than 2SD (Standard
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55 149 Deviation) of the cutoff point in the normative norm in that domain. Overall suspected

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4 150 development delay was defined as if there was delay in any one of five domains of ASQ,
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7 151 including communication, gross motor, fine motor, problem solving, and personal-social
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10 152 domain. The latent variable of children's developmental status was measured by five
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12 153 dimensions of ASQ-C in this study.

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15 154 *Social, biological and psychological factors*

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18 155 Household survey questionnaire

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20 156 A face-to-face interview was conducted with the child caregivers using a structured
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23 157 questionnaire developed based on UNICEF's 5th Multiple Indicator Cluster Survey (MICS5).
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26 158 The questionnaire contained questions on the household socioeconomic status, family
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29 159 structure, health and development of children under five years old and their mother in the
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32 160 household. Wealth index was developed based on the number of household appliances
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35 161 (telephone, TV, washing machine, refrigerator, and internet connection).

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38 162 Zung self-rating depression scale (ZSDS)

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40 163 The Zung Self-rating Depression Scale (ZSDS), validated and widely utilized in China[22-
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43 164 24], was used to assess caregivers' mental health status. The scale comprises 20 items and
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46 165 each question is scored on a scale of 1-4 based on the following responses: never or rarely,
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49 166 sometimes, most of the time, or always. A score between 50 and 69 indicates depression, and
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52 167 a score of 70 or above indicates severe depression. In this study, caregivers with a score of 50
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55 168 or more were identified as positive for depression [25].

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4 169 A modified infants and child feeding index (ICFI)
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7 170 A modified infant and child feeding index (ICFI) was constructed on the basis of current
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10 171 feeding practices for infants and young children recommended by WHO[26] and proposed by
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12 172 Ruel and Menon[27] and was used to gather information on current feeding practices of
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15 173 surveyed children. This modified ICFI was based on a dietary recall of the past 24 hours from
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18 174 a questionnaire and it includes practices related to breastfeeding, bottle feeding, feeding
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21 175 frequency and food diversity given to the children prior to the survey being conducted. To
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24 176 take into account the age specific feeding recommendations, the modified ICFI was compiled
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27 177 separately for three age groups: 6-8 months, 9-11 months and 12-35 months. A score of 2
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29 178 was added if the child was breastfed; 1 point added if the child had never been bottle-fed; 2
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32 179 points added if the child's feeding frequency met the recommendation; and 1 point if the
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35 180 feeding frequency was below the recommendation but above zero. Dietary diversity of food
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38 181 groups refers to the number of different food groups provided to the child. Altogether 7 food
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41 182 groups were counted, and a score of +2 was added if 4 or more food groups were consumed,
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44 183 and a score of +1 was added if 1 to 3 food groups were consumed.

45 184 Parent-child interaction

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49 185 The level of parent-child interaction was assessed based on the following six activities that
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52 186 caregivers did with their child: 1) reading books to the child, 2) telling stories to the child, 3)
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55 187 singing songs to or with the child, 4) taking the child outdoor, 5) playing toys with the child,
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4 188 and 6) naming, counting or drawing things to promote learning with the child. If one of the
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6 189 above mentioned behaviors were reported by the caregivers, +1 score was given, with the
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9 190 highest possible score of +6.

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12 191 Haemoglobin value

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15 192 Trained staff collected capillary blood sample from the child and measured their hemoglobin
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18 193 (Hb) concentration using a calibrated, automated analyzer (HemoCue 201 [HemoCue,
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20 194 Angelholm, Sweden]). Anemia is defined as a hemoglobin concentration <110 g/L, based on
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23 195 the global definition for preschool children and adjusted for altitude[28]. Children with
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26 196 anemia were referred to an appropriate health facility for treatment.

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29 197 Anthropometric measurements

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32 198 Birth weight was obtained from medical record.

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35 199 In this part, the latent variable, caregiver factor, was measured by caregivers' education,
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38 200 caregivers' age and wealth index. Care and stimulus was measured by parent-child
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41 201 interaction, number of books and score of ZSDS.

42 43 202 **Data Analysis**

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46 203 Data analysis was performed using SPSS for Windows (version 16.0, SPSS Inc., Chicago, IL,
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49 204 USA). Descriptive statistics were provided as median, range and interquartile range for
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52 205 continuous variables and count and percentage for categorical variables. A structural
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55 206 equation model (Amos 20 for Windows, IBM, Armonk, NY, USA) was used to test if the

207 hypothetical explanatory model fits the observed data and to apply the asymptotically
 208 distribution-free estimate. The hypothetical explanatory model was derived from literature
 209 [4,5]and the univariate regression result. The assignment rules and explanation of variables in
 210 the structural equation model are described in Table 1. The model was modified according to
 211 statistics suggested by the modification index in Amos. An absolute value of ≥ 1.96 ($p \leq 0.05$)
 212 for the standardized β -coefficient T was considered significant. Goodness of fit index (GFI),
 213 normal fit index (NFI), comparative fit index (CFI) and root mean squared error of
 214 approximation (RMSEA) were used to test model fit. For GFI, CFI and NFI, 1 means a
 215 perfect fit while >0.9 indicates an adequate fit. For RMSEA, <0.05 indicates a good model.
 216 Chi-square statistic to test the null hypothesis was not required as the sample size
 217 was >1000 [29].

218 Table 1. Assignment rules and explanation of variables in structural equation model

Variables	assignment rules or explanation
caregiver's education	illiteracy,+1 primary school,+2 junior high school,+3 senior high school and above,+4
caregiver's age	caregiver's integer age
wealth index	numbers of accessories including phone(telephone or mobile),washing machine, refrigerator, TV set, access to Internet

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5	parent-child interaction	6 behaviors including read books to child, told stories, sang songs, took child outside the home, played with child, and named, counted or drew things to promote learning would form stimulus signals
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10	numbers of books	numbers of books children owned presently
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12		
13	score of ZSDS	reversed score of caregiver's depression assessed by the Zung Self-rating Depression Scale
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17		Breastfeeding:
18		
19		6-9 mo: No=0; Yes= +2;
20		
21		9-11 mo: No=0; Yes=+2;
22		
23		12-35 mo: No=0; Yes=+1.
24		
25		Bottle feeding: Yes=0; No=+1;
26	modified ICFI	
27		Feeding frequency:
28		
29		6-9 mo: 0 meal = 0; 1 meal = +1; 2 meals or more = +2;
30		
31		9-11 mo: 0 meal = 0; 1-2 meals = +1; 3 meals or more = +2;
32		
33		12-35 mo: 0-1 meals = 0; 2-3 meals = +1; 4 meals or more = +2;
34		
35		Dietary diversity: 0 group = 0; 1-3 groups = +1; 4 or more groups = +2
36		
37	birth weight	birth weight of child (medical records or parental report)
38		
39	haemoglobin value for children	haemoglobin value we tested
40		
41	Communication	score of communication assessed by ASQ
42		
43	gross motor	score of gross motor assessed by ASQ
44		
45	fine motor	score of fine motor assessed by ASQ
46		
47	problem solving	score of problem solving assessed by ASQ
48		
49		
50	Personal-social	score of personal-social assessed by ASQ
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219 Note: ZSDS: Zung Self-rating Depression Scale; ICFI: infant and young child feeding index

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4 221 **RESULTS**

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6 222 **Demographic, Socio-economic Characteristics of Participants**

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9 223 About 21.0% of children surveyed were 6-11 months, while 41.1% were 12-23 months, and
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12 224 37.9% were 24-35 months. Slightly more boys were included in the survey than girls (56.8%
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15 225 versus 43.2%, respectively) (Table 2). About half (47.9%) were the firstborn children and
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18 226 11.4% were left-behind children (i.e. their parents are migrant workers who leave rural areas
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21 227 for the cities while leaving children behind in their hometowns). More than one-third (35.5%)
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24 228 were ethnic minority children. Most of the caregivers interviewed (79.6%) were mothers. The
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26
27 229 average age of caregivers was 30.19 years with a standard deviation (SD) of 9.71 years; a
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30 230 majority (62.1%) of caregivers interviewed aged 20-29 years. Most (63.5%) had completed
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32
33 231 at least 9 years of education (i.e. secondary education). Among the surveyed households,
34
35
36 232 51% lived under the national poverty line of US\$1 per day and 45% lived more than 5
37
38
39 233 kilometers to the nearest health facilities.

40 234 Table 2. Sociodemographic and clinical characteristics of sampled child-caregiver pairs (N=2514)

	N	%		N	%
Child age			Caregivers interviewed		
6-11	528	21.0	Mother	2002	79.6
12-23	1034	41.1	Father	189	7.5
24-35	952	37.9	Grandparents	320	12.7

Child gender			Others	3	0.1
Male	1427	56.8	Caregivers' age		
Female	1087	43.2	<20	42	1.7
Having elder sibling			20-	1561	62.1
Yes	1277	50.8	30-	539	21.4
No	1203	47.9	40-	349	13.9
Unknown	34	1.4	Unknown	23	0.9
Left-behind children			Caregivers' education		
Yes	286	11.4	Illiteracy	256	10.2
No	2228	88.6	Primary education	661	26.3
Ethnicity			Secondary	1277	50.8
Han	1621	64.5	Above secondary	320	12.7
Minority	893	35.5	Distance to health facility		
			<5km	1345	53.5
			≥5km	1131	45.0
			Unknown	38	1.5

235

236 **Suspected Developmental Delay among Children under 3 Years Old**

237 Overall, 35.7% of the surveyed children under 3 years of age had suspected developmental
 238 delay (Table 3). Across all age groups, prevalence of suspected developmental delay was
 239 inversely associated to the child's age, with the highest rate (48.0%) among children aged 6-
 240 11 months and lowest (22.8%) among children aged 30-35 months. Across all domains, delay
 241 in communication was the lowest (8.9%) and delay in fine motor was the highest (20.6%),
 242 while other domains ranged from 15.1% to 16.7%.

243 Table 3. Prevalence of child suspected development delay

	6-months	12-months	18-months	24-months	30-months	Total
	n(%)	n(%)	n(%)	n(%)	n(%)	n(%)
	N=538	N=473	N=561	N=517	N=435	N=2514
suspected Developmental delay	258(48.0)	210(44.4)	207(36.9)	123(23.8)	99(22.8)	897(35.7)
Delay in subscales:						
Communication	92(17.4)	46(9.7)	46(8.2)	22(4.3)	18(4.1)	224(8.9)
Grass motor	107(20.3)	85(18.0)	83(14.8)	61(11.8)	44(10.1)	380(15.1)
Fine motor	157(29.7)	145(30.7)	144(25.7)	50(9.7)	23(5.3)	519(20.6)
Problem solving	98(18.6)	131(27.7)	84(15.0)	50(9.7)	56(12.9)	419(16.7)
Personal-Social	102(19.3)	92(19.5)	96(17.1)	63(12.2)	52(12.0)	405(16.1)

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245 **Social, biological and psychological factors**

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4 246 The wealth index in the surveyed families ranged from 0 to 5, with a median of 4, indicating
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7 247 that most of the families owned major appliances. The parent-child interaction scores ranged
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10 248 from 0 to 6, with a median score of 6. On average, the surveyed children owned only 1 book
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12 249 (median=1, IQR=3). Caregivers' ZSDS in this survey ranged from 38 to 80, with a median
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15 250 score of 63.76. Nearly two-fifths of caregivers (38.5%) had symptoms of depression. The
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18 251 ICFI ranged from 0 to 7, with a median score of 2. The hemoglobin values for the surveyed
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21 252 children were 51 to 178 g/L, with a median of 110 g/L. Anemia prevalence was high at
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24 253 43.8%. Birth weight of the surveyed children ranged from 1.40 to 6.00 kilograms, with a
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27 254 median of 3.30 kilograms; 2.9% had low birth weight (i.e. birth weight less than 2.5 kg) .
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30 256 **Structural Equation Model for Children's Developmental Delay**

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33 257 About half of the squared multiple correlation of variables were more than 0.50 (Table S1),
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36 258 which indicated that the variables had a good reliability. In the final structural equation
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39 259 model (shown in Table 4), modified ICFI and birth weight were excluded from the model,
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42 260 because of lack of statistically significant relationships with other variables. Figure 1 shows
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45 261 the estimated covariance and paths for this model. Three factors influencing children's
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48 262 developmental status were identified: 1) caregiver socio-demographic factors such as
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51 263 caregiver's education, age, and wealth index (total effect =0.23 on child developmental
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54 264 status); 2) care and stimulus factors measured by parent-child interaction, number of books
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57 265 and ZSDS score (direct effect= 0.57); and 3) child's hemoglobin level (direct effect= 0.07).

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4 266 Younger caregivers were more likely to interact with children than older caregivers
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6 267 (covariance of residuals =-0.18) and the latent variable- caregiver factors-had a direct positive
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9 268 effect on ‘care and stimulus factors’ (path coefficient=0.40) and an indirect positive effect on
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12 269 children’s developmental status. The overall model fit was good as reflected by the goodness
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15 270 of fit index of 0.977 and the comparative fit index of 0.884.
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271 Table 4. Regression weights of structural equation model

Equation	Estimates (unstandardized)	Estimates (Standardized)	Standard Error	Critical ratio	P value
Regression weights					
Care and stimulus ← caregiver factor	0.402	0.401	0.047	8.497	<0.001
Children's developmental status ← care and stimulus	9.608	0.573	0.913	10.525	<0.001
Children's developmental status ← haemoglobin value for children	0.593	0.071	0.178	3.331	0.001
Caregivers' education ← caregiver factor	1.000	0.794			
Caregivers' age ← caregiver factor	-8.358	-0.576	0.543	-15.380	<0.001
Wealth index ← caregiver factor	0.775	0.461	0.055	14.163	<0.001
parent-child interaction ← care and stimulus	1.000	0.456			
Numbers of books ← care and stimulus	1.687	0.303	0.220	7.678	<0.001
Score of ZSDS ← care and stimulus	4.856	0.415	0.488	9.944	<0.001
Communication ← Children's developmental status	0.863	0.622	0.029	30.054	<0.001
Gross motor ← Children's developmental status	0.970	0.726	0.030	32.608	<0.001
Fine motor ← Children's developmental status	1.132	0.778	0.028	40.216	<0.001

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5	Problem solving ← Children's developmental status	1.188	0.848	0.030	40.212	<0.001
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7	Personal-social ← Children's developmental status	1.000	0.752			
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9	Covariance					
10						
11	e8 ↔ e10	-19.912	-0.248	2.961	-6.725	<0.001
12						
13	e3 ↔ e5	0.620	0.188	0.064	9.708	<0.001
14						
15	e2 ↔ e4	-1.695	-0.175	0.270	-6.290	<0.001
16						
17	e1 ↔ e5	0.364	0.215	0.051	7.136	<0.001
18						
19	e5 ↔ e7	3.079	0.076	0.680	4.527	<0.001
20						
21	e5 ↔ e6	-2.709	-0.115	0.575	-4.712	<0.001
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23	e2 ↔ e6	-5.270	-0.100	1.247	-4.228	<0.001
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Note: ZSDS: Zung Self-rating Depression Scale

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4 273 **DISCUSSION**

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6 274 Our results showed that the prevalence of suspected developmental delay among children
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9 275 aged 6-35 months was high and inversely associated with children's age in poor rural China.
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12 276 Furthermore, by using the structural equation model, some risk factors for children's
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15 277 suspected development delay and their relationship were identified. So far only one study
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18 278 examined developmental delay in rural China and reported a prevalence of 20.0% in
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21 279 cognitive development and 32.3% in psychomotor development among children aged 6-12
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24 280 months[30]. Our study revealed that 35.7% of rural children under 3 years of age had
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27 281 suspected developmental delay and that among children aged 6-12 months, 17-20% of them
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30 282 had delay in communication, problem solving, personal-social and gross motor, and nearly
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33 283 30% had delay in final motor development. Overall the prevalence observed in our study was
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36 284 comparable to the results from the previous study. According to the very limited data from
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39 285 the WHO report[31], the reported prevalence of developmental delay in young children was
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42 286 17% in Senegal, 15% in Nigeria, 13% in India, and 24% in Brazil. The lower prevalence
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45 287 reported by other developing countries may reflect the underestimated rates and inaccurate
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48 288 measurement of developmental delay. Promoting early childhood development (ECD) is a
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51 289 critical issue. It is recommended that government and healthcare providers should pay more
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54 290 attention to early diagnosis and intervention of developmental delay. Among the five
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4 291 domains of ASQ, suspected developmental delay of fine motor had the highest prevalence.
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6 292 This is a key finding that requires further intervention in poor rural areas of China.
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9 293 It was found in the structural equation model that caregiver factor, care and stimulus factor
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11 294 and hemoglobin values of children were directly or indirectly associated with suspected
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13 295 developmental delay. These findings indicate potential areas that future intervention
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15 296 programs should focus on, including improving child's feeding and nutrition, raising public
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17 297 awareness of the issue of developmental delay, and improving parenting skills to increase
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19 298 interaction with children.
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23 300 **Relations between caregiver factors and child development**

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28 301 Our results showed that younger caregivers with higher education level and wealth index had
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30 302 an indirect, positive effect on their child's development. Previous studies have investigated
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32 303 the relations between caregivers' socio-demographic factors and child development. In a
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34 304 population-based study in Argentina and a cohort study in Brazil, it was found that poverty
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36 305 and maternal education were positively associated with early attainment of selected
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38 306 developmental milestones or cognitive and motor development [32,33]. Another report also
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40 307 indicated that parenting cognitive stimulation, caregiver's responsiveness, and caregiver's
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42 308 affect are sensitive to contextual factors such as poverty, cultural values and practices[5]. The
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44 309 findings from our study are consistent with these previous results. In addition, our study
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46 310 revealed that caregiver factor were indirect predictors of their child's development delay.
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4 311 Although caregiver factor had no direct effect on their child's developmental status, these
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6 312 factors such as caregivers' education, age and poverty level may impact other factors
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9 313 therefore indirectly affecting developmental delay. More attention should be paid to change
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12 314 these contextual factors when designing future interventions to improve children's
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15 315 development and health.

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18 19 317 **Relations between care and stimulus factors and child development**

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22 318 The current study revealed that the most important predictor on child's suspected
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25 319 developmental delay was care and stimulus factors (path coefficient=0.57). Better parent-
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28 320 child interaction, more books and less maternal depression had positive effect on child
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31 321 development. Children who had one score point increase on care and stimulus factors had
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34 322 0.57 score increase on child development. The findings of the current study were consistent
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37 323 with previous studies showing the protective effect of parent-child interaction, children's
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40 324 books and optimistic caregivers on child development[34]. Thus, it is necessary to promote
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43 325 parent-child interactions, through encouraging activities such as reading books to their child,
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46 326 telling stories to their child, singing songs to and with their child, bringing their child to play
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49 327 outdoors, playing toys with their child, and naming, counting or drawing things to promote
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52 328 learning that would form stimulus signals[5,35,36]. Depression among caregivers was also
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55 329 alarmingly high in our study sample, confirming findings from previously published studies
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58 330 [37,38]. Our results also found caregivers with depression had increased risk on adverse

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4 331 effects on child development[17,39]. The previously published studies have shown
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6 332 depression among caregivers not only impact children's physical health, but also place
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9 333 children at a higher risk of developmental delay[40,41]. It is well-established that maternal
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12 334 depression during the period that the mother–infant interaction was observed (concurrent or
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15 335 recent maternal depression) was associated with reduced maternal responsiveness, which was
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18 336 positively associated with later emotional, cognitive and physical development of the
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21 337 infant[42,43]. Our study revealed a latent variable, care and stimulus factors that include
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24 338 caregiver depression scores and parent-child interaction scores, had a comprehensive impact
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27 339 on child development. Accordingly, these findings suggest an urgent need for child
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29 340 development interventions on children's care and stimulus factors in poor rural China.
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32 33 342 **Relations between Hb values and child development**

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36 343 Our study found hemoglobin values of children had a positive effect on child development.
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39 344 Other biological factors, such as birth weight of children and modified ICFI did not predict
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42 345 child development, which was not consistent with previous research[5]. A possible
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45 346 explanation might be that in our structural equation model, only continuous variables were
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48 347 involved and three variables in our study could not be converged as one latent variable, and
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51 348 each variable had poor correlations with the other two variables. Anemia among children was
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54 349 alarmingly high in our sample, confirming findings from a previous published study[44].
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56 350 These findings point to a severe public health problem[45], and provide further evidence on
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4 351 anemia's negative impact on child growth and development[4,5,46]. Our survey found that
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7 352 the hemoglobin value of children had a positive effect on child development. On the positive
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10 353 side, the Chinese government has realized this public health issue and has started providing
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12 354 micronutrient supplements named "Ying Yang Bao (YYB)" to 6-35 month old children living
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15 355 in poor rural areas free of charge. It is expected that this nutrition intervention program will
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18 356 decrease child anemia effectively. Although the current study did not find that birth weight
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21 357 and modified ICFI are associated with child development, it is known that poor maternal
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24 358 nutrition, infections and child feeding practices can impact child nutrition and development.
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27 359 Therefore, these areas still need to be monitored and improved through government
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30 360 interventions in poor rural China.

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33 362 **Limitations**

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36 363 Our study had several limitations that should be discussed and considered. First, as a cross-
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39 364 sectional study, the associations identified in our study do not suggest a causal relationship
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42 365 between these factors and child's suspected developmental delay. Although the structured
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45 366 equation model is a powerful statistical technique for simultaneous consideration of the
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48 367 multiple variables measured, further evidence from cohort studies and interventional studies
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51 368 is needed to infer causal relationship. Second, because of the restrictions and limitations on
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54 369 structural equation model methodology and the software, many binary variables were not
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57 370 incorporated in the structural equation model, especially the variables measuring infant and

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4 371 young child infections such as diarrhea and pneumonia. Third, this study was conducted in
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6 372 two provinces located in central and south-west regions of China. These study sites cannot
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9 373 represent all poor rural areas of China. Caution is warranted when generalizing findings from
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12 374 our studies to rural areas in China.

15 375 **Conclusions**

17 376 These preliminary findings indicated that the prevalence of suspected developmental delay is
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20 377 high in poor rural areas of China. More attention needs to be paid to early childhood
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23 378 development (ECD). Interventions should specifically target and support families in poverty
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26 379 and with low education levels, as well as prioritize maternal and children nutrition and mental
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29 380 health, so as to improve fetal and early child development.

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36
37
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47 386 **Competing interests**

50 387 The authors declare that they have no competing interests.

54 388 **Author's contributions**

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4 389 Ying Li did the data analysis. Jingxu Zhang drafted the article. Sufang Guo, Xiaoli Wang and
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7 390 Robert W. Scherpbier designed the study. Jingxu Zhang, Qianwei Wei, Cuihong Zhang and
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10 391 Shusheng Luo collected the data. Xiaoli Wang and Chunxia Zhao critically revised the
11
12 392 manuscript. All authors read and approved the final manuscript.
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15 393 **Data sharing statement**
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18 394 The datasets analyzed during the current study are not publicly available, but are available
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21 395 from the corresponding author on reasonable request.
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24 396 **Consent for publication**
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28 397 Not applicable.
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31 398 **Ethics approval and consent to participate**
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34 399 This study was approved by Peking University's Biomedical Ethics Committee. Consent was
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37 400 obtained from the participants/guardians/parents.
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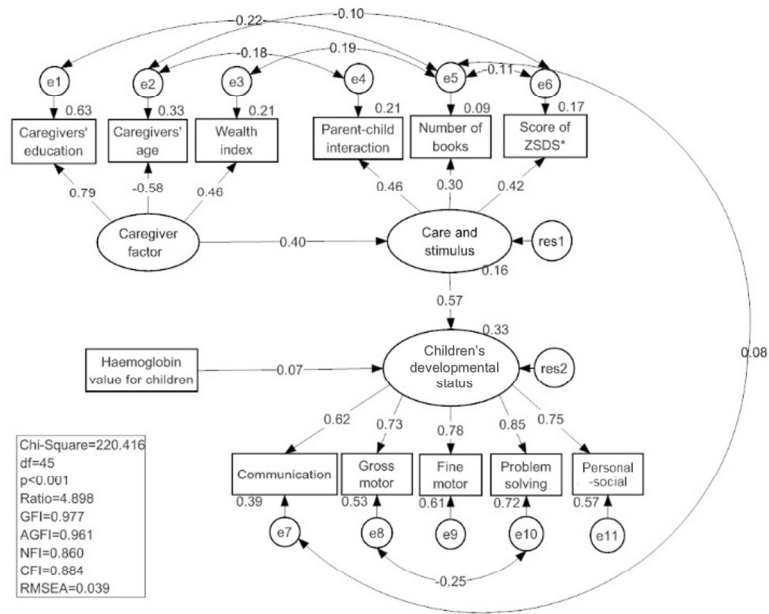
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4 Figure 1 Structural equation model and standardized coefficient for relationships between
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6 factors that theoretically influence children's suspected developmental delay
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Structural equation model and standardized coefficient for relationships between factors that theoretically influence children's suspected developmental delay

Supplementary 1

Table S1. The squared multiple correlations of variables

Variables	Squared multiple correlations
Caregivers' education	0.631
Caregivers' age	0.331
Wealth index	0.213
Parent-child interaction	0.208
Number of books	0.092
Score of ZSDS	0.172
Communication	0.387
Gross motor	0.527
Fine motor	0.605
Problem solving	0.719
Social emotional	0.566

Note: ZSDS: Zung Self-rating Depression Scale

STROBE 2007 (v4) Statement—Checklist of items that should be included in reports of cross-sectional studies

Section/Topic	Item #	Recommendation	Reported on page #
Title and abstract	1	(a) Indicate the study’s design with a commonly used term in the title or the abstract	3
		(b) Provide in the abstract an informative and balanced summary of what was done and what was found	3
Introduction			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	5-7
Objectives	3	State specific objectives, including any prespecified hypotheses	7
Methods			
Study design	4	Present key elements of study design early in the paper	7-8
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	
Participants	6	(a) Give the eligibility criteria, and the sources and methods of selection of participants	7-8
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	9-11
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	
Bias	9	Describe any efforts to address potential sources of bias	
Study size	10	Explain how the study size was arrived at	
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	
Statistical methods	12	(a) Describe all statistical methods, including those used to control for confounding	12
		(b) Describe any methods used to examine subgroups and interactions	
		(c) Explain how missing data were addressed	
		(d) If applicable, describe analytical methods taking account of sampling strategy	
		(e) Describe any sensitivity analyses	
Results			

Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed (b) Give reasons for non-participation at each stage (c) Consider use of a flow diagram	
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders (b) Indicate number of participants with missing data for each variable of interest	14
Outcome data	15*	Report numbers of outcome events or summary measures	
Main results	16	(a) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included (b) Report category boundaries when continuous variables were categorized (c) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	
Discussion			
Key results	18	Summarise key results with reference to study objectives	21-22
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias	25-26
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	22-25
Generalisability	21	Discuss the generalisability (external validity) of the study results	26
Other information			
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	27

*Give information separately for cases and controls in case-control studies and, if applicable, for exposed and unexposed groups in cohort and cross-sectional studies.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at <http://www.plosmedicine.org/>, Annals of Internal Medicine at <http://www.annals.org/>, and Epidemiology at <http://www.epidem.com/>). Information on the STROBE Initiative is available at www.strobe-statement.org.

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Factors influencing developmental delay among young children in poor rural China: a latent variable approach

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4 **1 Title Page**
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8 **2 Title:** Factors influencing developmental delay among young
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For peer review only

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4 **22 Abstract**

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6 **23 OBJECTIVES:** The aims of the study were to determine the prevalence of suspected
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9 **24** developmental delay in children living in poor rural China and to investigate factors
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12 **25** influencing child developmental delay.

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15 **26 DESIGN:** A community-based, cross-sectional survey was conducted.

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18 **27 SERRING:** 83 villages in Shangxi and Guizhou Provinces, China.

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21 **28 PARTICIPANTS:** 2,514 children aged 6-35 months and their primary caregivers.

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24 **29 OUTCOMES MEASURES:** Child suspected developmental delay was evaluated using the
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27 **30** Ages & Stages Questionnaires -Chinese version. Caregivers' education and age, wealth index
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29
30 **31** Infants, child feeding index, parent-child interaction, number of books and Zung self-rating
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32
32 **32** depression scale were all primary caregivers reported. Haemoglobin value was measured
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34
35 **33** using a calibrated, automated analyzer. Birth weight was obtained from medical record.

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37
38 **34 RESULTS:** Overall, 35.7% of the surveyed children aged 6-35 months demonstrated
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40
41 **35** suspected developmental delay. The prevalence of suspected developmental delay was
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43
44 **36** inversely associated with age, with the prevalence among young children aged 6-11 months
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47 **37** nearly doubling that of children aged 30-35 months (48.0% and 22.8%, respectively). Using a
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50 **38** structural equation model, it was demonstrated that caregiver's care and stimulus factors and
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53 **39** child's hemoglobin level were directly correlated, while caregiver's socio-demographic
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56 **40** factors were indirectly associated with suspected developmental delay.

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4 41 CONCLUSIONS: The prevalence of suspected developmental delay is high in poor rural
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6 42 areas of China. Interventions to improve child development are needed in poor rural area of
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9 43 China.

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12 44 Key words: suspected Developmental Delay; Infants and young children; Structural equation
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15 45 model; Rural China
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21 47 **Strengths and limitations of this study**

- 22
23 48 • This cross-sectional study includes suspected developmental delay among children under
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26 49 3 years of age in poor rural areas of China.
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29 50 • A structural equation model is a good approach to examine the influencing factors on
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32 51 suspected developmental delay.
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35 52 • A few binary variables were not incorporated in the structural equation model because of
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38 53 methodological limitation.
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55 INTRODUCTION

56 Developmental delay encompasses a wide spectrum of impairments or lack of developmental
57 features that are appropriate to the child's age. It may manifest in various aspects, including
58 motor, mental, language, and social domains[1,2]. Worldwide, developmental delay accounts
59 for more morbidity across the lifespan than any other chronic conditions[3]. A conservative
60 estimate is that across the world more than 200 million children under 5 years old failed to
61 reach their potential in cognitive and social emotional development. As a number of social
62 factors such as poverty, malnutrition, lack of appropriate care, and child abuse and neglect,
63 have been identified as potential contributing factors to developmental delay [4],
64 developmental delay has been a major issue in low and middle-income countries. Moreover,
65 national statistics on young children's cognitive or social emotional development are not
66 available for most developing countries. This gap contributes to the invisibility of the issue of
67 development delay. With a total of 15 million disadvantaged children (defined as stunted,
68 living in poverty, or both), China has the third largest number of disadvantaged children
69 globally, following India (65 million) and Nigeria (16 million)[4]. It is clear that
70 interventions and policies designed to promote child development and prevent or ameliorate
71 developmental delay are urgently needed as China moves forward.
72 The pathway between poverty and poor development described by Walker et al is built on the
73 fact that poverty is associated with inadequate food, and poor access to water, sanitation and

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4 74 hygiene [5]. Poverty is also related to poor maternal education, increasing maternal stress,
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7 75 depression, and inadequate stimulation at home. All these factors detrimentally affect child
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10 76 development, and this deprived development may lead to poor school performance and
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12 77 achievement. In addition, poverty and socio-cultural contextual risk factors may increase
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15 78 young children's exposure to biological and psychosocial risks, and the accumulation in risks
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18 79 often significantly harm child development. Children in developing countries are frequently
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21 80 exposed to multiple and cumulative risks negatively affecting their development, especially
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24 81 through changes in their brain structure and function, and behavioral changes[6].
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27 82 Biological risk factors related to young children's developmental delay include infectious
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30 83 disease, chronic malnutrition, iodine deficiency, iron deficiency, anemia, malaria, low birth
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32 84 weight, preterm birth, and exposure to lead or arsenic, etc.[5,7-10].
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35 85 Psychological risk factors associated with developmental delay are mainly related to
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38 86 parenting, more specifically, cognitive stimulation, caregiver sensitivity and responsiveness
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41 87 to the child, and caregiver affect in terms of emotional warmth or rejection of the child[5].
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44 88 Parents and caregivers can play an important role in providing the child with a healthy, safe
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47 89 and caring environment[11].
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50 90 The effects of these biological and psychological risk factors are sensitive to contextual
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53 91 factors such as poverty and maternal depression[5]. Common mental disorders, including
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56 92 depression and anxiety among women during pregnancy, or in the first post-partum year, are

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4 93 recognized as a public health issue globally. There are emerging evidence showing that
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6 94 maternal mental disorders have adverse impacts on physical and psychological development
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9 95 of fetuses and infants[12-18].
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12 96 To sum up, various social, biological and psychological factors may contribute to child
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15 97 developmental delay. The existing evidence indicated that four major risk factors affect at
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18 98 least 20–25% of children in developing countries[5]: inadequate cognitive stimulation,
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21 99 stunting, iron deficiency, and iodine deficiency. There is a paucity of data on the prevalence
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24 100 and risk factors for developmental delay in China, especially in poor rural areas where
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27 101 children are at high risk for developmental delay due to the economic and social restraints. In
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30 102 addition, although the influencing factors on child developmental delay have been widely
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33 103 studied, the relationships among these factors and their direct and indirect associations with
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36 104 the development outcome were seldom examined in the existing literature. Comparing to
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39 105 mostly commonly used methods, a structural equation model could effectively control
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42 106 measurement error [19]. More importantly, structural equation model could tackle multiple
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45 107 dependent variables simultaneously and examine the relationships between dependent
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48 108 variables and independent variables at the same time without adjusting confounders.
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51 109 Especially, the structural equation model can provide a latent variable approach by using the
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54 110 idea that theoretical concepts such as intelligence or desirability cannot be measured directly
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57 111 but instead observable indicators are given. The goals of this study were to determine the

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4 112 prevalence of developmental delay in young children in rural China and to explore factors
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7 113 contributing to child developmental delay.

8
9 114 **METHOD**

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12 115 **Participants and Design**

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15 116 A community-based cross-sectional survey on child health, nutrition and development was
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18 117 conducted between July and September 2013 in remote mountainous areas of Shanxi and
19
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21 118 Guizhou provinces, located in the central and south-west regions of China respectively. The
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24 119 survey sites were the project sites of the Integrated Early Childhood Development (IECD)
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27 120 Project funded by UNICEF. A total of 83 villages were selected from six counties of the two
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30 121 provinces based on the following criteria: 1) having at least 50 children under 3 years old; 2)
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32 122 having a township health center staffed with maternal and child health professionals; 3)
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35 123 reachable by vehicles. All the children under 3 years and their primary caregivers (defined as
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38 124 person(s) who take primary responsibility for taking care of child in the family) in the chosen
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41 125 villages were eligible for the study. Altogether, 2,953 children out of the 4,288 children in the
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44 126 83 villages participated in the study and their primary caregivers completed the survey. The
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47 127 response rate was 68.9%. All caretakers provided their written informed consent to
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50 128 participate in this study. The study was reviewed and approved by Peking University
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52
53 129 Biomedical Ethics Committee.

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55 130 For this analysis, apparently normal children were included in the analysis, children with

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4 131 hearing disabilities (e.g., deaf children) (n=16) were excluded because the disabilities may
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6 132 directly affect their performance. In addition, we excluded children aged 1-5 months (n=326)
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9 133 because their hemoglobin values were not tested; children with implausible hemoglobin
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12 134 values (n =1, Hb =225 g/L); and respondents who were not primary caregivers (n =96).
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15 135 Therefore, the final sample size for this analysis was 2,514 children.
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18 136 **Patient and Public Involvement**

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20 137 At survey day, children under 3 years old and their caregivers in the village were recruited
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23 138 and evaluated. The research questions were conducted face-to-face and children growth,
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26 139 Haemoglobin value and development were measured after interview. The status of growth,
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29 140 anemia and development were disseminated to the caregivers immediately.
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32 141 **Study Instruments**

33 34 35 142 *Outcome measure : Child developmental delay measurement*

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37 143 The Ages & Stages Questionnaires -Chinese version (ASQ-C), which was validated recently
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40 144 in Chinese, was used to assess children's development status [20].ASQ-C includes various
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43 145 dimensions, including communication, gross motor, fine motor , problem solving and
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46 146 personal-social [21]. Each of the domains contains six sub-items. The responses of 'yes',
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49 147 'sometimes', or 'not yet' were given scores of 10, 5, and 0 points, respectively. Development
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52 148 delay in a certain domain was defined as if domain score was lower than 2SD (Standard
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55 149 Deviation) of the cutoff point in the normative norm in that domain. Overall suspected
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4 150 development delay was defined as if there was delay in any one of five domains of ASQ,
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7 151 including communication, gross motor, fine motor, problem solving, and personal-social
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10 152 domain. The latent variable of children's developmental status was measured by five
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12 153 dimensions of ASQ-C in this study.

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15 154 *Social, biological and psychological factors*

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18 155 Household survey questionnaire

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20 156 A face-to-face interview was conducted with the child caregivers using a structured
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23 157 questionnaire developed based on UNICEF's 5th Multiple Indicator Cluster Survey (MICS5).

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26 158 The questionnaire contained questions on the household socioeconomic status, family
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29 159 structure, health and development of children under three years old and their mother in the
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32 160 household. Wealth index was developed based on the number of household appliances
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35 161 (telephone, TV, washing machine, refrigerator, and internet connection).

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38 162 Zung self-rating depression scale (ZSDS)

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40 163 The Zung Self-rating Depression Scale (ZSDS), validated and widely utilized in China[22-
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43 164 24], was used to assess caregivers' mental health status in the same research[25,26]. The
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46 165 scale comprises 20 items and each question is scored on a scale of 1-4 based on the following
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49 166 responses: never or rarely, sometimes, most of the time, or always. A score between 50 and
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52 167 69 indicates depression, and a score of 70 or above indicates severe depression. In this study,
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55 168 caregivers with a score of 50 or more were identified as positive for depression [27].
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4 169 A modified infants and child feeding index (ICFI)
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7 170 A modified infant and child feeding index (ICFI) was constructed on the basis of current
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10 171 feeding practices for infants and young children recommended by WHO[28] and proposed by
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12 172 Ruel and Menon[29] and was used to gather information on current feeding practices of
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15 173 surveyed children. This modified ICFI was based on a dietary recall of the past 24 hours from
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18 174 a questionnaire and it includes practices related to breastfeeding, bottle feeding, feeding
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21 175 frequency and food diversity given to the children prior to the survey being conducted. To
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24 176 take into account the age specific feeding recommendations, the modified ICFI was compiled
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27 177 separately for three age groups: 6-8 months, 9-11 months and 12-35 months. A score of 2
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29 178 was added if the child was breastfed; 1 point added if the child had never been bottle-fed; 2
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31
32 179 points added if the child's feeding frequency met the recommendation; and 1 point if the
33
34
35 180 feeding frequency was below the recommendation but above zero. Dietary diversity of food
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38 181 groups refers to the number of different food groups provided to the child. Altogether 7 food
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41 182 groups were counted, and a score of +2 was added if 4 or more food groups were consumed,
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44 183 and a score of +1 was added if 1 to 3 food groups were consumed.

45 184 Parent-child interaction

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49 185 The level of parent-child interaction was assessed based on the following six activities that
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52 186 caregivers did with their child: 1) reading books to the child, 2) telling stories to the child, 3)
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55 187 singing songs to or with the child, 4) taking the child outdoor, 5) playing toys with the child,

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4 188 and 6) naming, counting or drawing things to promote learning with the child. If one of the
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6 189 above mentioned behaviors were reported by the caregivers, +1 score was given, with the
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9 190 highest possible score of +6.

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12 191 Haemoglobin value

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15 192 Trained staff collected capillary blood sample from the child and measured their hemoglobin
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18 193 (Hb) concentration using a calibrated, automated analyzer (HemoCue 201 [HemoCue,
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20 194 Angelholm, Sweden]). Anemia is defined as a hemoglobin concentration <110 g/L, based on
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23 195 the global definition for preschool children and adjusted for altitude[30]. Children with
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26 196 anemia were referred to an appropriate health facility for treatment.

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29 197 Anthropometric measurements

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32 198 Birth weight was obtained from medical record.

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35 199 In this part, the latent variable, caregiver factor, was measured by caregivers' education,
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38 200 caregivers' age and wealth index. Care and stimulus was measured by parent-child
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41 201 interaction, number of books and score of ZSDS.

42 43 202 **Data Analysis**

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46 203 Data analysis was performed using SPSS for Windows (version 16.0, SPSS Inc., Chicago, IL,
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49 204 USA). Descriptive statistics were provided as median, range and interquartile range for
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52 205 continuous variables and count and percentage for categorical variables. A structural
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55 206 equation model (Amos 20 for Windows, IBM, Armonk, NY, USA) was used to test if the

207 hypothetical explanatory model fits the observed data and to apply the asymptotically
 208 distribution-free estimate. The hypothetical explanatory model was derived from literature
 209 [4,5]and the univariate regression result. The assignment rules and explanation of variables in
 210 the structural equation model are described in Table 1. The model was modified according to
 211 statistics suggested by the modification index in Amos. An absolute value of ≥ 1.96 ($p \leq 0.05$)
 212 for the standardized β -coefficient T was considered significant. Goodness of fit index (GFI),
 213 normal fit index (NFI), comparative fit index (CFI) and root mean squared error of
 214 approximation (RMSEA) were used to test model fit. For GFI, CFI and NFI, 1 means a
 215 perfect fit while >0.9 indicates an adequate fit. For RMSEA, <0.05 indicates a good model.
 216 Chi-square statistic to test the null hypothesis was not required as the sample size was >1000 .
 217 A latent variable approach assumes that all dimensions of ASQ share the same percentage
 218 and variance, and there is no measurement error. Thus a latent variable of children's
 219 development status will be generated[31].

220 Table 1. Assignment rules and explanation of variables in structural equation model

Variables	assignment rules or explanation
caregiver's education	illiteracy,+1 primary school,+2 junior high school,+3 senior high school and above,+4
caregiver's age	caregiver's integer age

wealth index	numbers of accessories including phone (telephone or mobile), washing machine, refrigerator, TV set, access to Internet
parent-child interaction	6 behaviors including read books to child, told stories, sang songs, took child outside the home, played with child, and named, counted or drew things to promote learning would form stimulus signals
numbers of books	numbers of books children owned presently
score of ZSDS	reversed score of caregiver's depression assessed by the Zung Self-rating Depression Scale
modified ICFI	Breastfeeding:
	6-9 mo: No=0; Yes= +2;
	9-11 mo: No=0; Yes=+2;
	12-35 mo: No=0; Yes=+1.
	Bottle feeding: Yes=0; No=+1;
	Feeding frequency:
	6-9 mo: 0 meal = 0; 1 meal = +1; 2 meals or more = +2;
9-11 mo: 0 meal = 0; 1-2 meals = +1; 3 meals or more = +2;	
12-35 mo: 0-1 meals = 0; 2-3 meals = +1; 4 meals or more = +2;	
	Dietary diversity: 0 group = 0; 1-3 groups = +1; 4 or more groups = +2
birth weight	birth weight of child (medical records or parental report)
haemoglobin value for children	haemoglobin value we tested
Communication	score of communication assessed by ASQ
gross motor	score of gross motor assessed by ASQ
fine motor	score of fine motor assessed by ASQ
problem solving	score of problem solving assessed by ASQ

Personal-social score of personal-social assessed by ASQ

221 Note: ZSDS: Zung Self-rating Depression Scale; ICFI: infant and young child feeding index

222

223 RESULTS

224 Demographic, Socio-economic Characteristics of Participants

225 About 21.0% of children surveyed were 6-11 months, while 41.1% were 12-23 months, and
 226 37.9% were 24-35 months. Slightly more boys were included in the survey than girls (56.8%
 227 versus 43.2%, respectively) (Table 2). About half (47.9%) were the firstborn children and
 228 11.4% were left-behind children (i.e. their parents are migrant workers who leave rural areas
 229 for the cities while leaving children behind in their hometowns). More than one-third (35.5%)
 230 were ethnic minority children. Most of the caregivers interviewed (79.6%) were mothers. The
 231 average age of caregivers was 30.19 years with a standard deviation (SD) of 9.71 years; a
 232 majority (62.1%) of caregivers interviewed aged 20-29 years. Most (63.5%) had completed
 233 at least 9 years of education (i.e. secondary education). Among the surveyed households,
 234 51% lived under the national poverty line of US\$1 per day and 45% lived more than 5
 235 kilometers to the nearest health facilities.

236 Table 2. Sociodemographic and clinical characteristics of sampled child-caregiver pairs (N=2514)

	N	%	N	%
Child age			Caregivers interviewed	

6-11	528	21.0	Mother	2002	79.6
12-23	1034	41.1	Father	189	7.5
24-35	952	37.9	Grandparents	320	12.7
Child gender			Others	3	0.1
Male	1427	56.8	Caregivers' age		
Female	1087	43.2	<20	42	1.7
Having elder sibling			20-	1561	62.1
Yes	1277	50.8	30-	539	21.4
No	1203	47.9	40-	349	13.9
Unknown	34	1.4	Unknown	23	0.9
Left-behind children			Caregivers' education		
Yes	286	11.4	Illiteracy	256	10.2
No	2228	88.6	Primary education	661	26.3
Ethnicity			Secondary	1277	50.8
Han	1621	64.5	Above secondary	320	12.7
Minority	893	35.5	Distance to health facility		
			<5km	1345	53.5
			≥5km	1131	45.0

	Unknown	38	1.5
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238 **Suspected Developmental Delay among Children under 3 Years Old**

239 Overall, 35.7% of the surveyed children under 3 years of age had suspected developmental

240 delay (Table 3). Across all age groups, prevalence of suspected developmental delay was

241 inversely associated to the child's age, with the highest rate (48.0%) among children aged 6-

242 11 months and lowest (22.8%) among children aged 30-35 months. Across all domains, delay

243 in communication was the lowest (8.9%) and delay in fine motor was the highest (20.6%),

244 while other domains ranged from 15.1% to 16.7%.

245 Table 3. Prevalence of child suspected development delay

	6-months	12-months	18-months	24-months	30-months	Total
	n(%)	n(%)	n(%)	n(%)	n(%)	n(%)
	N=538	N=473	N=561	N=517	N=435	N=2514
suspected Developmental delay	258(48.0)	210(44.4)	207(36.9)	123(23.8)	99(22.8)	897(35.7)
Delay in subscales:						
Communication	92(17.4)	46(9.7)	46(8.2)	22(4.3)	18(4.1)	224(8.9)
Gross motor	107(20.3)	85(18.0)	83(14.8)	61(11.8)	44(10.1)	380(15.1)
Fine motor	157(29.7)	145(30.7)	144(25.7)	50(9.7)	23(5.3)	519(20.6)
Problem solving	98(18.6)	131(27.7)	84(15.0)	50(9.7)	56(12.9)	419(16.7)

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3 Personal-Social 102(19.3) 92(19.5) 96(17.1) 63(12.2) 52(12.0) 405(16.1)
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7 247 **Social, biological and psychological factors**
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10 248 The wealth index in the surveyed families ranged from 0 to 5, with a median of 4, indicating
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12 249 that most of the families owned major appliances. The parent-child interaction scores ranged
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14 250 from 0 to 6, with a median score of 6. On average, the surveyed children owned only 1 book
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16 251 (median=1, IQR=3). Caregivers' ZSDS in this sample ranged from 38 to 80, with a median
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18 252 score of 63.76. Nearly two-fifths of caregivers (38.5%) had symptoms of depression. The
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20 253 ICFI ranged from 0 to 7, with a median score of 2. The hemoglobin values for the surveyed
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22 254 children were 51 to 178 g/L, with a median of 110 g/L. Anemia prevalence was high at
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24 255 43.8%. Birth weight of the surveyed children ranged from 1.40 to 6.00 kilograms, with a
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26 256 median of 3.30 kilograms; 2.9% had low birth weight (i.e. birth weight less than 2.5 kg) .
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31 258 **Structural Equation Model for Children's Developmental Delay**
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35 259 About half of the squared multiple correlation of variables were more than 0.50 (Table S1),
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37 260 which indicated that the variables had a good reliability. In the final structural equation
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39 261 model (shown in Table 4), modified ICFI and birth weight were excluded from the model,
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41 262 because of lack of statistically significant relationships with other variables. Figure 1 shows
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43 263 the estimated covariance and paths for this model. Three factors influencing children's
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45 264 developmental status were identified: 1) caregiver socio-demographic factors such as
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4 265 caregiver's education, age, and wealth index (total effect =0.23 on child developmental
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6 266 status); 2) care and stimulus factors measured by parent-child interaction, number of books
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9 267 and ZSDS score (direct effect= 0.57); and 3) child's hemoglobin level (direct effect= 0.07).
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12 268 Younger caregivers were more likely to interact with children than older caregivers
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15 269 (covariance of residuals =-0.18) and the latent variable- caregiver factors-had a direct positive
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18 270 effect on 'care and stimulus factors' (path coefficient=0.40) and an indirect positive effect on
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21 271 children's developmental status. The overall model fit was good as reflected by the goodness
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24 272 of fit index of 0.977 and the comparative fit index of 0.884.
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273 Table 4. Regression weights of structural equation model

Equation	Estimates (unstandardized)	Estimates (Standardized)	Standard Error	Critical ratio	P value
Regression weights					
Care and stimulus ← caregiver factor	0.402	0.401	0.047	8.497	<0.001
Children's developmental status ← care and stimulus	9.608	0.573	0.913	10.525	<0.001
Children's developmental status ← haemoglobin value for children	0.593	0.071	0.178	3.331	0.001
Caregivers' education ← caregiver factor	1.000	0.794			
Caregivers' age ← caregiver factor	-8.358	-0.576	0.543	-15.380	<0.001
Wealth index ← caregiver factor	0.775	0.461	0.055	14.163	<0.001
parent-child interaction ← care and stimulus	1.000	0.456			
Numbers of books ← care and stimulus	1.687	0.303	0.220	7.678	<0.001
Score of ZSDS ← care and stimulus	4.856	0.415	0.488	9.944	<0.001
Communication ← Children's developmental status	0.863	0.622	0.029	30.054	<0.001
Gross motor ← Children's developmental status	0.970	0.726	0.030	32.608	<0.001
Fine motor ← Children's developmental status	1.132	0.778	0.028	40.216	<0.001

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5	Problem solving ← Children’s developmental status	1.188	0.848	0.030	40.212	<0.001
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7	Personal-social ← Children’s developmental status	1.000	0.752			
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9	Covariance					
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11	e8 ↔ e10	-19.912	-0.248	2.961	-6.725	<0.001
12						
13	e3 ↔ e5	0.620	0.188	0.064	9.708	<0.001
14						
15	e2 ↔ e4	-1.695	-0.175	0.270	-6.290	<0.001
16						
17	e1 ↔ e5	0.364	0.215	0.051	7.136	<0.001
18						
19	e5 ↔ e7	3.079	0.076	0.680	4.527	<0.001
20						
21	e5 ↔ e6	-2.709	-0.115	0.575	-4.712	<0.001
22						
23	e2 ↔ e6	-5.270	-0.100	1.247	-4.228	<0.001
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Note: ZSDS: Zung Self-rating Depression Scale

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4 275 **DISCUSSION**

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6 276 Our results showed that the prevalence of suspected developmental delay among children
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9 277 aged 6-35 months was high and inversely associated with children's age in poor rural China.
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12 278 Furthermore, by using the structural equation model, some risk factors for children's
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15 279 suspected development delay and their relationship were identified. So far only one study
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18 280 examined developmental delay in rural China and reported a prevalence of 20.0% in
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21 281 cognitive development and 32.3% in psychomotor development among children aged 6-12
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24 282 months[32]. Our study revealed that 35.7% of rural children under 3 years of age had
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27 283 suspected developmental delay and that among children aged 6-12 months, 17-20% of them
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30 284 had delay in communication, problem solving, personal-social and gross motor, and nearly
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33 285 30% had delay in fine motor development. Overall the prevalence observed in our study was
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36 286 comparable to the results from the previous study. According to the very limited data from
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39 287 the WHO report[33], the reported prevalence of developmental delay in young children was
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42 288 17% in Senegal, 15% in Nigeria, 13% in India, and 24% in Brazil. The lower prevalence
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45 289 reported by other developing countries may reflect the underestimated rates and inaccurate
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48 290 measurement of developmental delay. Promoting early childhood development (ECD) is a
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51 291 critical issue. It is recommended that government and healthcare providers should pay more
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54 292 attention to early diagnosis and intervention of developmental delay. Among the five
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4 293 domains of ASQ, suspected developmental delay of fine motor had the highest prevalence.
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7 294 This is a key finding that requires further intervention in poor rural areas of China.
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10 295 It was found in the structural equation model that caregiver factor, care and stimulus factor

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12 296 and hemoglobin values of children were directly or indirectly associated with suspected

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15 297 developmental delay. These findings indicate potential areas that future intervention

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18 298 programs should focus on, including improving child's feeding and nutrition, raising public

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21 299 awareness of the issue of developmental delay, and improving parenting skills to increase

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24 300 interaction with children.
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28 302 **Relations between caregiver factors and child development**

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31 303 Our results showed that younger caregivers with higher education level and wealth index had

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34 304 an indirect, positive effect on their child's development. Previous studies have investigated

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37 305 the relations between caregivers' socio-demographic factors and child development. In a

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40 306 population-based study in Argentina and a cohort study in Brazil, it was found that poverty

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43 307 and maternal education were positively associated with early attainment of selected

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46 308 developmental milestones or cognitive and motor development [34,35]. Another report also

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49 309 indicated that parenting cognitive stimulation, caregiver's responsiveness, and caregiver's

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52 310 affect are sensitive to contextual factors such as poverty, cultural values and practices[5]. The

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55 311 findings from our study are consistent with these previous results. In addition, our study

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58 312 revealed that caregiver factor were indirect predictors of their child's development delay.
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4 313 Although caregiver factor had no direct effect on their child's developmental status, these
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6 314 factors such as caregivers' education, age and poverty level may impact other factors
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9 315 therefore indirectly affecting developmental delay. More attention should be paid to change
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12 316 these contextual factors when designing future interventions to improve children's
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19 319 **Relations between care and stimulus factors and child development**

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22 320 The current study revealed that the most important predictor on child's suspected
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25 321 developmental delay was care and stimulus factors (path coefficient=0.57). Better parent-
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28 322 child interaction, more books and less maternal depression had positive effect on child
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31 323 development. Children who had one score point increase on care and stimulus factors had
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34 324 0.57 score increase on child development. The findings of the current study were consistent
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37 325 with previous studies showing the protective effect of parent-child interaction, children's
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40 326 books and optimistic caregivers on child development[36]. Thus, it is necessary to promote
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43 327 parent-child interactions, through encouraging activities such as reading books to their child,
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46 328 telling stories to their child, singing songs to and with their child, bringing their child to play
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49 329 outdoors, playing toys with their child, and naming, counting or drawing things to promote
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52 330 learning that would form stimulus signals[5,37,38]. Depression among caregivers was also
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55 331 alarmingly high in our study sample, confirming findings from previously published studies
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58 332 [39,40]. Our results also found caregivers with depression had increased risk on adverse

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4 333 effects on child development[17, 41]. The previously published studies have shown
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6 334 depression among caregivers not only impact children's physical health, but also place
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9 335 children at a higher risk of developmental delay[42,43]. It is well-established that maternal
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12 336 depression during the period that the mother–infant interaction was observed (concurrent or
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15 337 recent maternal depression) was associated with reduced maternal responsiveness, which was
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18 338 positively associated with later emotional, cognitive and physical development of the
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21 339 infant[44,45]. Our study revealed a latent variable, care and stimulus factors that include
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24 340 caregiver depression scores and parent-child interaction scores, had a comprehensive impact
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27 341 on child development. Accordingly, these findings suggest an urgent need for child
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29 342 development interventions on children's care and stimulus factors in poor rural China.
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32 33 344 **Relations between Hb values and child development**

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36 345 Our study found hemoglobin values of children had a positive effect on child development.
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39 346 Other biological factors, such as birth weight of children and modified ICFI did not predict
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42 347 child development, which was not consistent with previous research[5]. A possible
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45 348 explanation might be that in our structural equation model, only continuous variables were
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48 349 involved and three variables in our study could not be converged as one latent variable, and
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51 350 each variable had poor correlations with the other two variables. Anemia among children was
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54 351 alarmingly high in our sample, confirming findings from a previous published study[46].
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56 352 These findings point to a severe public health problem[47], and provide further evidence on
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4 353 anemia's negative impact on child growth and development[4,5,48]. Our survey found that
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7 354 the hemoglobin value of children had a positive effect on child development. On the positive
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10 355 side, the Chinese government has realized this public health issue and has started providing
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12 356 micronutrient supplements named "Ying Yang Bao (YYB)" to 6-35 month old children living
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15 357 in poor rural areas free of charge. It is expected that this nutrition intervention program will
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18 358 decrease child anemia effectively. Although the current study did not find that birth weight
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21 359 and modified ICFI are associated with child development, it is known that poor maternal
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24 360 nutrition, infections and child feeding practices can impact child nutrition and
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27 361 development[5]. Therefore, these areas still need to be monitored and improved through
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30 362 government interventions in poor rural China.

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364 **Limitations**

365 Our study had several limitations that should be discussed and considered. First, as a cross-
366 sectional study, the associations identified in our study do not suggest a causal relationship
367 between these factors and child's suspected developmental delay. Although the structured
368 equation model is a powerful statistical technique for simultaneous consideration of the
369 multiple variables measured, further evidence from cohort studies and interventional studies
370 is needed for infer causal relationship. Second, because of the restrictions and limitations on
371 structural equation model methodology and the software, many binary variables were not
372 incorporated in the structural equation model, especially the variables measuring infant and

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4 373 young child infections such as diarrhea and pneumonia. Third, this study was conducted in
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6 374 two provinces located in central and south-west regions of China. These study sites cannot
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9 375 represent all poor rural areas of China. Caution is warranted when generalizing findings from
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12 376 our studies to rural areas in China.

13 14 15 377 **Conclusions**

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18 378 These preliminary findings indicated that the prevalence of suspected developmental delay is
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20 379 high in poor rural areas of China. More attention needs to be paid to early childhood
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23 380 development (ECD). Interventions should specifically target and support families in poverty
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26 381 and with low education levels, as well as prioritize maternal and children nutrition and mental
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29 382 health, so as to improve fetal and early child development.

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43
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45 46 47 388 **Competing interests**

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49
50 389 The authors declare that they have no competing interests.

51 52 53 390 **Author's contributions**

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4 391 Ying Li did the data analysis. Jingxu Zhang drafted the article. Sufang Guo, Xiaoli Wang and
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7 392 Robert W. Scherpier designed the study. Jingxu Zhang, Qianwei Wei, Cuihong Zhang and
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10 393 Shusheng Luo collected the data. Xiaoli Wang and Chunxia Zhao critically revised the
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12 394 manuscript. All authors read and approved the final manuscript.
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15 395 **Data sharing statement**
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18 396 The datasets analyzed during the current study are not publicly available, but are available
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21 397 from the corresponding author on reasonable request.
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24 398 **Consent for publication**
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28 399 Not applicable.
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31 400 **Ethics approval and consent to participate**
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34 401 This study was approved by Peking University's Biomedical Ethics Committee. Consent was
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37 402 obtained from the participants/guardians/parents.
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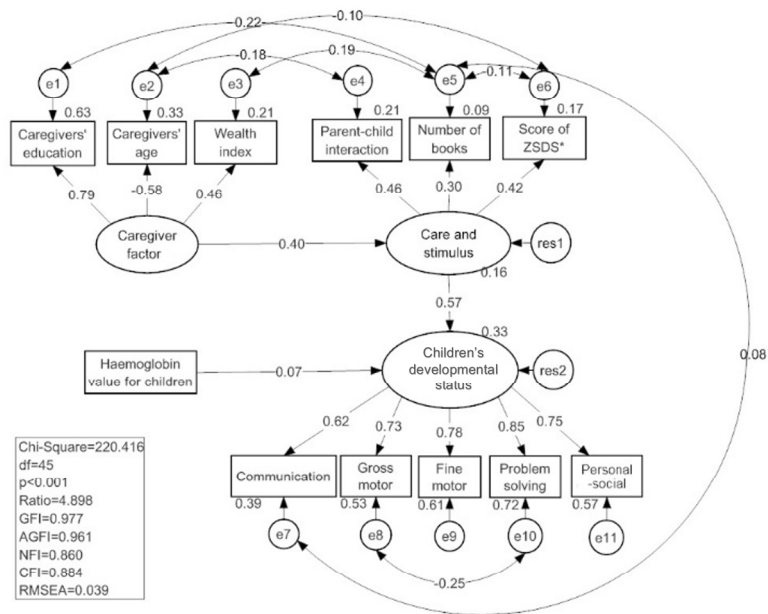
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Figure 1 Structural equation model and standardized coefficient for relationships between factors that theoretically influence children’s suspected developmental delay

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Structural equation model and standardized coefficient for relationships between factors that theoretically influence children's suspected developmental delay

Supplementary 1

Table S1. The squared multiple correlations of variables

Variables	Squared multiple correlations
Caregivers' education	0.631
Caregivers' age	0.331
Wealth index	0.213
Parent-child interaction	0.208
Number of books	0.092
Score of ZSDS	0.172
Communication	0.387
Gross motor	0.527
Fine motor	0.605
Problem solving	0.719
Social emotional	0.566

Note: ZSDS: Zung Self-rating Depression Scale

STROBE 2007 (v4) Statement—Checklist of items that should be included in reports of *cross-sectional studies*

Section/Topic	Item #	Recommendation	Reported on page #
Title and abstract	1	(a) Indicate the study's design with a commonly used term in the title or the abstract	3
		(b) Provide in the abstract an informative and balanced summary of what was done and what was found	3
Introduction			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	5-7
Objectives	3	State specific objectives, including any prespecified hypotheses	7
Methods			
Study design	4	Present key elements of study design early in the paper	7-8
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	
Participants	6	(a) Give the eligibility criteria, and the sources and methods of selection of participants	7-8
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	9-11
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	
Bias	9	Describe any efforts to address potential sources of bias	
Study size	10	Explain how the study size was arrived at	
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	
Statistical methods	12	(a) Describe all statistical methods, including those used to control for confounding	12
		(b) Describe any methods used to examine subgroups and interactions	
		(c) Explain how missing data were addressed	
		(d) If applicable, describe analytical methods taking account of sampling strategy	
		(e) Describe any sensitivity analyses	
Results			

Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed (b) Give reasons for non-participation at each stage (c) Consider use of a flow diagram	
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders (b) Indicate number of participants with missing data for each variable of interest	14
Outcome data	15*	Report numbers of outcome events or summary measures	
Main results	16	(a) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included (b) Report category boundaries when continuous variables were categorized (c) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	
Discussion			
Key results	18	Summarise key results with reference to study objectives	21-22
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias	25-26
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	22-25
Generalisability	21	Discuss the generalisability (external validity) of the study results	26
Other information			
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	27

*Give information separately for cases and controls in case-control studies and, if applicable, for exposed and unexposed groups in cohort and cross-sectional studies.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at <http://www.plosmedicine.org/>, Annals of Internal Medicine at <http://www.annals.org/>, and Epidemiology at <http://www.epidem.com/>). Information on the STROBE Initiative is available at www.strobe-statement.org.

BMJ Open

Factors influencing developmental delay among young children in poor rural China: a latent variable approach

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Manuscripts

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4 **1 Title Page**
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8 **2 Title:** Factors influencing developmental delay among young
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11 **3 children in poor rural China: a latent variable approach**
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13

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For peer review only

1
2
3 **25 Abstract**
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6 **26 OBJECTIVES:** The aims of the study were to determine the prevalence of suspected
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9 **27** developmental delay in children living in poor areas of rural China and to investigate factors
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12 **28** influencing child developmental delay.
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14 **29 DESIGN:** A community-based, cross-sectional survey was conducted.
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17 **30 SETTING:** Eighty-three villages in Shangxi and Guizhou Provinces, China.
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20 **31 PARTICIPANTS:** A total of 2,514 children aged 6–35 months and their primary caregivers.
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23 **32 OUTCOME MEASURES:** Suspected child developmental delay was evaluated using the
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26 **33** Ages & Stages Questionnaires–Chinese version. Caregivers' education and age, wealth index,
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29 **34** child feeding index, parent-child interaction, number of books and Zung self-rating
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32 **35** depression scale were reported by the primary caregivers. Haemoglobin levels were measured
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35 **36** using a calibrated, automated analyser. Birth weight was obtained from medical records.
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37 **37 RESULTS:** Overall, 35.7% of the surveyed children aged 6–35 months demonstrated
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40 **38** suspected developmental delay. The prevalence of suspected developmental delay was
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43 **39** inversely associated with age, with the prevalence among young children aged 6–11 months
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46 **40** being almost double that of children aged 30–35 months (48.0% and 22.8%, respectively).
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49 **41** Using a structural equation model, it was demonstrated that caregiver's care and stimulus
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52 **42** factors and child's haemoglobin level were directly correlated, while caregiver's socio-
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55 **43** demographic factors were indirectly associated with suspected developmental delay.
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4 44 CONCLUSIONS: The prevalence of suspected developmental delay is high in poor rural
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6 45 areas of China, and appropriate interventions to improve child development are needed.
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12 47 **Strengths and limitations of this study**
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14
15 48 • This cross-sectional study evaluated suspected developmental delay among children
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17 49 under 3 years of age in poor rural areas of China.
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20 50 • A structural equation model is a good approach to examine the factors influencing
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22 51 suspected developmental delay.
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26 52 • A few binary variables were not incorporated in the structural equation model because of
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28 53 methodological limitations.
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55 INTRODUCTION

56 Developmental delay encompasses a wide spectrum of impairments or lack of developmental
57 features that are appropriate to a child's age. It may manifest in various ways, including the
58 motor, mental, language, and social domains[1,2]. Worldwide, developmental delay accounts
59 for more morbidity across the lifespan than any other chronic condition[3]. A conservative
60 estimate is that across the world more than 200 million children under 5 years old failed to
61 reach their potential in cognitive and social-emotional development. As a number of social
62 factors such as poverty, malnutrition, lack of appropriate care, and child abuse and neglect,
63 have been identified as contributing to developmental delay[4], developmental delay has
64 become a major issue in low- and middle-income countries. Moreover, national statistics on
65 young children's cognitive or social emotional development are not available for most
66 developing countries. This gap contributes to the invisibility of the issue of developmental
67 delay. With a total of 15 million disadvantaged children (defined as stunted, living in poverty,
68 or both), China has the third largest number of disadvantaged children globally, following
69 India (65 million) and Nigeria (16 million)[4]. It is clear that interventions and policies
70 designed to promote child development and prevent or ameliorate developmental delay are
71 urgently needed as China moves forward.

72 The pathway between poverty and poor development described by Walker *et al.* is built on
73 the fact that poverty is associated with inadequate food, and poor access to water, sanitation
74 and hygiene [5]. Poverty is also related to poor maternal education, increasing maternal stress,

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4 75 depression, and inadequate stimulation at home. All of these factors detrimentally affect child
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7 76 development, and may lead to poor school performance and achievement. In addition,
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10 77 poverty and socio-cultural contextual risk factors may increase young children's exposure to
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12 78 biological and psychosocial risks, and the accumulation of risks can significantly harm child
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15 79 development. Children in developing countries are frequently exposed to multiple and
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18 80 cumulative risks that negatively affect their development, especially by changing their brain
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21 81 structure and function, and behaviour[6].

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23 82 Biological risk factors related to young children's developmental delay include infectious
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26 83 disease, chronic malnutrition, iodine deficiency, iron deficiency, anaemia, malaria, low birth
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29 84 weight, preterm birth, and exposure to lead or arsenic[5,7-10].

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32 85 The psychological risk factors associated with developmental delay are mainly related to
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35 86 parenting, more specifically, cognitive stimulation, caregiver sensitivity and responsiveness
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38 87 to the child, and caregiver affect in terms of emotional warmth or rejection of the child[5].

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40 88 Parents and caregivers can play an important role in providing the child with a healthy, safe
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43 89 and caring environment[11].

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46 90 The effects of these biological and psychological risk factors are sensitive to contextual
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49 91 factors such as poverty and maternal depression[5]. Common mental disorders, including
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52 92 depression and anxiety, among women during pregnancy or in the first post-partum year are
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55 93 recognised as a public health issue globally. There is emerging evidence showing that

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4 94 maternal mental disorders have adverse impacts on the physical and psychological
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7 95 development of foetuses and infants[12-18].
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10 96 To sum up, various social, biological and psychological factors may contribute to child
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12 97 developmental delay. The existing evidence indicates that four major risk factors affect at
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15 98 least 20–25% of children in developing countries[5]: inadequate cognitive stimulation,
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18 99 stunting, iron deficiency, and iodine deficiency. There is a paucity of data on the prevalence
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21 100 and risk factors for developmental delay in China, especially in poor rural areas where
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24 101 children are at high risk for developmental delay due to economic and social restraints. In
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27 102 addition, although the factors influencing child developmental delay have been widely
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30 103 studied, as well as in our previous publish[19], the relationships among these factors and their
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33 104 direct and indirect associations with the development outcome have been seldom examined.
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36 105 Compared to the most commonly used methods, a structural equation model can effectively
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39 106 control measurement error [20]. More importantly, a structural equation model can tackle
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42 107 multiple dependent variables simultaneously and examine the relationships between
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45 108 dependent variables and independent variables at the same time without adjusting for
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48 109 confounders. In particular, the structural equation model enables a latent variable approach by
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51 110 using the idea that theoretical concepts such as intelligence cannot be measured directly but,
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54 111 instead, observable indicators are given. The goals of this study were to determine the
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57 112 prevalence of developmental delay in young children in rural China and to the explore factors

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4 113 contributing to child developmental delay.
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6 114 **METHOD**
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9 115 **Participants and Design**
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12 116 A community-based cross-sectional survey on child health, nutrition and development was
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15 117 conducted between July and September 2013 in remote mountainous areas of Shanxi and
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18 118 Guizhou Provinces, which are located in the central and south-west regions of China
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21 119 respectively. The study locations belong to the Integrated Early Childhood Development
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24 120 (IECD) Project funded by UNICEF, and 83 villages from six counties in the two provinces
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27 121 were selected based on the following criteria: 1) more than 50 children under 3 years old; 2)
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29 122 having a township health centre staffed with maternal and child health professionals; and 3)
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32 123 reachable by vehicles. All children in the chosen villages under 3 years old and their primary
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35 124 caregivers (defined as person(s) who took primary responsibility for taking care of the child
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38 125 in the family) comprised the study population. The survey included 2,953 of 4,288 eligible
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41 126 children and their primary caregivers. The response rate was 68.9%. All caretakers provided
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44 127 their written informed consent to participate in this study. The study was reviewed and
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47 128 approved by Peking University Biomedical Ethics Committee.
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49 129 Apparently normal children were included in the present study, while children with hearing
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52 130 disabilities (*e.g.* deaf children) ($n = 16$) were excluded because the disabilities may directly
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55 131 affect their performance. In addition, we excluded children aged 1–5 months ($n = 326$)
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4 132 because their haemoglobin values had not been tested; children with implausible
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6 133 haemoglobin values (n = 1, Hb = 225 g/L); and respondents who were not primary caregivers
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9 134 (n = 96). Therefore, the final sample size for this analysis was 2,514 children.

12 135 **Patient and Public Involvement**

136 No patients were involved in setting the research question or the outcome measures, nor were
137 they involved in developing plans for design or implementation of the study. The results of
138 growth and anaemia were disseminated to the caregivers immediately. There are no plans to
139 disseminate the results of the research to study participants or the relevant patient community.

140 140 **Study Instruments**

141 141 *Outcome measure: Child developmental delay measurement*

142 The Ages and Stages Questionnaires – Chinese version (ASQ-C), which was validated
143 recently, was used to assess the development status of children[21]. This questionnaire
144 addresses communication, gross motor, fine motor, problem solving, and personal-social
145 skills[22]. Each domain contains six sub-items and responses of ‘yes’, ‘sometimes’, and ‘not
146 yet’ were given scores of 10, 5, and 0 points, respectively. A score of 2 standard deviations
147 (SD) below the cut-off point in any domain based on the normative norm indicated
148 developmental delay. Overall suspected development delay was defined as delay in any one
149 of the five domains of the ASQ, *i.e.* the communication, gross motor, fine motor, problem

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4 150 solving, and personal-social domains. The latent variable of children's developmental status

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7 151 was measured using the five dimensions of the ASQ-C.

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9 152 *Social, biological, and psychological factors*

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12 153 Household survey questionnaire

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15 154 A face-to-face interview was conducted with the child caregivers using a structured

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18 155 questionnaire developed based on UNICEF's 5th Multiple Indicator Cluster Survey (MICS5).

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21 156 The questionnaire contained questions on the household socioeconomic status, family

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24 157 structure, health, and development of children under 3 years old and their caregivers. Wealth

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27 158 index was assessed according to the number of home appliances (*e.g.* telephone, television,

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29 159 washing machine, refrigerator, and Internet connection) in each household.

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32 160 Zung self-rating depression scale

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35 161 The Zung Self-rating Depression Scale (ZSDS), which has been validated and is widely used

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38 162 in China[23-25], was employed to assess caregivers' mental health status[26,27]. This scale

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41 163 consists of 20 items scored on a scale of 1–4 based on the following responses: never or

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44 164 rarely, sometimes, most of the time, or always. A score between 50 and 69 indicates

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47 165 depression, and a score of 70 or above indicates severe depression. In the present study,

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49 166 caregivers with scores of 50 or higher were identified as positive [28].

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52 167 A modified infants and child feeding index (ICFI)

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4 168 A modified infant and child feeding index (ICFI) was constructed based on the current
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7 169 feeding practices for infants and young children recommended by the WHO [29] and those
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10 170 proposed by Ruel and Menon [30], and was used to gather information on the current feeding
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12 171 practices of the surveyed children. This modified ICFI was based on a dietary recall of the
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15 172 past 24 hours from a questionnaire and it included practices related to breastfeeding, bottle
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18 173 feeding, feeding frequency, and food diversity of the children prior to the survey being
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21 174 conducted. To account for the age-specific feeding recommendations, the modified ICFI was
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24 175 independently performed for three different age groups: 6–8, 9–11, and 12–35 months using
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27 176 the following variables: breastfeeding (regardless of age, a score of +2 was given to a child
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30 177 who was breastfed; bottle feeding (regardless of age, a score of +1 was given to a child who
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32
33 178 was never bottle-fed; feeding frequency (a score of +2 was given if the recommended level
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35
36 179 was reached, and a score of +1 was given if the child received fewer than recommended
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39 180 number of meals but not zero meals); and dietary diversity of food groups (refers to the
40
41
42 181 number of different food groups). Altogether, seven food groups were considered, and a score
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45 182 of +2 was given if four or more food groups were consumed; a score of +1 was given if 1–3
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48 183 food groups were consumed. Taken together, these values provided a final score for the
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51 184 modified ICFI.

52 185 Parent-child interaction
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4 186 Parent-child interaction was assessed based on the following six activities that caregivers
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6 187 partook in with their child: 1) reading books to a child; 2) telling stories to a child; 3) singing
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9 188 songs to or with a child; 4) taking a child outside the home, yard, or enclosure; 5) playing
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12 189 with toys with a child; and 6) naming, counting or drawing things with a child to promote
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15 190 learning. If one of the above-mentioned behaviours were present a +1 score was given; a total
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18 191 score of +6 was possible.

192 Haemoglobin concentration

193 Trained staff members measured each child's haemoglobin concentration using a capillary
194 blood sample with a calibrated and automated analyser (HemoCue 201 [HemoCue,
195 Angelholm, Sweden]). Anaemia was defined as a haemoglobin concentration < 110 g/L for
196 preschool children, based on the global definition with adjustment for altitude [31]. Children
197 with anaemia were referred to an appropriate health facility for treatment.

198 Anthropometric measurements

199 Birth weight was obtained from the medical records. The latent variable, caregiver factor,
200 was measured by assessing caregivers' education, caregivers' age, and the wealth index. Care
201 and stimulus were measured by assessing the parent-child interaction, number of books, and
202 ZSDS score.

203 **Data Analysis**

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4 204 All data analyses were performed using SPSS for Windows (version 16.0, SPSS Inc.,
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6 205 Chicago, IL, USA). Descriptive statistics are shown as medians, ranges, and interquartile
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9 206 ranges for continuous variables and counts and percentages for categorical variables. A
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12 207 structural equation model (Amos 20 for Windows, IBM, Armonk, NY, USA) was used to test
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15 208 whether the hypothetical explanatory model fits the observed data, by applying the
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18 209 asymptotically distribution-free estimate. The hypothetical explanatory model was derived
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21 210 from the literature[4,5] and the result of a univariate regression. The assignment rules and
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24 211 explanation of the variables in the structural equation model are listed in Table 1. The model
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27 212 was modified according to statistics suggested by the modification index in Amos, and an
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29 213 absolute value ≥ 1.96 ($p \leq 0.05$) for the standardised β -coefficient T was considered to
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32 214 indicate statistical significance. The goodness-of-fit index (GFI), normal fit index (NFI),
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35 215 comparative fit index (CFI), and root mean square error of approximation (RMSEA) were
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38 216 used to test model fit. For the GFI, CFI and NFI, a value of 1 refers to a perfect fit, whereas a
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41 217 value >0.9 indicates an adequate fit. For the RMSEA, a value < 0.05 indicates a good model.
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44 218 A chi-square statistic for the testing of the null hypothesis was not required, because the
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47 219 sample size was larger than 1000. A latent variable approach assumes that all dimensions of
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50 220 the ASQ have the same percentage and variance, and that there is no measurement error. This
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52 221 generates a latent variable of children's development status [32].
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54 222 Table 1. Assignment rules and explanations of variables in the structural equation model
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Variable	assignment rules or explanation
Caregiver's education	illiteracy,+1 primary school,+2 junior high school,+3 senior high school and above,+4
Caregiver's age	caregiver's integer age
Wealth index	numbers of accessories including phone(telephone or mobile),washing machine, refrigerator, TV set, access to Internet
Parent-child interaction	6 behaviors including read books to child, told stories, sang songs, took child outside the home, played with child, and named, counted or drew things to promote learning would form stimulus signals
Numbers of books	numbers of books children owned presently
Score of ZSDS	reversed score of caregiver's depression assessed by the Zung Self-rating Depression Scale
Modified ICFI	Breastfeeding:
	6-9 mo: No=0; Yes= +2;
	9-11 mo: No=0; Yes=+2;
	12-35 mo: No=0; Yes=+1.
Modified ICFI	Bottle feeding: Yes=0; No=+1;
	Feeding frequency:
	6-9 mo: 0 meal = 0; 1 meal = +1; 2 meals or more = +2; 9-11 mo: 0 meal = 0; 1-2 meals = +1; 3 meals or more = +2; 12-35 mo: 0-1 meals = 0; 2-3 meals = +1; 4 meals or more = +2;
Birth weight	Dietary diversity: 0 group = 0; 1-3 groups = +1; 4 or more groups = +2 birth weight of child (medical records or parental report)
Haemoglobin value for children	haemoglobin value we tested
Communication	score of communication assessed by ASQ
Gross motor	score of gross motor assessed by ASQ
Fine motor	score of fine motor assessed by ASQ
Problem solving	score of problem solving assessed by ASQ
Personal-social	score of personal-social assessed by ASQ

223 Note: ZSDS, Zung self-rating depression scale; ICFI, infant and young child feeding index

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225 RESULTS

226 Demographic and Socioeconomic Characteristics of Participants

227 Children aged 6–11 months (21.0%) accounted for the fewest subjects, and there were more

228 boys (56.8%) than girls in the study population (Table 2). Approximately half the subjects

229 (47.9%) were first-born children, 11.4% were left-behind children (*i.e.* their parents are

230 migrant workers who leave rural areas for the cities while leaving children behind in their

231 hometowns). More than one-third of the subjects (35.5%) were ethnic minorities. The
 232 majority of the caregivers interviewed (79.6%) were mothers of the children; the mean (\pm
 233 standard deviation) age of the caregivers was 30.19 \pm 9.71 years, and most of this group
 234 (63.5%) had completed 9 years of education (secondary) or more. Of the surveyed
 235 households, 51% lived under the national poverty line of \$1 per day (not shown in Table 2)
 236 and 45% lived more than 5 km from the nearest health facilities.

237 Table 2. Sociodemographic and clinical characteristics of sampled child-caregiver pairs (n = 2514)

	N	%		N	%
Child age			Caregivers interviewed		
6-11	528	21.0	Mother	2002	79.6
12-23	1034	41.1	Father	189	7.5
24-35	952	37.9	Grandparents	320	12.7
Child gender			Others	3	0.1
Male	1427	56.8	Caregivers' age		
Female	1087	43.2	<20	42	1.7
Having elder sibling			20-	1561	62.1
Yes	1277	50.8	30-	539	21.4
No	1203	47.9	40-	349	13.9
Unknown	34	1.4	Unknown	23	0.9
Left-behind children			Caregivers' education		
Yes	286	11.4	Illiteracy	256	10.2
No	2228	88.6	Primary education	661	26.3
Ethnicity			Secondary	1277	50.8
Han	1621	64.5	Above secondary	320	12.7
Minority	893	35.5	Distance to health facility		

<5km	1345	53.5
≥5km	1131	45.0
Unknown	38	1.5

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239 Suspected Developmental Delay among Children under 3 Years of Age

240 Overall, 35.7% of the surveyed children under 3 years of age had suspected developmental
 241 delay (Table 3). Across all age groups, the prevalence of suspected developmental delay was
 242 inversely associated with the child's age, with the highest rate (48.0%) among children aged
 243 6–11 months and the lowest (22.8%) among children aged 30–35 months. Across all domains,
 244 the prevalence of delay in communication was the lowest (8.9%) and that of delay in fine
 245 motor was the highest (20.6%); the prevalence of the other domains ranged from 15.1% to
 246 16.7%.

247 Table 3. Prevalence of suspected developmental delay

	6-months	12-months	18-months	24-months	30-months	Total
	n(%)	n(%)	n(%)	n(%)	n(%)	n(%)
	N=538	N=473	N=561	N=517	N=435	N=2514
suspected Developmental delay	258(48.0)	210(44.4)	207(36.9)	123(23.8)	99(22.8)	897(35.7)
Delay in subscales:						
Communication	92(17.4)	46(9.7)	46(8.2)	22(4.3)	18(4.1)	224(8.9)
Gross motor	107(20.3)	85(18.0)	83(14.8)	61(11.8)	44(10.1)	380(15.1)
Fine motor	157(29.7)	145(30.7)	144(25.7)	50(9.7)	23(5.3)	519(20.6)
Problem solving	98(18.6)	131(27.7)	84(15.0)	50(9.7)	56(12.9)	419(16.7)
Personal-Social	102(19.3)	92(19.5)	96(17.1)	63(12.2)	52(12.0)	405(16.1)

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249 Social, biological and psychological factors

250 The wealth index in the surveyed families ranged from 0 to 5, with a median of 4, indicating
251 that most of the families owned major appliances. The parent-child interaction scores ranged
252 from 0 to 6, with a median score of 6. On average, the surveyed children owned only one
253 book (median = 1, IQR = 3). The caregivers' ZSDS score in this sample ranged from 38 to 80,
254 with a median score of 63.76. Nearly two-fifths of the caregivers (38.5%) had symptoms of
255 depression. The ICFI ranged from 0 to 7, with a median score of 2. The haemoglobin
256 concentrations of the surveyed children were 51 to 178 g/L, with a median of 110 g/L. The
257 prevalence of anaemia was high at 43.8%. The birth weight of the surveyed children ranged
258 from 1.40 to 6.00 kg, with a median of 3.30 kg; 2.9% had low birth weight (i.e. a birth weight
259 of less than 2.5 kg).

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261 Structural Equation Model for Suspected Developmental Delay in Children

262 About half of the squared multiple correlations of variables were more than 0.50 (Table S1),
263 which indicated that the variables had good reliability. In the final structural equation model
264 (Table 4), modified ICFI and birth weight were excluded from the model, because no
265 statistically significant relationships were found between these and other variables. The
266 estimated covariance and paths for this model are shown in Figure 1. The following three
267 variables predicted the developmental status of subjects: 1) caregiver socio-demographic

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4 268 factors such as caregiver's education, age, and wealth index (total effect on child
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6 269 developmental status = 0.23); 2) care and stimulus factors measured by parent-child
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9 270 interaction, number of books, and ZSDS score (direct effect = 0.57); and 3) child
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12 271 haemoglobin concentration (direct effect = 0.07). For example, caregivers of a younger age
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15 272 were more likely to interact with the children (covariance of residuals = -0.18), and the latent
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18 273 variable of caregiver factors had a direct positive effect on the care and stimulus factors (path
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21 274 coefficient = 0.40) but an indirect positive effect on the developmental status of children. The
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24 275 overall model fit was good, as reflected by the GFI of 0.977 and the CFI of 0.884.
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276 Table 4. Regression weights of the structural equation model

Equation	Estimates (unstandardised)	Estimates (Standardised)	Standard Error	Critical ratio	P value
Regression weights					
Care and stimulus ← caregiver factor	0.402	0.401	0.047	8.497	<0.001
Children’s developmental status ← care and stimulus	9.608	0.573	0.913	10.525	<0.001
Children’s developmental status ← haemoglobin value for children	0.593	0.071	0.178	3.331	0.001
Caregivers’ education ← caregiver factor	1.000	0.794			
Caregivers’ age ← caregiver factor	-8.358	-0.576	0.543	-15.380	<0.001
Wealth index ← caregiver factor	0.775	0.461	0.055	14.163	<0.001
Parent-child interaction ← care and stimulus	1.000	0.456			
Numbers of books ← care and stimulus	1.687	0.303	0.220	7.678	<0.001
Score of ZSDS ← care and stimulus	4.856	0.415	0.488	9.944	<0.001
Communication ← Children’s developmental status	0.863	0.622	0.029	30.054	<0.001
Gross motor ← Children’s developmental status	0.970	0.726	0.030	32.608	<0.001
Fine motor ← Children’s developmental status	1.132	0.778	0.028	40.216	<0.001

Problem solving ← Children's developmental status	1.188	0.848	0.030	40.212	<0.001
Personal-social ← Children's developmental status	1.000	0.752			
Covariance					
e8 ↔ e10	-19.912	-0.248	2.961	-6.725	<0.001
e3 ↔ e5	0.620	0.188	0.064	9.708	<0.001
e2 ↔ e4	-1.695	-0.175	0.270	-6.290	<0.001
e1 ↔ e5	0.364	0.215	0.051	7.136	<0.001
e5 ↔ e7	3.079	0.076	0.680	4.527	<0.001
e5 ↔ e6	-2.709	-0.115	0.575	-4.712	<0.001
e2 ↔ e6	-5.270	-0.100	1.247	-4.228	<0.001

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Note: ZSDS, Zung self-rating depression scale

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4 278 **DISCUSSION**

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6 279 The present study showed that the prevalence of suspected developmental delay among
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9 280 children aged 6–35 months was high and inversely related to age in the surveyed areas of
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12 281 poor rural China. Furthermore, a structural equation model was used to investigate the risk
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15 282 factors of suspected development delay in children. To date, only one study has examined
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18 283 developmental delay in rural China, and reported a prevalence of 20.0% in cognitive
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21 284 development and 32.3% in psychomotor development among children aged 6–12 months[33].
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24 285 Our study revealed that 35.7% of rural children under 3 years of age had suspected
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27 286 developmental delay and that among children aged 6–12 months, 17–20% of them had delay
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30 287 in the communication, problem solving, personal-social, and gross motor domains, and nearly
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33 288 30% had delay in fine motor development. Overall, the prevalence in our study was
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36 289 comparable with the results of the previous study. According to the very limited data in the
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39 290 WHO report[34], the prevalence of developmental delay in young children is 17% in Senegal,
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42 291 15% in Nigeria, 13% in India, and 24% in Brazil. The lower prevalence reported by other
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45 292 developing countries may reflect the underestimation, and inaccurate measurement, of
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48 293 developmental delay. The promotion of early childhood development (ECD) is a critical issue.
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51 294 It is recommended that the government and healthcare providers pay more attention to the
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54 295 early diagnosis and treatment of developmental delay. Among the five domains of the ASQ,

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4 296 suspected developmental delay of the fine motor domain had the highest prevalence. This is a
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7 297 key finding that suggests the need for further intervention in poor rural areas of China.
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9 298 In the structural equation model, caregiver factors, care and stimulus factors, and child
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12 299 haemoglobin concentrations were directly or indirectly associated with suspected
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15 300 developmental delay. These findings indicate areas on which future intervention programs
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18 301 should focus, including improving feeding and nutrition, raising public awareness of the issue
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21 302 of developmental delay, and improving parenting skills to increase frequency of interaction
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24 303 with their children.
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305 **Relationships between caregiver factors and child development**

306 Younger caregivers with a higher level of education and a higher wealth index had an indirect
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33 307 positive effect on child development. Previous studies have primarily investigated
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36 308 relationships between the sociodemographic characteristics of caregivers and child
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39 309 development. For example, a population-based study in Argentina and a cohort study in
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42 310 Brazil showed that poverty and maternal education were positively associated with the early
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45 311 attainment of selected developmental milestones as well as cognitive and motor development
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48 312 [35,36]. Furthermore, parenting cognitive stimulation, caregivers' responsiveness, and
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51 313 caregivers' affect are related to poverty, cultural values and practices[5]. Similarly, the model
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54 314 in the present study revealed that there was a path between caregiver factors and child
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57 315 development, in which caregiver factors were indirect predictors of developmental delays.

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4 316 Although caregiver factors did not have a direct effect on childhood developmental status, the
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7 317 education, age and poverty level of caregivers should receive more attention in future
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9 318 interventions aimed at improving child development and health.

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12 13 320 **Relationships between care and stimulus factors and child development**

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16 321 The present study demonstrated that the most important predictors of suspected childhood
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19 322 developmental delay were care and stimulus factors (path coefficient = 0.57). Better parent-
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22 323 child interactions, more books and a lower level of maternal depression had positive effects
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25 324 on child development, and a one-point increase in care and stimulus factors was associated
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28 325 with a 0.57-point increase in child development. These findings are consistent with those of
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31 326 previous studies that demonstrated the protective effects of parent-child interactions,
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34 327 children's books and optimistic caregivers on child development[37]. Thus, it is necessary to
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37 328 promote parent-child interactions, such as reading books, telling stories, singing songs,
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40 329 taking the child outside the home, playing with the child, and naming, counting or drawing
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43 330 things to promote learning and the formation of stimulus signals[5,38,39]. The incidence of
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46 331 depression among caregivers was alarmingly high in the present sample, and is similar to
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49 332 previous findings[40,41]. Additionally, the present results confirm those of other studies that
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52 333 reported that caregivers with depression are at an increased risk of having adverse effects on
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55 334 child development[17, 42]. Depression among caregivers not only affects the health of the
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58 335 child but also places such children at a greater risk of developmental delay[43,44]. It is well-

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4 336 established that concurrent maternal depression during mother–infant interactions is
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7 337 associated with reduced maternal responsiveness, which, in turn, is positively associated with
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10 338 later alterations in the emotional, cognitive and physical development of the infant[45,46].
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12 339 The present study revealed that a latent variable, care and stimulus factors (including
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15 340 caregiver depression scores and parent-child interactions), had a joint impact on development.
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18 341 Thus, there is an urgent need for child development interventions directed at phenomena
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21 342 related to the care and stimulation of children in poor rural China.
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25 344 **Relationships between haemoglobin concentrations and child development**

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28 345 In the present study, the haemoglobin concentrations of children had a weak positive effect
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31 346 on child development, whereas other biological factors, such as birth weight and modified
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34 347 ICFI score, did not predict child development. These findings were not consistent with those
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37 348 of previous research[5]. It is possible that the structural equation model used in the present
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40 349 study, which involved only three continuous variables that could not be treated as one latent
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43 350 variable due to their poor correlations, may have played a role in this discrepancy. The
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46 351 incidence of anaemia among children was alarmingly high in the present sample, as in a
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49 352 previous study[47]. This issue constitutes a severe public health problem[48], and likely has a
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52 353 significant impact on child growth and development[4,5,49]. Our results indicate that the
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55 354 haemoglobin concentration of children has a positive effect on child development.
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58 355 Fortunately, the Chinese Government is aware of this public health issue and has initiated a

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4 356 program to provide the micronutrient supplements named Ying Yang Bao (YYB) to 6–35-
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6 357 month-old children living in poor rural areas free of charge. This intervention may decrease
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9 358 the prevalence of anaemia in children. Although we found that birth weight and modified
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12 359 ICFI did not predict child development, poor maternal nutrition, infections and child-feeding
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15 360 practices in poor areas of rural China should be regularly monitored and improved by the
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18 361 government.
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21 363 **Limitations**

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25 364 The present study has several limitations that should be considered. First, due to the cross-
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28 365 sectional design of this study, the associations revealed by the structural equation model
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31 366 could not be confirmed as causative relationships, even though these models are a powerful
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34 367 statistical technique for the simultaneous consideration of multiple variables, further evidence
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37 368 from cohort studies and interventional studies is needed to infer the causality of these
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40 369 relationships. Second, due to the restrictions and limitations inherent in the methodology and
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43 370 the software, many binary variables, including those measuring infant and young childhood
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46 371 infections (*e.g.* diarrhoea and pneumonia) were not incorporated into the structural equation
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49 372 model. Third, this study was conducted in two provinces in central and south-west China.
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52 373 These study sites are not representative of all poor rural areas of China. Caution is warranted
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55 374 when generalising our findings to other rural areas in China.

56 375 **Conclusions**

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4 376 These preliminary findings indicate that the prevalence of suspected developmental delay is
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7 377 high in poor rural areas of China. More attention needs to be paid to early childhood
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10 378 development. Interventions should specifically target and support families in poverty and
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12 379 those with low education levels, as well as prioritise maternal and children's nutrition and
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15 380 mental health, so as to improve foetal and early child development.
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32 386 **Competing interests**

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36 387 The authors declare that they have no competing interests.
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38 388 **Author's contributions**

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42 389 Ying Li did the data analysis. Jingxu Zhang drafted the article. Sufang Guo, Xiaoli Wang and
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45 390 Robert W. Scherpbier designed the study. Jingxu Zhang, Qianwei Wei, Cuihong Zhang and
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48 391 Shusheng Luo collected the data. Xiaoli Wang and Chunxia Zhao critically revised the
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51 392 manuscript. All authors read and approved the final manuscript.
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53 393 **Data sharing statement**

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4 394 The datasets analysed in the current study are not publicly available, but are available from
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6 395 the corresponding author upon reasonable request.
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10 396 **Consent for publication**
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13 397 Not applicable.
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16 398 **Ethics approval and consent to participate**
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19 399 This study was approved by the Peking University Biomedical Ethics Committee. Consent
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22 400 was obtained from the participants and their guardians or parents.
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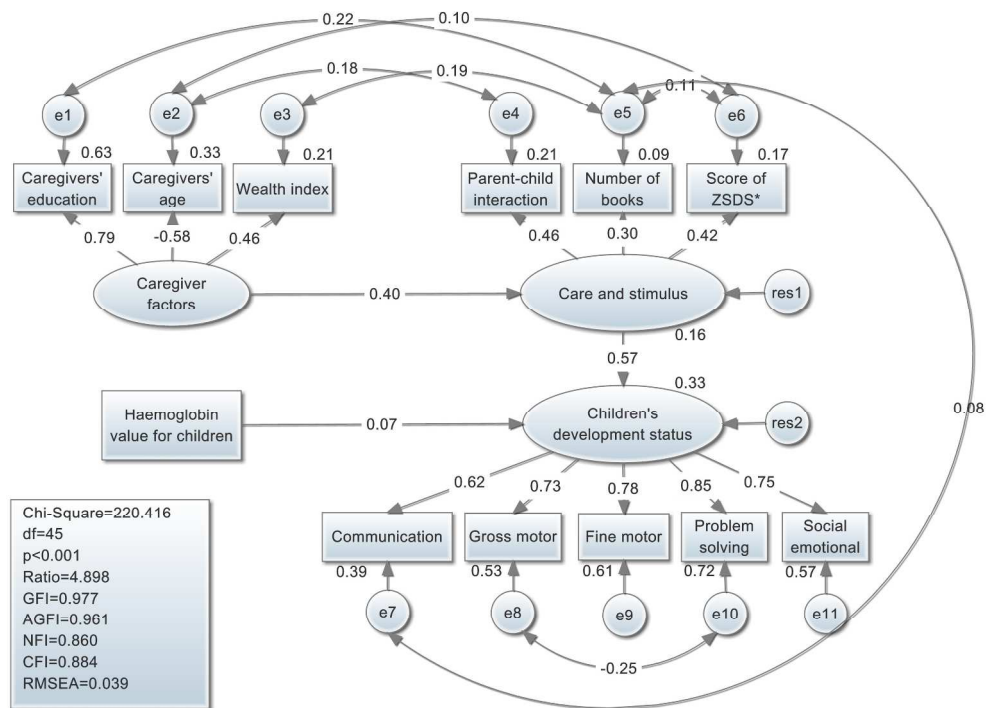
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3 Figure 1. Structural equation model and standardised coefficient for relationships between
4 factors that theoretically influence suspected developmental delay
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For peer review only



1054x758mm (72 x 72 DPI)

Peer review only

Supplementary 1

Table S1. The squared multiple correlations of variables

Variables	Squared multiple correlations
Caregivers' education	0.631
Caregivers' age	0.331
Wealth index	0.213
Parent-child interaction	0.208
Number of books	0.092
Score of ZSDS	0.172
Communication	0.387
Gross motor	0.527
Fine motor	0.605
Problem solving	0.719
Social emotional	0.566

Note: ZSDS: Zung Self-rating Depression Scale

STROBE 2007 (v4) Statement—Checklist of items that should be included in reports of *cross-sectional studies*

Section/Topic	Item #	Recommendation	Reported on page #
Title and abstract	1	(a) Indicate the study’s design with a commonly used term in the title or the abstract	3
		(b) Provide in the abstract an informative and balanced summary of what was done and what was found	3
Introduction			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	5-7
Objectives	3	State specific objectives, including any prespecified hypotheses	7
Methods			
Study design	4	Present key elements of study design early in the paper	7-8
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	
Participants	6	(a) Give the eligibility criteria, and the sources and methods of selection of participants	7-8
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	9-11
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	
Bias	9	Describe any efforts to address potential sources of bias	
Study size	10	Explain how the study size was arrived at	
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	
Statistical methods	12	(a) Describe all statistical methods, including those used to control for confounding	12
		(b) Describe any methods used to examine subgroups and interactions	
		(c) Explain how missing data were addressed	
		(d) If applicable, describe analytical methods taking account of sampling strategy	
		(e) Describe any sensitivity analyses	
Results			

Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed (b) Give reasons for non-participation at each stage (c) Consider use of a flow diagram	
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders (b) Indicate number of participants with missing data for each variable of interest	14
Outcome data	15*	Report numbers of outcome events or summary measures	
Main results	16	(a) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included (b) Report category boundaries when continuous variables were categorized (c) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	
Discussion			
Key results	18	Summarise key results with reference to study objectives	21-22
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias	25-26
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	22-25
Generalisability	21	Discuss the generalisability (external validity) of the study results	26
Other information			
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	27

*Give information separately for cases and controls in case-control studies and, if applicable, for exposed and unexposed groups in cohort and cross-sectional studies.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at <http://www.plosmedicine.org/>, Annals of Internal Medicine at <http://www.annals.org/>, and Epidemiology at <http://www.epidem.com/>). Information on the STROBE Initiative is available at www.strobe-statement.org.