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Association of dietary diversity and cognition in preschoolers in rural China

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A B S T R A C T

Objectives: We sought to investigate the cognition of preschoolers in rural China and examine the relationship between dietary diversity and cognition.
Methods: We performed a cross-sectional survey analysis. In 1334 preschoolers ages 3 to 5, from 26 preschools in two nationally designated poverty counties in Hunan Province in China, we calculated the dietary diversity score (DDS) using a 24-h recall method. To measure children's cognitive ability, we assessed the Working Memory Index and Verbal Comprehension Index on the Mandarin-language version of the Wechsler Preschool and Primary Scale of Intelligence, Fourth Edition. Multiple linear regression models were used to estimate the association between DDS and cognitive test scores.
Results: A total of 22% of children had a Working Memory Index that was either extremely low or borderline, and 31% of children had a Verbal Comprehension Index that was either extremely low or borderline. The mean (± SD) DDS was 5.65 ± 1.30. Those preschoolers with medium DDS (5 or 6) or high DDS (7 to 9) scored higher on both Working Memory Index—respectively, mean difference (MD), 1.327; 95% confidence interval (CI), 0.246–3.901; and MD, 2.067, 95% CI, 0.261–4.641—and Verbal Comprehension Index—MD, 0.168; 95% CI, 0.072–2.135; and MD, 0.398; 95% CI, 0.032–2.137—than did those with low DDS (0 to 4).
Conclusions: Consuming a more diverse diet may contribute to better cognition in preschoolers. Future research is needed to better understand the possible causal effect of dietary diversity on cognitive development.

Introduction

Early childhood, especially the first 5 y of life, is a crucial period for the development of cognitive function, as the brain develops most rapidly at this stage [1]. Brain development requires essential nutrients, implying that nutrition might play a key role in early childhood development [2,3]. A large body of literature has shown that good nutrition is associated with high cognitive performance [2–4], whereas malnutrition is linked to hampered cognitive growth [5]. Over the past several decades, the world has witnessed a huge improvement in child nutrition [6]. However, cognitive deficiency due to malnutrition in children remains a severe problem in developing countries [7]. It is estimated that globally, about 250 million children under age 5 are at risk of not reaching their development potential, with malnutrition being one of the major causes [7]. Moreover, most of these children are concentrated in poor, rural communities of low- and middle-income countries [8]. We cannot afford to ignore these children, because cognitive deficiencies may negatively affect their future school performance [9] and socioeconomic success in adulthood [10], and even lead to participation in crime [11,12].

Successful cognitive development during early ages requires an adequate intake of various nutrients. Deficiencies of some nutrients will have adverse effects on cognitive domains, such as verbal knowledge and reasoning (iodine deficiency) [13,14], memory and learning ability (iron deficiency) [15], and information processing (iodine and zinc deficiencies) [16]. However, those nutrients are not available in one single food group, so a varied diet might be needed for children to meet their nutritional

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requirements and thus facilitate the achievement of their cognitive potential. Dietary diversity (DD), which is defined as the number of unique foods consumed over a given period [17], has been recognized as a good proxy of diet quality [18–20]. To the best of our knowledge, however, only a limited number of studies have directly examined the association between DD and cognitive ability, in adults and older people [21,22], leaving this field of study in children less understood. Thus, a key question is whether dietary diversity is associated with better cognition in children.

The present study contributes to the literature by addressing this question using data from rural China. Our focus is on preschoolers ages 3 to 5 y, during the key period of cognitive development. The overall goal of the study was to determine whether there was an association between child dietary diversity and cognition and whether this association remained once characteristics of households and preschools were controlled for. Answers to these questions are of great importance in better understanding the relationship between dietary diversity and cognitive development of children, and for policymaking aiming to promote child development.

Methods

Study area and sampling

We used baseline data collected in September 2018 as part of a preschool nutrition pilot program launched by the Xiangxi Prefecture government, with support from the World Food Program. The baseline survey was carried out in two nationally designated poverty counties in Xiangxi Prefecture, Hunan Province, central south China. Because the baseline survey was conducted before any intervention associated with the pilot program, the intervention can be ignored here. The sample included 26 preschools from 15 townships across the two project counties. Of these, 10 preschools were in Longling County and the remaining 16 were in Yongshun County. Within each sample preschool, all children ages 3 to 5 y who attended the preschool on the survey day were included in the sample. In total, we surveyed 1334 preschoolers. Among them, 47 preschoolers did not provide information on food consumption or did not finish the cognitive-ability test; therefore, the full sample size of the present study was 1287.

Measures

The survey team collected three types of data: cognitive performance of preschoolers (assessing verbal comprehension and working memory using the Mandarin-language version of the Wechsler Preschool and Primary Scale of Intelligence, Fourth Edition); dietary data of preschoolers (as measured by detailed food consumption within the past 24 h at home and in preschool); and sociodemographic data (sociodemographic information both of household members and of preschool staff for the sample population).

Cognitive ability

Cognitive development was assessed with the Mandarin-language version of the Wechsler Preschool and Primary Scale of Intelligence, Fourth Edition (WPPSI-IV). The test was administered by well-trained examiners on a one-on-one basis, without any guidance from teachers or guardians. The WPPSI-IV is a measure of cognitive development in children ages 2 years and 6 months to 7 years and 7 months; its reliability and validity have been well documented [23,24]. The test structure of the WPPSI-IV has five Primary Index scales: Verbal Comprehension Index (VCI), Visual Spatial Index, Working Memory Index (WMI), Fluid Reasoning Index, and Processing Speed Index. Considering the pronounced effect of nutrition on verbal reasoning and comprehension [25], attention, working memory, and learning ability [26], we focused on VCI and WMI. The VCI is derived from two subtests, Similarities and Information, which measure children's acquired knowledge and verbal reasoning. Similarly, the WMI is derived from two other subtests, namely Picture Memory and Zoo Location, which reflect children's ability to concentrate and manipulate visuospatial working memory. Raw scores obtained from the four subtests of the WPPSI-IV were converted to age-scaled index scores using tables of norms in the Mandarin version of the WPPSI-IV administration and scoring manual. Both WMI and VCI can range from 40 to 160. Scores are grouped based on internationally recognized cutoffs: a score of 90 to 110 is considered average, a score of 80 to 89 is considered low average, a score of 70 to 79 is considered borderline, and a score below 70 is considered extremely low and at risk of intellectual disabilities or mental retardation.

Dietary diversity

According to the Guidelines for Measuring Household and Individual Dietary Diversity provided by the Food and Agriculture Organization of the United Nations [27], each child's dietary diversity was assessed using a dietary diversity score (DDS) based on nine food groups: starchy staples, dark-green leafy vegetables, other vitamin A–rich fruits and vegetables, other fruits and vegetables, organ meat, meat and fish, eggs, milk and milk products, and legumes, nuts, and seeds. Detailed food-group classifications and example food items from each group can be found in our previous study [28]. Trained enumerators used two questionnaires to collect detailed dietary intake for children. A 24-h recall method was used in both questionnaires. One questionnaire aimed to ask the primary caregivers (mostly grandparents or parents) what the children ate at home as well as at restaurants or other shops over the past 24 h. The other questionnaire aimed to ask the preschool kitchen managers what the children ate at preschools over the past 24 h. We thus collected detailed food consumption for each child both at home and in preschool over the past 24 h, which allowed us to measure each child's total dietary consumption within the past 24 h. The DDS was calculated by counting the number of food groups that a child consumed in the past 24 h without consideration of a minimum quantity requirement for any food group. Any individual food item in a food group consumed by a child earns one point for their dietary diversity score, but different individual food items consumed in the same group are not counted repeatedly. Therefore, the DDS ranges from 0 to 9. Moreover, to identify possible nonlinear relationships between DDS and cognition, we divided DDS into three categories: low (0 to 4), medium (5 or 6), and high (7 to 9).

Covariates

Because the association between DD and cognitive ability is likely to be confounded by socioeconomic factors [29], we also collected socioeconomic and sociodemographic information from households and preschools. Through interviews with children's caregivers, we collected data on child gender and ethnicity (Han versus non-Han); age and years of schooling (starting from primary school) of mother, father, and primary caregiver, and parental migration status (whether any parent migrated out for more than 6 mo in the previous 12 mo); and household size and household asset index (obtained from a principal components analysis of possession of a list of 13 durable assets and goods). For the preschool, homeroom teachers were asked to report their education level, whether they held a degree in preschool education, and their years of teaching experience. Moreover, preschool information such as its ownership type (public or private) and the number of students enrolled was gathered. The student–teacher ratio was also calculated for each class.

Statistical analysis

Assuming a design effect up to 0.3 SD, a sample size of approximately 1287 could give a power of 99 and a 5% level of significance. One-way analysis-of-variance models were used to determine whether there were any statistically significant differences between the means of child, household, teacher, and preschool characteristics among preschoolers with low, medium, and high DDS. The results are shown as mean and P value. The predictors of cognitive performance and the association of DDS and cognitive function were explored by linear regression. A value of $P < 0.05$ was considered statistically significant for all findings. These estimates were adjusted for the clustered sampling design at the class level.

Statistical analysis was performed using STATA software, version 15.1, for Windows.

Results

Sample characteristics

Table 1 shows the socioeconomic and sociodemographic characteristics of the study population by DDS category. A total of 1287 preschoolers (89% non-Han ethnicity) participated in the study. Slightly more boys than girls were involved, and the average age of all children was 4.6 y. The mean DDS was 5.65 ± 1.30. The means for low DDS (n = 190), medium DDS (n = 726), and high DDS (n = 371) were 3.66, 5.49, and 7.10, respectively. Participants with a higher DDS tended to be those whose mother, father, or caregivers had more years of schooling, whose primary caregivers were younger, and whose household socioeconomic status (household asset index) was high. By contrast, left-behind children (those whose parents migrate outside of their hometowns for employment or other purposes) were more likely to have a lower variety in their diet than were their peers whose parents were at home. For the preschool, teachers with more teaching experience were more likely to contribute to a higher child DDS. Participants who were enrolled in public preschools or preschools with lower enrollment showed higher diversity in their diets.

Table 1
Sample characteristics by dietary diversity score category ($N = 1287$).

Characteristic	Full sample	Dietary diversity score Low (1–4; $n = 190$)	Medium (5–6; $n = 726$)	High (7–9; $n = 371$)	P
Child cognition					
Working Memory Index	90.35 ± 12.39	87.32 ± 13.89	89.05 ± 12.27	92.07 ± 13.25	0.003
Verbal Comprehension Index	86.16 ± 12.63	85.64 ± 13.30	86.36 ± 12.06	86.40 ± 13.00	0.001
Child characteristics					
Dietary diversity score	5.83 ± 1.24	3.85 ± 1.37	5.56 ± 1.42	7.34 ± 1.39	<0.001
Age, mo	55.74 ± 11.28	54.55 ± 11.24	55.38 ± 11.74	55.11 ± 12.29	0.709
Female (1 = yes, 0 = no)	47	43	47	49	0.589
Non-Han ethnicity (1 = yes, 0 = no)	88	88	89	85	0.167
Household characteristics					
Father's education, y	8.02 ± 2.63	8.16 ± 2.37	7.88 ± 2.49	8.33 ± 2.40	0.003
Mother's age, y	29.23 ± 4.65	29.01 ± 5.11	29.20 ± 5.01	29.35 ± 4.19	0.734
Mother's education, y	8.05 ± 2.23	7.83 ± 3.08	7.88 ± 2.34	8.66 ± 2.18	<0.001
Parental migration (1 = yes, 0 = no)	73	71	76	68	0.041
Primary caregiver's age, y	48.19 ± 14.04	49.24 ± 13.47	49.11 ± 14.05	46.05 ± 14.16	0.003
Primary caregiver's education, y	5.34 ± 4.10	5.13 ± 4.05	5.01 ± 4.00	6.07 ± 3.34	<0.001
Household size	6.23 ± 1.09	6.21 ± 1.09	6.36 ± 1.14	6.19 ± 1.07	0.253
Household asset index	0.01 ± 1.01	−0.08 ± 0.99	−0.03 ± 0.97	0.12 ± 1.00	0.007
Teacher characteristics					
Teacher has preschool education degree (1 = yes, 0 = no)	35	38	34	36	0.389
Teaching experience, y	6.34 ± 7.04	5.64 ± 5.00	5.87 ± 7.12	7.79 ± 9.13	<0.001
Preschool characteristics					
Public preschool (1 = yes, 0 = no)	22	19	18	31	<0.001
Preschool enrollment	125.04 ± 50.14	129.11 ± 56.14	129.32 ± 50.93	117.77 ± 46.99	0.002
Student–teacher ratio	22.23 ± 7.04	22.03 ± 7.16	22.45 ± 7.24	22.87 ± 7.24	0.704

Results are given as mean ± SD or as %

Frequency of each food group consumed

Table 2 shows the frequency of each food group consumed, by DDS category. All children consumed starchy staples in the past 24 h, and nearly all children ate meat or fish. Therefore, there was no statistically significant difference between children with low, medium, and high DDS in consumption of starchy staples and of meat and fish. However, there was statistical significance to differences between children in different DDS categories on consumption of the other seven food groups. The least-consumed food group was organ meat; none in the low-DDS group consumed it in the past 24 h, and the percentage was < 10% for children with high DDS.

Performance on and predictors of cognitive tests

A total of 21% of children had a WMI that was either extremely low (<70; 5% of participants) or borderline (70 to 79; 16% of participants). A total of 30% of children had a VCI that was either extremely low (< 70; 10% of participants) or borderline (70 to 79; 20% of participants).

Table 2
Frequency of food groups consumed by dietary diversity score.

Food group	Low DDS	Medium DDS	High DDS
Starchy staples	100.0	100.0	100.0
Dark-green leafy vegetables	11.6	55.1	88.4
Other vitamin A–rich fruits and vegetables	33.7	67.2	88.4
Other fruits and vegetables	74.7	86.9	96.5
Organ meat	0.0	1.2	8.9
Meat and fish	98.9	99.9	100.0
Eggs	17.9	57.6	87.6
Legumes, nuts, and seeds	37.4	53.9	76.5
Milk and milk products	6.8	32.4	79.0

DDS, dietary diversity score
Values are given as percentages

Table 3 shows the predictors of WMI and VCI. Older children tended to perform better on both tests. For the households, only the father's schooling was positively associated with WMI and VCI scores; neither that of the mother or caregivers was an important contributor to child cognitive ability, nor was the household asset index. For the preschool, children who were enrolled in public preschools and those whose teachers were more experienced were more likely to score higher on the WMI and VCI.

DDS and cognition indicators

Table 4 shows the results of the linear regression for the unadjusted and adjusted models. In the unadjusted model, children whose diet was more diversified tended to have better cognitive performance. Specifically, there were significant positive associations of DDS with WMI and VCI. Children in the high- and medium-DDS categories had higher WMI scores by, respectively, 2.53 and 1.78 points compared to those in the low-DDS category. Similarly, children in the high- and medium-DDS categories had higher VCI scores by 0.74 and 0.45 points compared to those in the low-DDS category. In the adjusted model, with confounders adjusted for, the positive associations of DDS with WMI and VCI still hold. When we reestimated the models by considering DDS as a continuous variable, the results remained substantially the same. Specifically, when DDS increased by 1 point, WMI increased by 0.4 and VCI increased by about 0.08 point. Specifically, preschoolers with medium and high DDS scored higher in both WMI (respectively, mean difference (MD), 1.327; 95% confidence interval (CI), 0.246–3.901; and MD, 2.067; 95% CI, 0.261–4.641) and VCI (MD, 0.168; 95% CI, 0.072–2.135; and MD, 0.398; 95% CI, 0.032–2.137) than did those with low DDS.

Discussion

Previous studies have shown that nutrient deficiencies and dietary quality in childhood could affect later cognitive function

Table 3
Predictors of preschoolers' cognition.

Characteristic	Working Memory Index				Verbal Comprehension Index			
	Normal (≥80; *n* = 1018, 79%)	Borderline (70–79; *n* = 207, 16%)	Extremely low (<70; *n* = 62, 5%)	*P*	Normal (≥80; *n* = 895, 70%)	Borderline (70–79; *n* = 261, 20%)	Extremely low (<70; *n* = 131, 10%)	*P*
Child characteristics								
Age, mo	56.89 ± 11.15	48.98 ± 13.16	46.14 ± 9.48	<0.001	57.0 ± 11.65	53.17 ± 12.53	47.09 ± 10.83	<0.001
Female	48	44	51	0.498	47	47	48	0.899
Non-Han ethnicity	88	84	89	0.302	88	88	88	0.947
Household characteristics								
Father's education, y	8.35 ± 2.38	7.83 ± 2.64	8.61 ± 2.88	0.035	8.86 ± 2.30	8.04 ± 2.36	7.72 ± 2.37	0.001
Mother's age, y	29.32 ± 5.02	29.26 ± 4.77	28.09 ± 4.38	0.054	29.14 ± 4.42	29.14 ± 5.06	29.43 ± 4.76	0.087
Mother's education, y	8.16 ± 2.83	7.73 ± 2.61	8.29 ± 2.77	0.529	8.04 ± 2.49	7.64 ± 2.62	8.14 ± 2.43	0.135
Parental migration	79	68	78	0.602	70	69	70	0.895
Primary caregiver's age, y	48.48 ± 14.09	47.43 ± 13.39	47.24 ± 15.83	0.204	48.41 ± 14.24	47.81 ± 14.14	48.49 ± 14.02	0.782
Primary caregiver's education, y	5.35 ± 4.14	5.49 ± 3.39	5.79 ± 3.43	0.724	5.43 ± 4.14	5.49 ± 3.74	5.02 ± 3.82	0.343
Household size	6.29 ± 1.31	6.38 ± 1.19	6.63 ± 1.05	0.637	6.12 ± 1.32	6.42 ± 1.33	6.32 ± 1.25	0.682
Household asset index	0.03 ± 0.97	0.03 ± 1.02	0.01 ± 1.00	0.976	0.04 ± 0.94	−0.04 ± 1.00	−0.04 ± 1.02	0.448
Teacher characteristics								
Teacher has preschool education degree	36	35	23	0.075	35	38	34	0.734
Teaching experience, y	6.89 ± 7.44	5.58 ± 6.72	4.14 ± 4.43	0.003	6.90 ± 7.75	5.80 ± 6.14	5.52 ± 6.47	0.029
Preschool characteristics								
Public preschool	21	20	14	0.343	23	12	17	<0.001
Preschool enrollment	125.63 ± 50.82	124.28 ± 48.62	124.29 ± 59.73	0.504	125.90 ± 50.28	12.27 ± 48.33	123.92 ± 52.38	0.737
Student–teacher ratio	23.13 ± 7.06	22.95 ± 7.74	19.89 ± 7.88	0.089	23.22 ± 7.17	22.032 ± 6.9	20.21 ± 7.01	0.073

Values are given as mean ± SD or as %

[30,31]. As a good proxy of diet quality [18–20,32], higher DD is more likely to guarantee a greater, sufficient intake of various nutrients [33,34]. Given the correlations of DD with diet quality and of diet quality with cognition development [35–37], we aimed to test whether a varied diet plays a key role in the development of cognitive functions in preschool children. The results of this study provide supporting evidence by verifying a significant, positive, cross-sectional relationship between dietary diversity and cognitive test scores in a large, rural population of preschoolers. The mean DDS of this population was 5.65 (±1.30), which is significantly lower than that reported by some similar studies in children and young adolescents in China [38–40]. One possible explanation is the difference in the sampling areas, as previous studies have focused mostly on urban areas, where people have better access to a variety of foods and higher socioeconomic status [28], which may contribute to the observed gap between urban and rural areas in terms of nutrient intake. Our results also show that even though nearly all children consumed starchy staples and meat and fish, there was a huge difference in dietary patterns between children with low, medium, and high DDS. For example, only 11.6% of children with low DDS consumed dark-green leafy vegetables, whereas the proportions of children with medium and high DDS were 55.1% and 88.4%, respectively.

The age of the child and the number of semesters the child had been enrolled in preschool were positively associated with both VCI and WMI. Older children tended to have spent more time in preschool than their younger peers, which may help improve their learning ability. Among parental education, only the father's education was correlated with a child's cognition. In addition, children who were enrolled in public preschools performed better in verbal comprehension than those who attended private preschools. In rural China, public preschools are more likely to offer more cognitively stimulating activities than private preschools [41]. Furthermore, teachers with more teaching experience were associated with better VCI scores and WMI scores in their pupils. One possible explanation is that experienced teachers were more likely to establish better teacher–child interactions than were novice teachers [42].

In addition to these predictors, we also examined the association between DDS and cognitive test scores. After adjusting for potential confounders, such as child age, parent/caregiver education level, socioeconomic status, and teacher experience, we found that children consuming a wider variety of foods had significantly higher scores on both the working-memory test and the verbal-comprehension test, a similar result to that of a study conducted in Ethiopia that revealed that DD was an essential contributor to child cognitive performance [43]. Another study, in children in Kenya, also showed a positive association between improved DD and cognitive ability [44]. Moreover, higher dietary quality or diversity has been linked with better cognition and lower cognitive impairment in adults and older people [21,22]. This may imply that dietary diversity is essential for cognition in all age groups. Nutritional adequacy promotes not only brain development but also brain functioning and maintenance. Regarding the mechanism behind this, a possible explanation could be that nutritional adequacy is likely to promote the development of the brain [37]. For example, nutrition can affect the brain's macrostructure (e.g., hippocampus) and microstructure (e.g., myelination of neurons), and the level of operation of neurotransmitters (dopamine levels of receptor numbers), all of which can have an impact on the development of cognition [45].

Some strengths are worth noting in the present study. To the best of our knowledge, it is the first to examine the association between dietary diversity and child cognitive ability. Previous studies have linked DD with cognitive performance in adults, but the correlation between DD and child cognition is not as well understood. Our study fills the gap by comprehensively assessing

[Table 4
Correlations between DDS and child cognitive performance and other covariates

Characteristic	Working Memory Index				Verbal Comprehension Index			
	B	95% CI	*B*	95% CI	*B*	95% CI	*B*	95% CI
Medium DDS	1.775	0.537–4.088	1.327	0.246–3.901	0.449	0.062–1.461	0.168	0.072–2.135
High DDS	2.528	0.416–4.641	2.067	0.261–4.396	0.740	0.046–2.94	0.398	0.032–2.137
Child characteristics								0.149–0.284
Age	0.213	0.151–0.275	0.270	0.199–0.342	0.181	0.122–0.240	0.216	−1.33 to 1.627
Female	−0.534	−1.981 to 0.913	−0.771	−2.333 to 0.792	0.190	−1.188 to 1.568	0.149	−2.936 to 1.864
Non-Han ethnicity			1.553	−0.983 to 4.089			−0.536	0.292–0.905
Household characteristics								−0.072–0.242
Father's education			0.541	0.217–0.865			0.599	−0.177 to 0.469
Mother's age			0.124	−0.042 to 0.289			0.085	−2.771 to 0.815
Mother's education			0.144	−0.196 to 0.485			0.146	−0.042 to 0.087
Parental migration			−1.122	−3.017 to 0.773			−0.978	−0.136 to 0.35
Primary caregiver's age			−0.006	−0.074 to 0.062			0.022	−1.186 to 0.106
Primary caregiver's education			0.064	−0.193 to 0.321			0.107	−0.312 to 1.236
Household size			−0.136	−0.818 to 0.574			−0.540	−1.219 to 2.189
Household asset index			0.569	−0.249 to 1.397			0.462	−0.094 to 0.117
Teacher characteristics								−0.219 to 3.737
Teacher has preschool education degree			1.219	−0.582 to 3.020			0.485	−0.005 to 0.029
Teaching experience			−0.060	−0.172 to 0.051			0.012	−0.083 to 0.14
Preschool characteristics								−2.272 to 2.135
Public preschool			−1.172	−3.262 to 0.919			1.759	−2.732 to 2.137
Preschool enrollment			0.010	−0.007 to 0.028			0.012	0.149–0.284
Student–teacher ratio			0.008	−0.109 to 0.126			0.029	−1.33 to 1.627

CI, confidence interval; DDS, dietary diversity score
All models adjusted for intraclass correlation by clustering standard errors at class level

dietary diversity and cognitive ability in preschool children in rural China and examining the relationship between the two. In addition, most previous studies on child DDS, if not all, have only taken into account meals at home, ignoring meals away from home. This may underestimate dietary diversity. In our study, the role that preschools might play in preschoolers' dietary diversity was considered and included in the computation of the DDS, making the results more realistic and accurate.

However, some limitations should be noted. Although the dietary diversity score used in this article has been widely used in the literature [38–40], it has some limitations. First, it uses only one 24-h recall period, which means it cannot indicate an individual's habitual diet. In fact, previous studies show that there are huge differences in food consumption between seasons, with more vegetables and fruits in summer than in other seasons. Therefore, there are also various other valid time frames for recall, such as the previous 6 mo. However, the recall period of 24 h was chosen in this study because it is less subject to recall error and is also used in many dietary diversity studies [27]. Second, such a definition of dietary diversity score includes only nine food groups. Some food groups (e.g., oil) may get ignored or merged into others (e.g., fish with meat) even though they uniquely provide key nutrients for brain development (long-chain fatty acids). The dietary diversity score is expected to reflect the probability of micronutrient adequacy of the diet. Nevertheless, there is no international consensus on which food groups to include in the scores. In addition, this was only a cross-sectional study; therefore, the causal relationship between children's dietary diversity and cognitive ability cannot be established. Furthermore, only working memory and verbal comprehension were included in this study to assess child cognitive ability. A comprehensive measurement should also include tests of other cognitive domains.

Conclusion

The present study observed an association between a more diverse diet for preschoolers and better performance on cognitive tests. The possible causal effect of dietary diversity on cognitive development in young children and the mechanism involved should be examined in future prospective studies.

Credit Author Statement

K. C., C. L., J. B., and R. L. designed research; K. C., C. L., J. B., Z. H., Y. Y. and Z. W. conducted research; S. L. and Z. H. analyzed data; and S. L., C. L., and Z. H. wrote the paper. C. L. had primary responsibility for final content. All authors read and approved the final manuscript.

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Ethical Standards Disclosure

This study was conducted according to the guidelines laid down in the Declaration of Helsinki and all procedures involving research study participants were approved by the Institutional Review Board of the International Food Policy Research Institute, Washington, DC. Written informed consent was obtained from all subjects/patients.

Declaration of Competing Interest

None.

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