Applied nutritional investigation

Association of dietary diversity and cognition in preschoolers in rural China

Shaoping Li Ph.D., Kevin Chen Ph.D., Chengfang Liu Ph.D., Jieying Bi Ph.D., Zhenya He M.S., Renfu Luo Ph.D., Yanying Yu M.S., Zimeiyi Wang M.S.

China Center for Agricultural Policy, School of Advanced Agricultural Sciences, Peking University, Beijing, China
China Academy for Rural Development, Zhejiang University, Hangzhou, China
East and Central Asia Office, International Food Policy Research Institute, Beijing, China
Agricultural Information Institute of Chinese Academy of Agricultural Sciences, Beijing, China
Faculty of Business and Economics, The University of Hong Kong, Hong Kong, China

ARTICLE INFO

Article History:
Received 28 April 2021
Received in revised form 9 August 2021
Accepted 24 August 2021

Keywords:
Cognition
Dietary diversity
Preschoolers
Rural China

ABSTRACT

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.

© 2021 Elsevier Inc. All rights reserved.

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
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 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 VMI and WCI 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 mean 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 school, 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.
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 category. All children consumed starchy staples 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; 10% of participants).

Table 2 shows the frequency of each food group consumed by dietary diversity score category. 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.

**Discussion**

Previous studies have shown that nutrient deficiencies and dietary quality in childhood could affect later cognitive function.
Predictors of preschoolers’ cognition.

A cross-sectional study was conducted in kindergarten children aged 3–6 years old. Cognition was assessed by using the Working Memory Index (WMI) and Verbal Comprehension Index (VCI). Dietary diversity (DD) was calculated using the Dietary Diversity Score (DDS). The sample included 206 kindergarten children, and their parents and teachers completed questionnaires on the children’s socio-economic status, caregiver’s characteristics, and school characteristics. Multivariable linear regression analysis was used to examine the relationship between DD, child characteristics, and teacher characteristics, controlling for potential confounders such as child age and number of semesters attended. Results showed a significant positive association between DD and both WMI and VCI. Among child characteristics, parental education level was positively associated with DD. Among teacher characteristics, teaching experience was positively associated with VCI. The results provide supporting evidence 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. 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.
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.

Financial Support

This research was supported by the National Natural Science Foundation of China (grant number 71861147003 and 71925009), the International Food Policy Research Institute (grant number 602174002001), and the China Postdoctoral Science Foundation (grant number 2019M650361). The study design, statistical analysis, interpretation of findings, and the preparation of the manuscript were conducted independently of the National Natural Science Foundation of China, the International Food Policy Research Institute, and the China Postdoctoral Science Foundation.

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.