Associations between dietary patterns and cognitive ability in 10-15 years old Chinese children: evidence from the 2010 China Family Panel Studies

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Research

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Abstract

Background

Limited study is currently available concerning the associations between dietary patterns and cognitive ability during childhood and adolescence, especially studies come out of Chinese data. Our aim was to analyze the associations between dietary patterns and cognitive ability in 10 to 15 year-old Chinese children.

Methods

2029 children's dietary, cognitive ability and sociodemographic data were available from the 2010 China Family Panel Studies (CFPS). Dietary patterns were identified by the principal component method (PCA). Associations between dietary patterns and cognitive ability were assessed using Ordinal-Logistic regression models.

Results

Three dietary patterns were identified namely as 'High protein', 'High fat' and 'High salt-oil'. Following adjustment for the gender, age, nationality, household registration, school, parents' education, family education environment, family annual income and family size, we found that higher score on the 'High protein' pattern was associated with higher scores of mathematics test (OR=1.62; CI: 1.23~2.15; P=0.001) but was not significant with vocabulary test (OR=1.21; CI: 0.93~1.58; P=0.149). Higher score on the 'High fat' pattern was associated with lower score of mathematics (OR=0.76; CI: 0.59~0.98; P=0.031) and vocabulary test (OR=0.77; CI: 0.61~0.97; P=0.029). There was no significance between 'High salt-oil' pattern and mathematics (OR=0.99; CI:0.77~1.27; P=0.915) and vocabulary test (OR=0.93; CI:0.73~1.18; P=0.544).

Conclusions

The study indicated that 'High protein' pattern may has positive associations with cognitive ability in Chinese children, while 'High fat' pattern may has negative associations.

Background

The cognitive ability of children has always been the focus of public health researchers. A person's school performance usually affects their future education, which ultimately determines a person's socio-economic status. In turn, education is related to health and healthy behavior[1]. So the factors that help achieve childhood and adolescent academic success should be paid more attention on.

Nutrition is one of the most important and changeable environmental factors that affect brain development and thus affect cognition and academic performance. Adolescence is a key period of brain development, because the developing brain and cognitive system mature at different rates under the control of common and independent biological processes, this period is more fragile and adjusted[2]. Some studies have investigated how nutrition influences cognitive brain development during childhood and adolescence. In Norway, frequent lunch and dinner are positively correlated with teenagers' math learning, while high intake of drinks, pizza, hot dogs, candy and snacks is positively correlated with self-reported math learning difficulties [3]. In the same study, regular breakfast was negatively correlated with learning difficulties in math, reading and writing[3]. Besides, regular eating[4] and high intake of fish[5] have been associated with improved cognitive performance. In addition, compared with children who ate sufficient food, children with malnutrition or insufficient nutrient intake were restrained in learning and behavioral development[6, 7]. As for the effect of nutritional status on children's cognitive ability, malnourished children usually have lower academic performance in school than well-nourished children[8]. However, limited study is currently available concerning the associations between dietary patterns and cognitive ability during childhood and adolescence.

Evaluating a single food or nutrient ignores the complex interactions between nutrients and foods and may not reflect the total diet consumed by an individual[9, 10]. We do not eat foods in insolation, rather consuming combinations of foods in meals. Therefore, it is important to investigate a whole diet. Principal components analysis (PCA) takes advantage of complex diet and multiple food groups into account instead of individual foods or nutrients. Thus, dietary pattern analysis might reflect the complexity of dietary intake and provide insights into the whole diet.

The current study, based on the 2010 China Family Panel Studies, was aimed to identify the associations between dietary patterns obtained by PCA and cognitive ability.

Methods

Study population and ethical statement

Our study was a cross-sectional research, which data was sourced from the 2010 China Family Panel Studies (CFPS). The CFPS, funded by Peking University and carried out by the Institute of Social Science Survey (ISSS) of Peking University. The CFPS survey is a nearly nationwide, comprehensive, longitudinal social survey that is intended to serve research needs on a large variety of social phenomena in contemporary China. In the CFPS, the survey samples covered 25 provinces / municipalities / autonomous regions, and questionnaires include community, family, adult and children, which reflect the changes of society, economy, population, education and health. Details of the original study are reported elsewhere[11].

In the present study, we selected children aged 10–15 years as samples. After matching and screening of family, children and community databases, we excluded the individuals whose index values in the sample were unknown, rejected, not applicable and missing. Finally, 2,029 children with complete information were used in the analyses. The children were approximately equally divided by gender (49.3% boys, 50.7% girls). This study was conducted according to the guidelines laid down in the Declaration of Helsinki and all procedures involving human subjects were approved by the Ethics Committee of Peking University. Written informed consent was obtained from all subjects.

Dietary patterns

The diet was assessed using food frequency questionnaires (FFQ) administered by trained investigators at a face to face interview. Foods were divided into eight groups, including meat, aquatic products, fresh vegetables and fruits, milk and dairy products, beans and bean products, eggs, pickled food, puffed and fried food. The participants were given the following questions, whether they had eaten these foods during last month, how often, on average they had consumed these foods in the last month. Response to the food intake frequency was ranging from 'never, or less than once' to 'two times or more times' per week in the last month. If the answer was 'never' or 'not applicable' and less than once per week, it was recorded as 0 times and 1 times, respectively. Two times or more times per week was recorded as accordingly times. We used principal component analysis (PCA)[12] to identify dietary patterns. The analysis was limited to factors with an eigenvalue > 1, factor loadings ≥ 0.40 and variance rotation was used to improve the separation of the factors. In the study, the quartile (Quartile, Q) according to the factor score could be divided into four groups, which represented the different degrees of the dietary pattern score, Q1 presented the lowest level and Q4 presented the highest level.

Cognitive ability

Cognitive ability tests usually include the measurement of language ability, memory ability, computing ability, reasoning ability, decision-making ability, spatial ability and so on. American psychologist Cattell divided cognitive ability into two components, fluid intelligence and crystalized intelligence[13]. Fluid intelligence is based on neurophysiological development, such as perception, memory and so on. Fluid intelligence is the basis of the development of crystal intelligence. Crystal intelligence refers to the skills acquired through the accumulation of acquired knowledge and experience, such as vocabulary, calculation, speech understanding, common sense and so on. The CFPS 2010 used vocabulary test and mathematics test as measurement tools to collect the participants' crystal intelligence scores: vocabulary scores and mathematical scores[11, 14].

The vocabulary test consists of thirty-four Chinese characters drawn from the language textbooks used in primary and secondary schools and sorted in ascending order of difficulty. The test seeks to measure one's vocabulary by how difficult a character he or she can recognize. To make the test more efficient, respondents were assigned to one of three entry points, based on their self-reported highest level of education. Respondents were asked to recognize the increasingly difficult characters one by one until they failed to recognize three consecutive characters. The final test score would be the rank order of the last character that a respondent correctly recognized and the score was ranged from 0(lowest score) to 34(highest score).

Similarly, the mathematics test consists of twenty-four mathematical questions. Again, respondents were assigned to one of three entry points, based on their highest level of education. The test continued until a respondent failed to answer three consecutive problems. The test score was assigned using the same rank order rule as that in the vocabulary test and recorded from 0 (lowest score) to 24 (highest score)[15]. In the study, the quartile (Quartile, Q) according to the vocabulary test score could be divided into four levels, 0 ~ 17(Q1), 18 ~ 22(Q2), 23 ~ 26(Q3) and 27 ~ 34(Q4). Similarly, the mathematics test score could also be divided into four levels, 0 ~ 8(Q1), 9 ~ 11(Q2), 12 ~ 14(Q3) and 15 ~ 24(Q4).

Covariates

We considered sociodemographic and family characteristics as covariates. These included gender, age, nationality, household registration, school, parents' educational level, family education environment, family income, family size. Age ranged from 10 to 15. Nationality was characterized into two categories: Han nationality and minority nationality. Household registration included urban and countryside. Parents' educational level were categorized into three groups: (a) low (finished primary school or less); (b) medium (finished junior middle school but did not complete the tertiary entrance exam); (c) high (finished the tertiary entrance exam or higher). Family education environment: (a) good; (b) neutrality; (c) bad. Family annual income (per capital) was categorized into three categories: <3,500RMB; 3,500 ~ 7,000RMB; >7,000RMB. Family size included 3 ~ 6 persons and 7 ~ 14 persons. Data of family characteristics was obtained from children, family and urban questionnaire.

Statistical analysis

The data were initially analyzed to generate descriptive statistics. PCA with varimax rotatio was performed on the standardised food items. The methods have been described in detail elsewhere[10]. Foods with loadings above 0.4 were thought to be strongly associated with the component and were considered to be the most informative food in describing the dietary patterns. Labels were given to different components, though these do not perfectly describe each underlying pattern, they help in reporting and discussion of the results. Cognitive ability was assessed using the mathematics and vocabulary test in the 2010 CFPS. Firstly, we analyzed the associations between covariates and cognitive ability by using the chi-square test. Then, Ordinal-Logistic regression were used to analyze the associations between covariates, dietary patterns and cognitive ability. Finally, we built three models using Ordinal-Logistic regression to evaluate the relationships between dietary patterns and cognitive ability. In model one, we adjusted for gender, age, nationality, household register to ensure that outcomes were independent of children and adolescents common characteristics. In model two, we additionally adjusted for school types, parents' educational level. In model three, except variables that included in model one and two, we additionally adjusted for family characteristics, family education environment, family annual income and family size. All analysis was performed using STATA13.0.

Results

Characteristics of the study sample

Table 1 showed the general characteristics of the participants. Approximately half of the participants were girls (50.7%, n = 1,001), and most of them were Han nationality (88.4%, n = 1,794). Nearly 60.0% participants came from countryside.

Table 1
Descriptive statistics of participants in the sample (n = 2029)

	Number	**Percentage(%)**
Gender		
Girl	1001	50.7
Boy	1028	49.3
Age		
10	342	16.9
11	348	17.2
12	325	16.0
13	320	15.8
14	334	16.5
15	360	17.7
Nationality		
Minority nationality	235	11.6
Han nationality	1794	88.4
Household registration		
Countryside	1228	60.5
Urban	801	39.5
School		
Common school	1940	95.6
Key school	89	4.4
Father education level Low Medium High	935 973 121	46.1 48.0 6.0
Mother education level Low Medium High	1245 693 91	61.4 34.2 4.5
Family education environment Bad Neutrality Good	195 877 957	9.61 43.22 47.17
Family annual income (per person) <3500RMB 3500 ~ 7000RMB >7000RMB	680 696 653	33.5 34.3 32.2
Family size 3 ~ 6 7 ~ 14	1822 207	89.8 10.2
Mathematics test(score) 0–8 9–11 12–14 14–24	536 476 536 481	26.4 23.5 26.4 23.7
Vocabulary test(score) 0–17 18–22 23–26 27–34	486 504 462 577	24.0 24.8 22.8 28.4

Dietary patterns of study participants

Table 2 presented the factor loadings of different dietary patterns. Three dietary patterns were extracted and labeled as ‘High protein’, ‘High fat’ and ‘High salt-oil’ dietary pattern. Foods that loaded highly on the ‘High protein’ dietary pattern were milk, dairy products, eggs, beans and bean products. Meat and aquatic product loaded highly on the ‘High fat’ dietary pattern. Pickled food, puffed and fried food loaded highly on the ‘High salt-oil’ dietary pattern.

Table 2
Factor loadings of three dietary patterns

meat	0.0261	0.6531[a]	0.0189
aquatic products	-0.0321	0.6523[a]	-0.1367
vegetables and fruits	0.0031	0.3687	0.3287
milk and dairy products	0.5713[a]	0.0485	-0.0633
bean and bean products	0.5605[a]	-0.0514	0.0791
eggs	0.5851[a]	-0.0076	-0.0528
pickled food	-0.0547	-0.0751	0.7632[a]
puffed and fried food	0.1111	0.0375	0.5266[a]
a: dietary pattern factor loadings ≥ 0.4			

Influencing factors of cognitive ability: results from Chi-square test

Table 3 displayed the chi-square test results of the associations between children's cognitive ability and its influencing factors. In the cognitive ability test, there was a statistically significant correlation between mathematics scores and age, nationality, household registration, family educational environment, school, parents educational level, family income, family size($P < 0.05$), except gender($P > 0.05$). In addition, there was a statistically significant correlation between vocabulary scores and all variables ($P < 0.05$).

Table 3
Chi-square test for influencing factors of 10 to 15 year-old children’s cognitive ability

Variables	Mathematics test scores				χ^2	P value	Vocabulary test scores				χ^2
	Q1[0–8] n(%)	Q2[9–11] n (%)	Q3[12–14] n (%)	Q4[15–24] n (%)			Q1[0–17] n (%)	Q2[18–22] n (%)	Q3[23–26] n(%)	Q4[27–34] n (%)	
n	536	476	536	481			486	504	462	577	
Gender											
Girl	271(50.6)	226(47.5)	27(50.4)	234(48.6)	1.299	0.729	208(42.8)	237(47.0)	233(50.4)	323(56.0)	19.798
Boy	265(49.4)	250(52.5)	26(49.6)	247(51.4)			278(57.2)	267(53.0)	229(49.6)	254(44.0)	
Age											
10	224(41.8)	106(22.3)	9(1.7)	3(0.6)	1.4e + 03	< 0.001	180(37.0)	97(19.3)	43(9.3)	22(3.8)	485.985
11	147(27.4)	161(33.8)	36(6.7)	4(0.8)			125(25.7)	107(21.2)	76(16.5)	40(6.9)	
12	87(16.2)	115(24.2)	100(18.7)	23(4.8)			80(16.5)	98(19.4)	78(16.9)	69(12.0)	
13	46(8.6)	60(12.6)	161(30.0)	53(11.0)			49(10.1)	77(15.3)	87(18.8)	107(18.5)	
14	18(3.4)	22(4.6)	144(26.9)	150(31.2)			22(4.5)	66(13.1)	99(21.4)	147(25.5)	
15	14(2.6)	12(2.5)	86(16.0)	248(51.6)			30(6.2)	59(11.7)	79(17.1)	192(33.3)	
Nationality											
Minority nationality	439(81.9)	412(86.6)	495(92.4)	448(93.1)	42.395	< 0.001	104(21.4)	65(12.9)	36(7.8)	30(5.2)	76.023
Han nationality	97(18.1)	64(13.4)	41(7.6)	33(6.9)			382(78.6)	439(87.1)	426(92.2)	547(94.8)	
Household registration											
Countryside	386(72.0)	277(58.2)	313(58.4)	252(52.4)	45.037	< 0.001	340(70.0)	327(64.9)	272(58.9)	289(50.1)	48.945
Urban	150(28.0)	199(41.8)	223(41.6)	229(47.6)			146(30.0)	177(35.1)	190(41.1)	288(49.9)	
School											
Common school	525(98.0)	466(97.9)	505(94.2)	444(92.3)	27.921	< 0.001	476(97.9)	495(98.2)	447(96.8)	522(90.5)	52.271
Key school	11(2.0)	10(2.1)	31(5.8)	37(7.7)			10(2.1)	9(1.8)	15(3.2)	55(9.5)	
Family educational environment											
Bad	79(40.5)	36(18.5)	58(29.7)	22(11.3)	56.343	< 0.001	68(34.9)	50(25.6)	49(25.1)	28(14.4)	61.321
Neutrality	261(29.8)	203(23.2)	221(25.2)	192(21.9)			240(27.4)	238(27.1)	176(20.1)	223(25.4)	
Good	196(20.5)	237(24.8)	257(26.9)	267(27.9)			178(18.6)	216(22.6)	237(24.8)	326(34.1)	
Father education level											
Low	309(57.7)	211(44.3)	244(45.5)	171(35.5)	90.999	< 0.001	286(58.9)	246(48.8)	207(44.8)	196(34.0)	116.108
Medium	211(44.3)	237(49.8)	260(48.5)	265(55.1)			186(38.3)	240(47.6)	227(49.1)	320(55.5)	
High	16(3.0)	28(5.9)	32(6.0)	45(9.4)			14(2.9)	18(3.6)	28(6.1)	61(10.6)	
Mother education level											
Low	405(75.6)	276(58.0)	305(56.9)	259(53.8)	119.648	< 0.001	361(74.3)	337(66.9)	271(58.7)	276(47.8)	156.641

Variables	Mathematics test scores				χ2	P value	Vocabulary test scores				χ2
	Q1[0–8] n(%)	Q2[9–11] n (%)	Q3[12–14] n (%)	Q4[15–24] n (%)			Q1[0–17] n (%)	Q2[18–22] n (%)	Q3[23–26] n(%)	Q4[27–34] n (%)	
Medium	116(21.6)	181(38.0)	209(39.0)	187(38.9)			116(23.9)	155(30.8)	170(36.8)	252(43.7)	
High	15(2.8)	19(4.0)	22(4.1)	35(7.3)			9(1.9)	12(2.4)	21(4.6)	49(8.5)	
Family annual income (per person)											
<3500RMB	244(45.5)	143(30.0)	155(32.6)	122(25.4)	67.300	< 0.001	208(42.8)	182(36.1)	145(31.4)	145(25.1)	55.669
3500 ~ 7000 RMB	167(31.2)	178(37.4)	190(35.5)	153(31.8)			163(33.5)	176(34.9)	158(34.2)	191(33.1)	
>7000 RMB	125(23.3)	155(32.6)	175(32.7)	206(42.8)			115(23.7)	146(29.0)	159(34.4)	241(41.8)	
Family size											
3 ~ 6	455(84.9)	425(89.3)	487(90.9)	455(94.6)	26.978	< 0.001	412(84.8)	445(88.3)	423(91.6)	542(93.9)	26.975
7 ~ 14	81(15.1)	51(10.7)	49(9.1)	26(5.4)			74(15.2)	59(11.7)	39(8.4)	35(6.1)	

Influencing factors of cognitive ability: results from Ordinal-Logistic regression

Table 4 showed the results of the Ordinal-Logistic regression for each variable compared with cognitive ability tests. Children with higher scores of ‘High protein’ dietary pattern had significantly higher odds of achieving higher performance in mathematics (OR = 1.28; CI: 1.21 ~ 1.35; P < 0.001) and vocabulary test (OR = 1.25; CI: 1.18 ~ 1.32; P < 0.001). However, the higher scores of ‘High fat’ and ‘High salt-oil’ dietary patterns were significantly related to the lower scores of vocabulary test(OR = 0.89; CI: 0.83 ~ 0.96; P = 0.002; OR = 0.91; CI: 0.84 ~ 0.98; P = 0.012). We failed to find a significant relationship between mathematics test score and ‘High fat’ or ‘High salt-oil’ dietary patterns.

Table 4
Ordinal-Logistic regression between cognitive ability test scores and covariates of children aged 10–15 years in the 2010 China Family Panel Studies.

Variables	Mathematics			Vocabulary		
	OR	P value	95%CI	OR	P value	95%CI
'High protein' dietary patterns	1.28	< 0.001	(1.21;1.35)	1.25	< 0.001	(1.18;1.32)
'Traditional' dietary pattern	0.96	0.287	(0.90;1.03)	0.89	0.002	(0.83;0.96)
'Western' dietary pattern	0.96	0.503	(0.90;1.05)	0.91	0.012	(0.84;0.98)
Gender						
Girl			0			0
Boy	1.02	0.763	(0.88;1.20)	0.70	< 0.001	(0.60;0.82)
Age						
10 ~ 15	2.93	< 0.001	(2.73; 3.13)	1.73	< 0.001	(1.64;1.82)
Nationality						
Minority nationality			0			0
Han nationality	2.23	< 0.001	(1.74;2.86)	2.97	< 0.001	(2.31;3.83)
Household registration						
Countryside			0			0
Urban	1.65	< 0.001	(1.40;1.93)	1.77	< 0.001	(1.51;2.08)
School						
Common school			0			0
Key school	2.68	< 0.001	(1.82; 3.94)	4.08	< 0.001	(2.66;6.27)
Family educational environment						
Bad			0			0
Neutrality	1.56	0.002	(1.18; 2.07)	1.46	0.007	(1.11; 1.93)
Good	2.26	< 0.001	(1.71; 2.99)	2.38	< 0.001	(1.81; 3.14)
Father education level						
Low			0			0
Medium	1.62	< 0.001	(1.38;1.91)	1.79	< 0.001	(1.52;2.10)
High	2.56	< 0.001	(1.81;3.60)	3.72	< 0.001	(2.60;5.31)
Mother education level						
Low			0			0
Medium	1.71	< 0.001	(1.45;2.02)	2.00	< 0.001	(1.69;2.37)
High	2.35	< 0.001	(1.59;3.47)	4.11	< 0.001	(2.73;6.16)
Family annual income(per person)						
<3500RMB			0			0
3500 ~ 7000 RMB	1.46	< 0.001	(1.20;1.76)	1.41	< 0.001	(1.16;1.70)
>7000 RMB	1.46	< 0.001	(1.71;2.53)	2.09	< 0.001	(1.72;2.54)
Family size						
7 ~ 14			0			0
3 ~ 6	1.97	< 0.001	(1.52;2.55)	1.98	< 0.001	(1.53;2.56)

Compared children with lower score of mathematics test, those with higher scores were older (OR = 2.93; CI: 2.73 ~ 3.13; P < 0.001), and most of them tended to be Han nationality (OR = 2.23; CI: 1.74 ~ 2.86; P < 0.001) and from urban (OR = 1.65; CI: 1.40 ~ 1.93; P < 0.001). Besides, they usually went to key school (OR = 2.68; CI: 1.82 ~ 3.94; P < 0.001) and had a higher recognition of family education environment (OR = 2.26; CI: 1.71 ~ 2.99; P < 0.001), and their parents had higher education (OR = 2.56; CI: 1.81 ~ 3.60; $P < 0.001$ for father education; OR = 2.35; CI: 1.58 ~ 3.47; $P < 0.001$ for mother education). Their families tended to have higher income (OR = 1.46; CI: 1.71 ~ 2.53; $P < 0.001$) and lived in a small family (OR = 1.97; CI: 1.52 ~ 2.55; $P < 0.001$). There was no significant difference between gender and mathematics test scores ($P > 0.05$). The proportion of boys with higher vocabulary score was lower than girls (OR = 0.70; CI: 0.60 ~ 0.82; $P < 0.001$). Moreover, associations between vocabulary test and age, nationality and others variables are similar to mathematics test.

Associations between dietary patterns and cognitive ability

In Table 5, it presented the relationship between cognitive ability and dietary patterns (both as continuous variables and quartiles). In model one, children with higher score of 'High protein' dietary patterns (continuous variable) was associated with higher mathematics (OR = 1.29; CI: 1.21 ~ 1.37; $P < 0.001$) and vocabulary (OR = 1.19; CI: 1.12 ~ 1.26; $P < 0.001$) test score. While, children with higher score of the 'High fat' dietary patterns (continuous variable) was associated with lower mathematics (OR = 0.89; CI: 0.82 ~ 0.96; $P = 0.004$) and vocabulary (OR = 0.85; CI: 0.78 ~ 0.91; $P < 0.001$) test score. However, children with higher score of the 'High salt-oil' dietary patterns (continuous variable) was only associated with lower scores of vocabulary test (OR = 0.90; CI: 0.83 ~ 0.98; $P = 0.012$).

Table 5
Ordinal-Logistic regression models of the association between 10 to 15 year-old children' cognitive ability test scores and dietary patterns (both as continuous variables and as quartiles).

Test	Dietary pattern	Quartile	Model one			Model two			Model three		
			OR	P value	95%CI	OR	P value	95%CI	OR	P value	95%CI
Mathematics		1.29	< 0.001	(1.21;1.37)	1.19	< 0.001	(1.11;1.27)	1.15	< 0.001	(1.07;1.23)	
		0.89	0.004	(0.82;0.96)	0.93	0.090	(0.86;1.01)	0.94	0.136	(0.86;1.02)	
		0.94	0.182	(0.87;1.03)	1.00	0.955	(0.92;1.09)	1.03	0.568	(0.94;1.12)	
Vocabulary		1.19	< 0.001	(1.12;1.26)	1.10	0.005	(1.03;1.17)	1.06	0.076	(0.99;1.13)	
		0.85	< 0.001	(0.78;0.91)	0.88	0.002	(0.82;0.95)	0.88	0.002	(0.82;0.96)	
		0.90	0.012	(0.83;0.98)	0.95	0.238	(0.88;1.03)	0.96	0.372	(0.89;1.05)	
Mathematics	Q1*			0			0			0	
		Q2*	1.20	0.151	(0.94;1.54)	1.10	0.449	(0.86;1.42)	1.06	0.664	(0.82;1.36)
		Q3*	2.09	< 0.001	(1.63;2.68)	1.80	< 0.001	(1.40;2.33)	1.67	< 0.001	(1.29;2.16)
		Q4*	2.47	< 0.001	(1.90;3.20)	1.84	< 0.001	(1.41;2.41)	1.62	0.001	(1.23;2.15)
	Q1*			0			0			0	
		Q2*	0.74	0.014	(0.58;0.94)	0.84	0.160	(0.66;1.07)	0.86	0.234	(0.67;1.10)
		Q3*	0.85	0.182	(0.67;1.08)	0.95	0.700	(0.75;1.22)	1.00	0.995	(0.78;1.28)
		Q4*	0.69	0.002	(0.54;0.87)	0.77	0.042	(0.61;0.99)	0.76	0.031	(0.59;0.98)
	Q1*			0			0			0	
		Q2*	0.58	< 0.001	(0.45;0.74)	0.66	0.001	(0.52;0.85)	0.73	0.013	(0.56;0.93)
		Q3*	0.55	< 0.001	(0.43;0.71)	0.68	0.003	(0.53;0.87)	0.75	0.028	(0.59;0.97)
		Q4*	0.76	0.028	(0.60;0.97)	0.91	0.431	(0.71;1.16)	0.99	0.915	(0.77;1.27)
Vocabulary	Q1*			0			0			0	
		Q2*	1.18	0.170	(0.93;1.48)	1.07	0.580	(0.85;1.35)	1.03	0.776	(0.82;1.31)
		Q3*	1.29	0.036	(1.02;1.63)	1.10	0.438	(0.87;1.40)	1.03	0.809	(0.81;1.31)
		Q4*	1.82	< 0.001	(1.43;2.33)	1.36	0.017	(1.06;1.75)	1.21	0.149	(0.93;1.58)
	Q1*			0			0			0	
		Q2*	0.94	0.622	(0.75;1.19)	1.03	0.778	(0.82;1.31)	1.06	0.624	(0.84;1.34)
		Q3*	0.85	0.165	(0.68;1.07)	0.94	0.627	(0.75;1.19)	0.97	0.780	(0.76;1.22)
		Q4*	0.69	0.002	(0.55;0.87)	0.78	0.036	(0.62;0.98)	0.77	0.029	(0.61;0.97)
	Q1*			0			0			0	
		Q2*	0.65	< 0.001	(0.51;0.81)	0.75	0.016	(0.59;0.95)	0.80	0.064	(0.63;1.01)
		Q3*	0.67	0.001	(0.53;0.85)	0.82	0.101	(0.65;1.04)	0.88	0.305	(0.69;1.12)
		Q4*	0.75	0.014	(0.59;0.94)	0.87	0.269	(0.69;1.11)	0.93	0.544	(0.73;1.18)

* Q1 = lowest level; Q4 = highest level; Model one includes: gender, age, nationality, household registration; Model two includes: variables in model 1 + school, mother education, father education; Model three includes: variables in model 2 + family education environment, family income, family size.

In model two, these results remained significant with respect to the 'High protein' dietary patterns (continuous variable) (OR = 1.19; CI: 1.11 ~ 1.27; P < 0.001 for mathematics test; OR = 1.10; CI: 1.03 ~ 1.17; P = 0.005 for vocabulary), but children with higher score of the 'High fat' dietary patterns (continuous variable) was only associated with lower vocabulary scores (OR = 0.88; CI: 0.82 ~ 0.95; P = 0.002), and cognition test scores were no longer significant for the 'High salt-oil' dietary patterns (continuous variable).

With respect to model three, children with higher score of the 'High protein' dietary patterns (continuous variable) was associated with higher mathematics test scores (OR = 1.15; CI: 1.07 ~ 1.23; P < 0.001). The higher score of the 'High fat' dietary patterns (continuous variable) was associated with lower scores for vocabulary test (OR = 0.88; CI: 0.82 ~ 0.96; P = 0.002), and there was no significance between cognition test and the 'High salt-oil' dietary patterns (continuous variable). When dividing the ‘High protein’, ‘High fat’ and ‘High salt-oil’ dietary patterns into four quartiles, the results were similar to the previously described associations between the continuous dietary pattern scores and cognitive ability outcomes.

Discussion

Based on the present study, we examined the associations between children’s dietary patterns and cognitive ability. We found that child with higher score of the ‘High protein’ dietary pattern was associated with better cognitive ability. However, children with higher score for the ‘High fat’ dietary pattern was associated with poorer cognitive ability. Thus, it is of great importance for families to select a suitable dietary pattern.

Sociodemographic Characteristics And Cognitive Ability Of Children

The current study indicated that parents’ higher education and better family education environment were related to higher cognition of children. A study reported that the parent’s educational level can interpreter 19% of the children’s intelligence variation[16] and children whose parents had higher educational level were more likely to get higher IQ scores[17, 18]. In addition, parents with higher degree of education usually pay more attention to children’s education, and they would more consciously cultivate their children and promote children’s cognition[18].

This study found that children who live in the rural areas and lived in a larger family tend to have lower cognitive ability. The reason might be that in the rural areas or in a lager family, many families live a poor life and parents might contribute less to their children’s school performance, children would get less educational resources and then have a poorer performance in cognition[19, 20]. Our discussion of the relationship between family annual income levels and cognition also support this view, similar to that found in Australia and America[21, 22]. In our study, about half of the parents just finished primary school or less and 33.5% children whose family annual income were less than 3,500RMB per person. According to these results, although our country is developing and making progress, the education and overall economic level of the country still needs to be improved.

Diet And Cognitive Ability Of Children

Cognitive ability has been shown to be affected by a good diet (such as fish[5] and milk[23]) and a bad diet (such as French fries, hot dogs, drinks, red meat[24, 25]). These previous reports were basically consistent with our current findings that showed relationships of ‘High protein’ and ‘High fat’ dietary pattern and children’s cognition.

In current study, children with higher score of ‘High protein’ dietary pattern had higher intake of milk, dairy products, beans, bean products and eggs, and usually got higher cognitive ability scores. Studies in Kenya and South Korean both showed higher milk and dairy products intake was associated with better academic achievement[23, 26]. Besides, previous study on Korean adolescents showed that higher milk consumption could also improve overall nutritional status[27]. Childhood is a period of rapid growth and development of children, and the demanding of nutrition is the highest in the whole life. It is necessary to meet the intake of protein, especially high-quality protein. Milk, beans and eggs are the source of high-quality protein and play an important role in three meals a day. Research and analysis of food consumption of Chinese residents found that the annual consumption of milk, bean, eggs and other food is increasing, but there is still a considerable gap between people actual intake of milk, beans and eggs and the recommended amount of Chinese dietary guideline[28, 29].

In addition, this study showed that ‘High fat’ dietary pattern was related to poorer cognitive ability and this might because children had higher intake of red meat or refined meat. In recent years, the contradiction between food consumption and demand of Chinese is mainly manifested in the excessive supplement of grain and meat but the shortage of milk, beans, eggs, fruits and other food, besides, the consumption of meat has approached the maximum recommended intake of 75 g in the Chinese dietary guidelines[28, 29]. A study reported that ‘Western’ dietary pattern at the age of 14 (high intake of takeout foods, red and processed meat, soft drinks, fried and refined foods) has a negative impact on the cognitive performance of 17-year-olds[30]. Furthermore, red meat contains more saturated fatty acids, and excessive intake of saturated fatty acids may have a negative effect on cognition.

Strengths And Limitations

One of the strengths was that we used dietary patterns as a whole to analyze their effects on cognitive ability instead of analyzing the effects of a single food or nutrient on cognitive ability. In addition, the cognitive ability test in CFPS 2010 was based on the educational level of the interviewees to choose the corresponding starting point of the answer questions and the test questions were based on primary and secondary school textbooks. The results of these tests were reliable and could be used as a means to determine the level of cognitive ability. Furthermore, we were able to adjust and analyze for a series of family socioeconomic covariates and the characteristics of children that may have represented confounding factors.

A limitation of the study was that CFPS 2010’s annual diet data were limited to the frequency for each type food and could not be quantitatively calculated, this might result in poorer accuracy of the dietary results. Another was that we just analyzed the data of CFPS 2010 and it was a cross-section study. However, the findings could be valuable to provide directed public health messaging and interventions. Finally, we acknowledged that we failed to rule out the possibility of other confounding factors that we were not able to adjust in the analysis, and which might have been important driver of cognitive ability.

Conclusions

In this study, we have identified the ‘High protein’ dietary pattern as a favorable factor for promoting cognitive ability while the ‘High fat’ dietary pattern as a risk factor for the cognitive ability. Both childhood and adolescence are sensitive periods of brain development and vulnerable periods of nutrition in life, therefore, public health policies and health promotion programs should realize the significant of targeting the food intake during these periods of individual growth and development. So far, few studies have reported the relationships between dietary patterns and cognitive ability, more prospective studies are needed to support our findings.

Declarations

Ethics approval and consent to participate

This study was conducted according to the guidelines laid down in the Declaration of Helsinki. All procedures involving human subjects were approved by the Ethics Committee of Peking University. Written informed consent was obtained from all subjects.

Consent for publication

Not applicable

Availability of data and materials

The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

Competing interests

The authors declare that they have no competing interest.

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Authors' contributions

JZ designed the study; TW and DL performed statistical analyses; QJ collected the data; TW and FC wrote the original draft; JZ, TW and SC reviewed and edited the manuscript. All authors read and approved the final manuscript.

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