Association 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

Keywords: Children, dietary pattern, cognitive ability, China Family Panel Studies

Posted Date: June 2nd, 2020

DOI: https://doi.org/10.21203/rs.3.rs-19766/v2

Abstract

Background: At present, limited information is available concerning the association between dietary patterns and cognitive ability during childhood and adolescence, especially in regards to the epidemiological studies in China. Therefore, This study aimed to analyze the association between dietary patterns and cognitive ability in 10 to 15 year-old Chinese children.

Methods: The dietary information, cognitive ability and sociodemographic data of 2029 children were retrieved from the 2010 China Family Panel Studies (CFPS). Dietary patterns were assessed by principal component analysis (PCA). The association between dietary patterns and cognitive ability was determined using Ordinal-Logistic regression models.

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

Conclusions: The findings of this study indicate that 'High protein' pattern is positively associated with cognitive ability in Chinese children, while 'High fat' pattern exhibits a negative association.

Background

The cognitive ability of children has always been a key focus of public health researchers. Children's school performance usually affects their future education, which ultimately determines their socio-economic status. In turn, education is closely associated with health and healthy behavior [1]. Hence, more attention should be paid to the factors that influence academic achievement during childhood and adolescence.

Nutrition is one of the most important and changeable environmental factors that can affect brain development, cognition ability and academic performance. Adolescence is a key period of brain and cognitive development, mainly due to its various developmental stages regulated by some common and independent biological processes, and this period is more fragile and adjusted [2]. Several studies have investigated how nutrition influences the changes in brain and cognitive development during childhood and adolescence. In Norway, frequent lunch and dinner are positively correlated with teenagers' math learning, while high intakes of pizza, sausages, candy, snacks and soft drinks are positively correlated with self-reported math learning difficulties [3]. On the contrary, regular breakfast consumption is negatively correlated with learning difficulties in mathematics, reading and writing [3]. Besides, regular meals [4] and high intake of fish [5] have been associated with improved cognitive performance. In addition, children with malnutrition or insufficient nutrient intake are likely to have learning restrains and developmental disabilities compared to those who ate sufficient food [6, 7]. As for the effect of nutritional status on children's cognitive ability, malnourished children often exhibit lower academic performance in school than well-nourished children[8]. However, limited information is available concerning the association between dietary patterns and cognitive ability during childhood and adolescence.

The evaluation of a single food or nutrient often ignores their complex interactions, thus may not reflect the total diet consumed by an individual [9, 10]. We do not consume only one type of food, but instead of a combination of foods at every meal. Therefore, it is important to assess the whole foods diet. In principal components analysis (PCA), complex diet and multiple food groups are taken into account for pattern classification, rather than individual nutrients or specific foods or food groups. Therefore, dietary pattern analysis can be used to reflect the complexity of dietary intake and provide insights into the whole foods diet.

The aim of this study was to investigate the association between dietary patterns (obtained by PCA) and cognitive ability in 10-15 year-old Chinese children.

Methods

Study population and ethical statement

This was a cross-sectional research, in which the data source was retrieved from the 2010 China Family Panel Studies (CFPS). The CFPS survey has been carried out by Peking University. It is a nearly nationwide, comprehensive, longitudinal social survey that is intends to serve research needs on a large variety of social phenomena in contemporary China. In that survey, the study participants were recruited form 25 provinces / municipalities / autonomous regions, and the questionnaires included diverse communities, families, adults and children, which can reflect the changes of society, economy, population, education and health. Details of the original study have been reported elsewhere [11].

In the present study, we selected children aged 10-15 years as target samples. After matching and screening against children, family and community databases, we excluded the individuals whose index values 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 vs. 50.7% girls). This study was conducted in accordance with the ethical 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.

Classification of dietary patterns

The dietary patterns were assessed using whit a food-frequency questionnaire (FFQ) administered by trained investigators during face-to-face interview. Foods were divided into eight groups, meat, aquatic products, fresh vegetables and fruits, milk and dairy products, beans and bean products, eggs, pickled food, and puffed and fried food. All participants were given the following questions: (i) whether they had eaten these eight groups of foods during the last three months, and (ii) the average frequency of eating these foods per week for the past three month. Responses to the food intake frequency were 'never', 'less than once', '2 times', and 'more than 2 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 and 1, respectively. 2 times or more 2 times per week were recorded according to their respective numbers. Next, PCA method was used to identify major dietary patterns [12]. The analysis was limited to factors with an eigenvalue of >1 and a standardized loading of≥0.40. Then, variance rotation was employed to improve the separation of the factors. Finally, the factor scores were divided into four quartiles(Q) groups, in which Q1 presented the lowest level of dietary pattern score and Q4 presented the highest level of dietary pattern score.

Evaluation of cognitive ability

Cognitive ability tests usually included the measurement of language ability, memory ability, computing ability, reasoning ability, decision-making ability, spatial ability and so on. The American psychologist Cattell has divided cognitive ability into two components: fluid intelligence and crystalized intelligence [13]. Fluid intelligence is on the basis of neurophysiological development, such as perception, memory and so on. 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 applied both vocabulary and mathematics tests as measurement tools to collect the crystal intelligence scores of study participants [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, survey respondents were assigned to one of three entry points, based on their self-reported highest level of education. The respondents were asked to recognize the increasingly difficult characters one by one until they failed to recognize three consecutive characters. The final test score was based on the rank order of the last character recognized by each respondent and the scores were ranged from 0(lowest) to 34(highest). Lastly, the test scores were categorized into four quartile (Q) groups: 0~17 (Q1), 18~22 (Q2), 23~26 (Q3) and 27~34 (Q4).

The mathematics test consists of twenty-four mathematical questions. The procedures for the mathematics test were similar to those mentioned above. The test score was assigned using the same rank-order rule as that in the vocabulary test, and recorded from 0 (lowest) to 24 (highest) [15]. As similar to the vocabulary test, the mathematics test scores were also categorized into four quartile (Q) groups: 0~8(Q1), 9~11(Q2), 12~14(Q3) and 15~24(Q4).

Covariates

Sociodemographic and family characteristics were considered as covariates, including gender, age, nationality, household registration, school types, parents' educational level, family learning environment, annual household income, and family size. Nationality was classified into two categories: Han nationality and minority nationality. Household registration included urban and countryside. Parents' educational levels were categorized into three groups: (a) low (completed primary school or less); (b) medium (completed junior middle school but did not undergo the tertiary entrance exam); and (c) high (had taken the tertiary entrance exam or higher). Family learning environment was classified as (a) good; (b) neutrality; and (c) bad. Annual household income (per capital) was divided into three groups: <3,500RMB; 3,500~7,000RMB; and >7,000RMB. Family size included 3~6 persons and 7~14 persons. The data of family characteristics were obtained from children, family and urban questionnaire.

Statistical analysis

The data were initially analyzed to generate descriptive statistics. PCA with varimax rotation was performed on the standardized food items. This method has been described in detail elsewhere [10]. Foods with factor loadings above 0.4 were thought to be strongly associated with the component, and were considered as the most informative variable for describing the dietary patterns. Labels were given to different components, even though these do not perfectly describe each underlying pattern. Indeed, they help in reporting and discussion of the results. Cognitive ability was assessed using both mathematics and vocabulary tests in the 2010 CFPS. Firstly, we analyzed the association between covariates and cognitive ability by using the chi-square test. Then, Ordinal-Logistic regression was used to determine the associations among covariates, dietary patterns and cognitive ability. Finally, three models were constructed using the Ordinal-Logistic regression method in order to confirm the relationships between dietary patterns and cognitive ability. In model ▯, we adjusted for gender, age, nationality and household registration to ensure that outcomes were independent of the common characteristics of children and adolescents. In model ▯, we further adjusted for school types and parents' educational level. In model ▯, except the variables that included in model ▯ and ▯, we additionally adjusted for family characteristics, family learning environment, annual household income and family size. All analyses were carried out using STATA 13.0. A p value of < 0.05 was considered statistically significant.

Results

Characteristics of the study subjects

Table 1 shows 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% of participants (n=1,228) came from countryside.

Table 1. Descriptive statistics of the participants (n=2029) in this study.

	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 [a]		
Low	935	46.1
Medium	973	48.0
High	121	6.0
Mother education level [a]		
Low	1245	61.4
Medium	693	34.2
High	91	4.5
Family learning environment		
Bad	195	9.61
Neutrality	877	43.22
Good	957	47.17
Annual household income (per person)		
<3500RMB	680	33.5
3500~7000RMB	696	34.3
>7000RMB	653	32.2
Family size		
3~6	1822	89.8
7~14	207	10.2
Mathematics test (score)[b]		
0-8	536	26.4
9-11	476	23.5
12-14	536	26.4
14-24	481	23.7
Vocabulary test (score)[c]		
0-17	486	24.0
18-22	504	24.8
23-26	462	22.8
27-34	577	28.4

[a] Education level: low (completed primary school or less); medium (completed junior middle school but did not undergo the tertiary entrance exam); and high (had taken the tertiary entrance exam or higher).
[b] The scores of mathematics test were ranged from 0 to 24.
[c] The scores of vocabulary test were ranged from 0 to 34.

Dietary patterns of the study participants

Table 2 presents the factor loadings of different dietary patterns. Three dietary patterns were identified 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 products were loaded highly on the ‘High fat’ dietary pattern. Pickled food, as well as puffed and fried food were loaded highly on the ‘High salt-oil’ dietary pattern.

Table2. Factor loadings of the three dietary patterns [a].

[a] Dietary pattern factor loadings≥0.4.
[b] ‘High protein’ dietary pattern (e.g., milk and dairy products, bean and bean products and eggs).
[c] ‘High fat’ dietary pattern (e.g., meat and aquatic products).
[d] ‘High salt-oil’ dietary pattern (e.g., pickled food, puffed and fried food).

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

Food group	‘High protein’ [b]	‘High fat’ [c]	‘High salt-oil’ [d]
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]

Table 3 displays the chi-square test results for the association between children’s cognitive ability and its influencing factors. In the cognitive ability test, there were statistically significant relationships between mathematics scores and all variables (P<0.05), except for gender(P>0.05). Similarly, there were statistically significant relationships between vocabulary scores and all variables (P<0.05).

Table 3.Influencing factors for the cognitive ability of 10 to 15 year-old children.

Variables	Mathematics test scores [a]				c^2	*P* value	Vocabulary test scores [a]				c^2	*P* value
	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	<0.001
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	<0.001
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	<0.001
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	<0.001
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	<0.001
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 learning 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	<0.001
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	<0.001
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	<0.001
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)		
Annual household 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	<0.001
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	<0.001
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)		

[a] Q=Quartile; Q1 represented 0% to 25%, Q2 represented 25% to 50%, Q3 represented 50% to 75%, and Q4 represented 75% to 100%.

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

As shown in Table 4, there was a significant positive relationship between ‘High protein’ dietary pattern and mathematics /vocabulary test scores. The results revealed that a 1-unit increase in ‘High protein’ dietary pattern scores was associated with a 1.28-fold (CI: 1.21~1.35) increase in children’s mathematics test scores or a 1.25-fold (CI: 1.18~1.32) increase in children’s vocabulary test scores. In contract, there were significant inverse relationships between ‘High fat’ (OR=0.89, CI: 0.83~0.96; P=0.002) and ‘High salt-oil’ (OR=0.91, CI：0.84~0.98; P=0.012) dietary patterns and vocabulary test scores. The findings of Ordinal-Logistic regression for the influencing factors associated with children’s cognitive ability were similar to those of chi-square test.

Table 4. Ordinal-Logistic regression between cognitive ability test scores and covariates of children aged 10-15 years in the 2010 CFPS.

Association between dietary patterns and cognitive ability

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)
'High fat' dietary pattern	0.96	0.287	(0.90;1.03)	0.89	0.002	(0.83;0.96)
' High salt-oil ' 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 learning 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)
Annual household 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)

Table 5 demonstrates the relationship between cognitive ability and dietary patterns (both as continuous variables and quartiles) in three models. An increase in 'High protein' dietary pattern score (continuous variable) was associated with higher mathematics test scores, and the results were similar for crude model (OR=1.29, CI: 1.21~1.37; P<0.001) and fully adjusted model (OR=1.15, CI: 1.07~1.23; P<0.001). The association between 'High protein' dietary pattern and vocabulary test scores was statistically significant in the first two models, but not in model ▯(OR=1.06, CI: 0.99~1.13; P=0.076). While, an increase in 'High fat' dietary pattern score (continuous variable) was significantly associated with lower scores of mathematics test in crude model (OR=0.89, CI: 0.82~0.96; P =0.004) and vocabulary test in the three models (OR=0.88, CI: 0.82~0.96; P=0.002 in model ▯). However, children with higher scores of 'High salt-oil' dietary pattern (continuous variable) tended to have lower scores of vocabulary test in model▯(OR=0.90, CI: 0.83~0.98; P=0.012).

When dividing the 'High protein', 'High fat' and 'High salt-oil' dietary patterns into four quartiles, the results obtained were similar to the above-described associations between continuous dietary pattern scores and cognitive ability outcomes.

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 quartiles).

Test	Dietary pattern	Quartile	Model ▯[a]			Model ▯[b]			Model ▯[c]		
			OR	*P* value	95%CI	*OR*	*P* value	95%CI	*OR*	*P* value	95%CI
Mathematics	'High protein'		1.29	<0.001	(1.21;1.37)	1.19	<0.001	(1.11;1.27)	1.15	<0.001	(1.07;1.23)
	'High fat'		0.89	0.004	(0.82;0.96)	0.93	0.090	(0.86;1.01)	0.94	0.136	(0.86;1.02)
	'High salt-oil'		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	'High protein'		1.19	<0.001	(1.12;1.26)	1.10	0.005	(1.03;1.17)	1.06	0.076	(0.99;1.13)
	'High fat'		0.85	<0.001	(0.78;0.91)	0.88	0.002	(0.82;0.95)	0.88	0.002	(0.82;0.96)
	'High salt-oil'		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	'High protein'	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)
	'High fat'	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)
	'High salt-oil'	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	'High protein'	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)
	'High fat'	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)
	'High salt-oil'	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)

[a]Model includes: gender, age, nationality, household registration.
[b]Model includes: variables in model 1+ school type,, mother education, father education.
[c]Model includes: variables in model 2 + family education environment, family income, family size.

Discussion

In the present study, we found that children with higher scores of ‘High protein’ dietary pattern tended to associated with better cognitive ability. However, children with higher score for the ‘High fat’ dietary pattern were associated with poorer cognitive ability. Thus, it is of great importance for families to select a proper dietary pattern.

Sociodemographic Characteristics and Cognitive Ability of Children

Our findings indicated that parents’ higher education levels and better family learning environment were related to children’s higher cognition scores. Previous studies have reported that parent’s educational status can indicate 19% of the variance in children’s intelligence [16], and children whose parents have higher levels of education are more likely to achieve higher IQ scores [17, 18]. In addition, parents with higher education level usually pay more attention to early childhood education, and they would cultivate their children more concertedly, thus promoting children’s cognitive development [18].

Besides, this study found that children who live in rural areas and a large family tended to have diminished cognitive ability. The reason might be that child poverty is more common among rural communities and large families. In poor household, parents are less engaged in their children’s school performance, thus children may suffer from less educational resources and subsequently have poorer cognitive outcomes [19, 20]{Lynn, 2013 #27}. Our findings of the relationship between annual household income and cognition ability also support this view, which are consisted with those found in Australia and America [21, 22]{Duncan, 2014 #21}{[{Duncan, 2014 #21}]}. In our study, about half of the parents had completed primary school or less, and 33.5% children lived in household with an annual income of less than 3,500 RMB per person. According to these results, although our country is developing and making great progress, the economic status and educational attainment still need to be improved substantially.

Dietary patterns and Cognitive Ability of Children

Cognitive ability has been shown to be affected by a good diet (e.g., fish and milk) [5, 23] and a bad diet (e.g., French fries, hot dogs, soft drinks and red meat) [24, 25]. These findings basically consistent with our results showing the significant associations between ‘High protein’ and ‘High fat’ dietary patterns and children’s cognition ability.

It was found that children with higher score of ‘High protein’ dietary pattern had higher intakes of milk, dairy products, beans, bean products and eggs, and often achieved higher cognitive ability scores. Previous studies in Kenya and South Korea both demonstrated that higher intake of milk and dairy products was associated with better academic achievement [23, 26]. Besides, another study on Korea adolescents showed that higher milk consumption could also improve overall nutritional status [27]. Childhood or preadolescence is a period of rapid growth and development, in children, and the demanding of nutrition is the highest throughout their whole life. Therefore, it is necessary to meet the intake of protein, especially high-quality protein. Milk, beans and eggs are the major sources of high-quality protein, which play an important role in the daily three meals. The analysis of food consumption patterns in China has revealed that the annual consumption of milk, bean, eggs and other food is increasing, but there is still a considerable gap between the 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, which might be attributed to the fact that children had higher intake of red meat or refined meat. In recent years, the contradiction between food supply and demand in China is not only manifested by the excessive production of grain and meat, but also the shortage of milk, beans, eggs, fruits and other food products. Specifically, the consumption of meat has approached the maximum recommended intake of 75g according to the Chinese dietary guidelines [28, 29]. A study has 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) exerts 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 confer a negative effect on cognition ability.

Strengths and Limitations

One of the strengths was that we used three dietary patterns as a whole to analyze their effects on cognitive ability, rather than analyzing the effect of a single food or nutrient. 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 for a series of family socioeconomic covariates and children’s characteristics that may have represented confounding factors.

A limitation of this study was that CFPS 2010’s annual diet data were limited to the frequency on consumption of each food and could not be quantitatively measured, which might result in poorer accuracy of the dietary pattern results. Another was that we only analyzed the data of CFPS 2010 and it was a cross-sectional study. Despite that, our findings could provide valuable information to help develop public health messages and interventions. Nevertheless, we acknowledged that we did not rule out the possibility of other confounding factors that are not adjusted in the analysis, which might have been important drivers of cognitive ability.

Conclusions

To sum up, ‘High protein’ dietary pattern was identified as a favorable factor for promoting children’s cognitive ability, while ‘High fat’ dietary pattern might serve as a risk factor. Both childhood and adolescence are the most sensitive periods of brain development and vulnerability to nutrient deficiency. Therefore, public health policies and health promotion programs should realize the importance of targeting food intake patterns during these critical periods.

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.

Funding

This work was supported by the Ministry of Education Foundation for Humanities and Social Sciences (No. 15YJAZH104).

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.

Acknowledgements

The authors gratefully acknowledge all the team members of Institute of Social Science Survey (ISSS) of Peking University.

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