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Effect of Eating Breakfast on Cognitive Development of Elementary and Middle School Students: An Empirical Study Using Large-Scale Provincial Survey Data

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Background: In existing research on the importance of student breakfast, few studies have focused on the impact of breakfast on student cognitive development. Further, empirical research in this field is mostly based correlation analysis, in which it is difficult to control the influence of selection bias on the analysis results.

Material/Methods: Here, we used student academic performance, based on the academic quality monitoring data of Jiangsu basic education students, as a proxy variable for cognitive development, and used both ordinary least-squares regression and propensity score matching methods to analyze the impact of eating breakfast on the cognitive development of primary and middle school students.

Results: We found that it is still common for students in primary and secondary schools to go without breakfast, and that this is even true in middle schools. Whether students eat breakfast is affected by many factors, and the frequency of eating breakfast has a significant positive impact on student achievement.

Conclusions: In primary school, students who eat breakfast every day in a week scored 31.322 points higher in academic performance than those who did not. In middle school, students who ate breakfast on time every day had significantly better academic performance (31.335 points higher) than those who did not eat breakfast every day. This indicates that eating breakfast every day has a significant effect on the cognitive development of students.

MeSH Keywords: Breakfast • Cognitive Science • Propensity Score

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Background

Adequate intake of healthy, nutritious food is a key factor in the physical and mental development of children. Children receiving better nutrition have better physical and mental development compared to those who are malnourished [1–3]. For example, a systematic review done by the International Initiative for Impact Evaluation (3iE) analyzed Latin America, the Caribbean, sub-Saharan Africa, East Asia, and South Asia and found that school feeding programs implemented in low- and middle-income areas increase student learning outcomes and educational opportunities. The results show that improving the nutrition of students through a school meal plan can improve student participation and learning, thereby positively affecting students [4]. The United States (US) enacted the Child Nutrition Act in 1966, and subsequently established federal welfare programs such as the School Breakfast Program (SBP) and the National School Lunch Program (NSLP). Compared to the lunch program, the US breakfast program provides greater nutritional benefits for lower-income families and to a greater percentage of students [5,6]. Bhattacharya et al. found that students in the SBP did not consume more breakfast, but had higher fiber, potassium, and iron intake, higher levels of vitamins C, E, and folic acid, and had lower fat intake. The intake of calories for students in the SBP brings daily nutrient intake more in line with health standards, which in turn improves the overall nutritional quality of the students' diet [7]. Frisvold used a difference-in-difference and regression discontinuity design to estimate the impact of SBP on student achievement, and found that SBP significantly improved students' mathematics scores [8].

These studies show that breakfast affects not only children's nutritional status, but also students' cognitive development. Several possible reasons for this exist. First, adequate nutrition can reduce the risk of children suffering from malnutrition, improve student attendance, and improve the length and effectiveness of students' learning time [9]. Second, breakfast has a short-term positive impact on children's memory, attention, and information processing [10]. Thus, students who regularly eat breakfast are in a better state for learning in the morning than those who do not eat breakfast or who have it only irregularly. A recent systematic review based on 39 studies found that, in addition to the frequency of eating breakfast, the content of breakfast affects students' cognitive ability and learning behavior in the morning. Breakfast foods that do not create high blood glucose levels after the meal are better at improving students' intellectual performance [11]. Third, breakfast may be more effective in improving children's cognitive performance than are other family interventions. Hau found that eating breakfast had a greater effect on Hong Kong student performance than did learning methods, motivation, self-confidence, parental education, or family income [12]. Similar studies have shown that compensating low-income families for breakfast costs is equivalent to increasing the income of these families, and that while the cost is not high, it effectively improves students' math and reading scores [13,14].

In contrast, some experimental studies indicate that the effect of eating breakfast on the level of cognitive development, as demonstrated by students' academic performance, is uncertain. Researchers evaluating the effectiveness of the New York City Free Breakfast Program found little evidence that the policy improved student academic performance [15]. Experimental and quasi-experimental studies in developing countries, such as Jamaica and Chile, gave similar results. Experimental groups that consumed more calories at breakfast did not show better academic performance than those in a control group [16,17]. These are well-designed experimental studies, and thus are more reliable and valid for the assessment of a causal relationship between eating breakfast and student achievement. The conflicting results of the published literature suggest that more rigorous research is needed to elucidate the relationship between eating breakfast and student cognitive development.

To date, research on eating breakfast has focused mainly on the impact of breakfast on students' nutritional and physical health. Research on the impact of breakfast on students' cognitive development is still lacking; this is especially true in China. In the few studies on the relationship between breakfast and student cognitive development, sample sizes were small and lacked appropriate representation. In addition, most studies could only show a correlation between variables, as opposed to a causal relationship. As the influence of confounding variables was not controlled, the regression coefficient estimation is suspect.

Here, we used ordinary least-squares (OLS) regression and propensity score matching on large-scale survey data to address the following questions: Does having breakfast affect students' cognitive development? How large is this effect after strict control of the relevant variables? We sought to provide more robust evidence for the relationship between breakfast and cognitive development through improvements in data and methods. Such evidence is not only beneficial for improving family education strategies, but also helps parents adopt more effective measures to improve academic performance in their children. At the same time, it provides a scientific basis on which schools and governments can modify allocation of educational resources to maximize the nutritional status and academic performance of students.

Material and Methods

Analysis method

For the purposes of this study, we used students' grades as the explained variables. In general, cognitive ability refers to the

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Table 1. Variable setting description.

Variable type	Variable name	Variable description
Dependent variable	Cognitive development	With the student achievement agent, the Elementary school grade is the average of the 2 courses of language and mathematics; the middle school grade is the average of the 6 courses of language, mathematics, English, physics, biology, and geography
Independent variable	Breakfast frequency	The number of days of breakfast in a week, 1–7 days, respectively
	Do not eat breakfast	1=breakfast irregularly (skip breakfast at least one day a week), 0= eat breakfast every day in the week
Control cariable	Family characteristics	
	Student family socioeconomic status	The calculation of family socioeconomic status uses the 3 indicators of parental education, parental occupation, and family economic background to conduct Principal Component Analysis and convert it into a numerical value between 0 and 100
	Student characteristics	
	Student gender	1=Male; 0=Female, dummy variable, "girl" is the control group
	Is it an only child?	1=Yes; 0=No, dummy variable, "non-only child" is the control group
	School characteristics	
	Type of school area	Divided into rural, county, urban, dummy variables, "rural" as a control group

1. The socioeconomic status of the students' families was calculated as follows: First, the education level of the parents is calculated according to the education information of the parents in the questionnaire, and the family economic status is calculated by the household facilities and durable consumer goods data in the questionnaire. The relevant literature is assigned [28,29]. Second, the original data is normalized, and the calculation method is: $K_i=(X_i–X_{min})/(X_{max}–X_{min})$ where K is an index The standard value, X, is the original value of the indicator, X_{min} is the minimum value of the indicator, X_{max} is the maximum value of the indicator, *i* represents each sample, and the principal component method is used to weight each indicator to obtain the weight, w_i, and $INDEX=\Sigma_{i=1}^{n} w_i k_i$ calculate the family background score for each sample, and multiply the calculated result by 100 to convert to value between 0 and 100.
2. Jiangsu Province is a province with relatively large internal differences. From an economic and cultural perspective, people are used to dividing Jiangsu into 3 regions: Northern Jiangsu, Central Jiangsu, and Southern Jiangsu. In order to control the socioeconomic background of the school's region, we divided the school's area into 3 regions: Northern Jiangsu, Central Jiangsu, and Southern Jiangsu.

ability of the human brain to process information, and then understand and explore the general principles involved [18]. Based on this, many cognitive aptitude tests use language ability, computational ability, speed and spatial perception ability, and reasoning ability as the main dimensions [19] to measure a student's cognitive level in a subject. However, because such tests are more complicated and difficult to implement, researchers generally use well-designed standardized test scores as a proxy variable for students' cognitive development level. In the existing research on the relationship between eating breakfast and cognitive development in students, the majority of studies used student scores to scale the level of cognitive development [20,21]. In some early studies in China, because it was difficult to obtain large-scale and comparable student achievement data, the relevant research was either a small-scale investigation or omitted study of the relationship between breakfast and performance [22,23]. The present study used the academic quality monitoring data of basic education students in Jiangsu Province to solve this problem. The student's academic performance data is not only large in size and wide in scope, it is also highly reliable and authoritative, and appropriately represents the level of cognitive development in students.

Whether students eat breakfast is the main independent variable of this study. In order to more carefully describe the student's breakfast behavior, we further considered the frequency of eating breakfast, with the number of days of eating breakfast set as an independent variable. The student's family background, personal characteristics, and school characteristics were controlled using a measurement model constructed to analyze the relationship between eating breakfast and student achievement. We first used a multiple linear regression model to analyze the relationship between the above independent variables and dependent variables. The multivariate linear model can only analyze the correlation between variables, making it

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Table 2. Descriptive statistics of variables.

Variable	Elementary school (N=56,238)				Middle school (N=91,543)			
	Mean	S.D.	Min	Max	Mean	S.D.	Min	Max
Cognitive development	523.677	80.649	193.897	719.251	506.258	88.499	147.151	783.572
Do not eat breakfast	0.104	0.305	0	1	0.289	0.453	0	1
Breakfast frequency	6.771	0.808	1	7	6.342	1.289	1	7
Family socioeconomic status index	58.414	20.613	0	100	48.445	18.631	0	100
Student characteristics								
Gender	0.537	0.499	0	1	0.539	0.499	0	1
Only child	0.456	0.498	0	1	0.504	0.500	0	1
Type of school area								
City	0.724	0.447	0	1	0.634	0.482	0	1
County town	0.223	0.416	0	1	0.308	0.462	0	1
School area								
Central Jiangsu	0.104	0.305	0	1	0.157	0.364	0	1
Southern Jiangsu	0.660	0.474	0	1	0.487	0.500	0	1

difficult to infer the causal relationships among them. At the same time, with traditional regression analysis, it is difficult to rule out the impact of data selection bias and confounding variables on the analysis results. In response to this, we used propensity score matching (PSM) to further analyze the impact of students eating breakfast on cognitive development. PSM was first proposed by Rosenbaum and Rubin in 1983 [24,25]. Given the theoretical basis of the counterfactual framework, this method better solves the problem of selectivity bias in the process of observational data analysis. As a result, it has quickly developed into a commonly used method for causal effect estimation, and is widely used in the fields of medicine, public health, and education.

Data source and processing

Data were derived from the academic quality monitoring data of basic education students in Jiangsu Province in 2018. Jiangsu Province began to establish a quality education system for basic education students in 2006. This monitoring tests the academic level of students in the third and eighth grades every 2 years. In addition to test scores, student, teacher, and principal questionnaires are simultaneously distributed, and a two-stage stratified sampling method is used to collect data related to student studies. Relevant testing and investigation tools are designed and revised by a team of authoritative experts to provide good reliability and validity.

Using student test papers and questionnaires, corresponding indicator data were selected; student records with missing data were omitted from the analysis. Data collected included 56 238 elementary school (third grade) students and 91 543 middle school (eighth grade) students. Variable setting description is specified in Table 1 and descriptive statistical results of the variables in elementary and middle schools are provided in Table 2. Table 2 reveals that even in a region with a relatively developed social economy such as Jiangsu Province, there is still a high proportion of students who do not eat breakfast. About 10.4% of elementary students skip breakfast at least 1 day per week, and for the middle school students this proportion is as high as 28.9%. In the relatively prosperous eastern provinces of China such as Jiangsu, very few students skip breakfast because of poverty. Thus, the statistical results show that both parents and students still need to pay more attention to eating breakfast.

Results

OLS regression results of breakfast and student achievement

According to the above research design, we set student scores as the dependent variable and established 4 OLS regression models to examine the relationship between breakfast and cognitive development. Model 1 uses the number of breakfasts eaten per week, or frequency of breakfast eating. Model 2 adds possible confounding variables such as family background, student characteristics, and school characteristics to model 1. Model 3 looks at the effect of not eating breakfast to examine the effects of irregular breakfast eating. Model 4 adds variables such as family background, student characteristics, and school characteristics to model 3. We used the 4 models for regression because we wanted to describe the

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Table 3. OLS regression results (dependent variable: cognitive development).

	Elementary school				Middle school			
	(1)	(2)	(3)	(4)	(1)	(2)	(3)	(4)
Breakfast frequency	16.967***	14.263***			13.689***	12.390***		
	(32.930)	(28.066)			(58.482)	(54.113)		
Do not eat breakfast			–38.037***	–32.105***			–35.777***	–32.032***
			(–30.746)	(–25.879)			(–55.947)	(–51.365)
Family socioeconomic background		0.563***		0.566***		0.957***		0.949***
		(33.585)		(33.638)		(60.112)		(59.305)
Only child		19.270***		19.517***		8.643***		8.720***
		(28.199)		(28.456)		(14.431)		(14.505)
Gender		–7.084***		–7.255***		–18.156***		–18.790***
		(–10.949)		(–11.175)		(–33.017)		(–34.028)
City		8.536***		8.946***		15.610***		15.826***
		(5.102)		(5.335)		(12.172)		(12.295)
County town		–5.231***		–5.021***		9.339***		9.582***
		(–3.009)		(–2.880)		(7.195)		(7.353)
Central Jiangsu		25.167***		25.459***		14.286***		14.277***
		(19.236)		(19.374)		(16.502)		(16.442)
Southern Jiangsu		6.785***		7.053***		12.167***		12.522***
		(7.531)		(7.798)		(18.276)		(18.742)
Constant term	408.788***	377.138***	527.619***	476.202***	419.448***	365.794***	516.590***	453.944***
	(115.644)	(99.285)	(1509.668)	(263.937)	(275.896)	(187.084)	(1523.316)	(321.046)
Number of samples	56,238	56,216	56,238	56,216	91,543	91,543	91,543	91,543
R^2	0.029	0.098	0.021	0.092	0.040	0.118	0.034	0.112
F	1084.416	693.427	945.315	676.154	3420.111	1510.669	3130.041	1481.399

The value of t in parentheses; *** , ** , and * Indicate the levels of significance of 1%, 5%, and 10%, respectively.

relationship between breakfast and cognitive development in more detail. Model 1 and model 3 describe the separate effects of 2 independent variables – breakfast frequency and skipping breakfast, respectively – on students' academic performance without controlling for related variables. Model 2 and model 4 investigated the influence of eating breakfast on students' academic performance when relevant variables are controlled. This approach is very common in the social science research. Its advantage is that it explains the independent influence of core explanatory variables and also describes the factors that affect dependent variables in a more comprehensive way under the control of relevant variables. Using these 4 models, the elementary and middle school samples were regressed separately. No multicollinearity was present in the models, but the White test results indicated data were heteroscedastic, so the robust standard error was used to eliminate the effect of heteroscedasticity, and the regression results are shown in Table 3.

Eating breakfast has a significant impact on the cognitive development of students (Table 3). As the frequency of eating breakfast during the week increased, the student's academic performance also increased significantly. Regression coefficient analysis indicated that every increase in the frequency of eating breakfast within a week improved students' scores by 12–17 points. Students who ate no breakfast during the week had significantly lower academic performance – 32 to 38 points lower – than those who ate breakfast every day. These results indicate that eating or nor eating breakfast has important positive and negative effects on cognitive development of students.

Consistent with the conclusions of many previous studies, family background has a significant positive impact on student cognitive development [26,27]. Compared to children with siblings, an only child has a clear cognitive advantage; this may be related to the fact that an only child can have more family

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resources. In terms of gender differences, in both elementary school and middle school, the cognitive development level boys is lower than that of girls. The present study verifies the problem of China's "boys' academic crisis" noted in previous research [30,31]. In terms of school characteristics, the cognitive development of elementary school students in urban schools is significantly better than that in rural schools; however, the disparity in cognitive development of students in county and town schools differs between primary and middle schools. Compared to rural schools, the cognitive level of elementary school students in urban areas is lower but it is higher in middle schools. Finally, students in central and southern Jiangsu have higher levels of cognition than those in northern Jiangsu.

Breakfast effects: PSM regression results

After clarifying the significant correlation between students' breakfast behavior and cognitive development, we sought to further explore the possible causal relationship between eating breakfast and cognitive development. We especially wished to explore whether students with irregular breakfast habits would have relatively lower cognitive development. In general, experimental research is an effective means of revealing causality. However, for ethical reasons, we are unable to conduct randomized experiments on students for "not eating breakfast." In the natural state, interactive effects between the student family background and other groups may lead to biased estimation results in OLS regression. Thus, we used the PSM method to address this problem.

We first constructed a logit regression model to calculate a propensity score based on whether the students had eaten breakfast, and including other confounding factors such as student gender, family socioeconomic background, school area, and region type as independent variables. We then used the tendency score indicator instead of assigning an imbalanced number of variables between the experimental group (students who skip breakfast at least 1 day a week) and the control group (students who eat breakfast every day), and matched the students with similar propensity scores between groups. In theory, the selection of the 2 groups of students thereby occurs after the exclusion of the selection bias. It can be considered random grouping, and the confounding factors are balanced across the groups. The only difference between the 2 groups – eating breakfast every day *vs.* not eating breakfast at least 1 day a week – can thus be considered as the cause of the difference in the level of cognitive development of students.

Calculating propensity score

Using logit regression, the treatment factor (skipping breakfast) was used as the dependent variable, and the propensity score was calculated as an independent variable with factors such as student family background, student personal characteristics, and school characteristics, which can affect the outcome variable (student achievement), included. Regression results are shown in Table 4. Most of the relevant influencing factors were highly statistically significant, revealing that there is a selection bias in terms of those students who do not eat breakfast. This confirms that PSM is needed to correct for this bias.

Table 4. Estimation of the influencing factors of not eating breakfast: logit model.

Variables	Coefficient (elementary school)	Coefficient (middle school)
Family socioeconomic status index	–0.015***	–0.011***
	(–19.847)	(–25.068)
Only child	–0.059*	–0.186***
	(–1.960)	(–11.700)
Male	0.130***	–0.175***
	(4.626)	(–11.834)
City	–0.021	0.099***
	(–0.351)	(3.039)
County town	–0.004	0.040
	(–0.062)	(1.202)
Central Jiangsu	–0.335***	–0.164***
	(–6.429)	(–7.043)
Southern Jiangsu	–0.280***	0.063***
	(–8.200)	(3.635)
Constant	–1.166***	–0.281***
	(–18.215)	(–7.887)
N	56216	91543
Log likelihood	–18365.526	–54404.64
LR Chi^2 (7)	691.47	1237.79
Prob >Chi^2	0.000	0.000
Pseudo R^2	0.0185	0.0112

Z value in parentheses; ***, **, and * indicate the levels of significance of 1%, 5%, and 10%, respectively.

Common support and balancing test

Data matching involves a trade-off between precision and skewness. To avoid the error of different estimation methods and generate more stable results, we used radius matching and kernel matching methods to match the student data [32–34].

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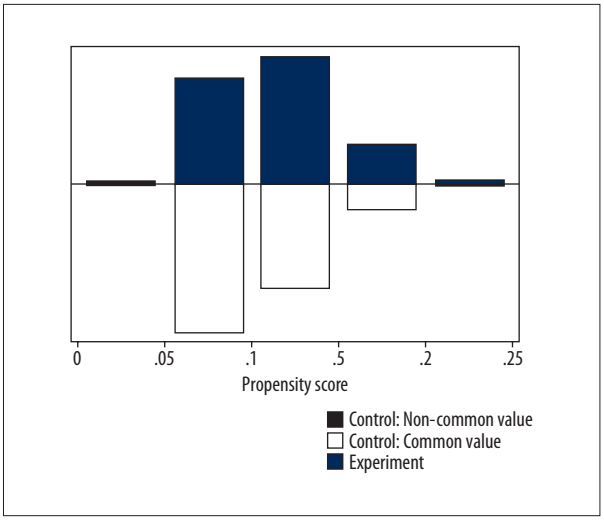

Figure 1. Common value range of propensity score matching (elementary school).

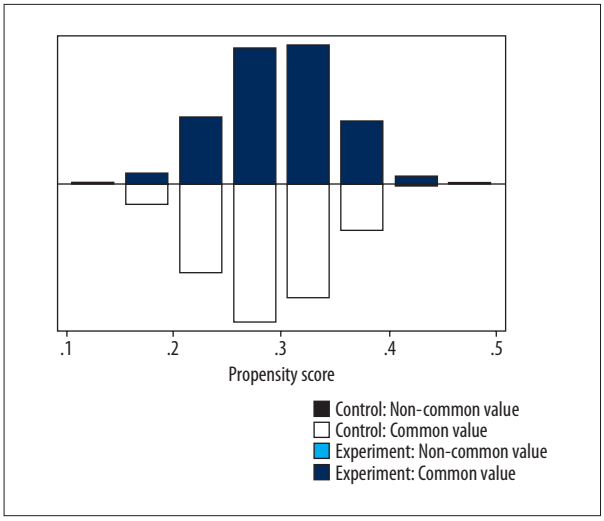

Figure 2. Common ranges of values for propensity score matching (middle school).

For PSM analysis, matching must also satisfy the common support assumption and the balancing assumption to ensure the matching quality [35,36].

Common support test

A common range of values between the treatment group and the control group is required for the implementation of PSM analysis. Generally, a bar chart can be drawn to observe the common value range of the propensity score matching. Figures 1 and 2 show that there was a clear common value range for the data of the treatment group (skipping breakfast) and the control group (having breakfast every day), thus satisfying the assumption of a common support domain.

Balancing test

Referring to the calculation process of Caliendo et al. [32], we tested the balancing of data in 3 ways: 1) comparison of the standard deviation before and after the matching between the treatment group and the control group; 2) comparison of matching variables between the control and experimental groups, before and after matching by *t* test; and 3) a joint significance test. Since the results of all 3 methods were similar, we reported only the results of the 2 nuclear matching tests (Tables 5–8**)**. The test results indicate that, after matching, no significant differences were present in the variables of the primary and secondary samples, and both passed the joint significance test. This suggests that pre-treatment heterogeneity had been eliminated and verified the data balance.

Effect of not eating breakfast on the cognitive development of students

Using radius matching and kernel matching methods, we estimated how student cognitive development is affected by not eat breakfast. In both elementary school students and middle school students, not eating breakfast every day has an adverse impact on cognitive development. The average treatment effect (ATT) of the elementary school sample was –31.322, meaning the academic score of the treatment group who skip breakfast is 31.222 points lower than in the control group who have breakfast every day. The average treatment effect in middle school was 31.334, indicating that skipping breakfast leads middle school students to have a cognitive score 31.334 points lower than those who ate breakfast every day. The specific analysis results are shown in Tables 9 and 10.

Although PSM is used to avoid selection bias, it is never possible to consider all hidden biases that may affect results. To evaluate the sensitivity of results to hidden bias, we estimated the range of possible values (i.e., gamma coefficients) attributable to hidden bias. The gamma coefficient of the primary and middle school samples in this study was between 2.0 and 2.1. According to Lin et al. [37] and Rosenbaum and Rubin [24], when the gamma coefficient is very large (generally close to 2), the analysis conclusions are robust. Therefore, the conclusions of this study are reliable.

Discussion

Eating breakfast is an important variable that affects students' cognitive development. Good breakfast habits help improve students' cognitive development. However, research on

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Table 5. Balance test of matching variables before and after elementary school matching.

Covariate	Sample	Mean		bias (%)	% reduction in |bias|	t Test	
		Treatment group	Control group			t	p>|t|
Family socioeconomic status index	Before matching	52.340	59.115	−33.2	99.0	−23.86	0.000
	After matching	52.340	52.269	0.3		0.19	0.849
Only child	Before matching	0.399	0.462	−12.7	99.1	−9.11	0.000
	After matching	0.399	0.400	−0.1		−0.06	0.953
Male	Before matching	0.570	0.533	7.5	95.3	5.38	0.000
	After matching	0.570	0.568	0.4		0.19	0.848
City	Before matching	0.666	0.731	−14.2	99.5	−10.54	0.000
	After matching	0.666	0.666	−0.1		−0.04	0.968
County town	Before matching	0.264	0.218	10.8	99.7	8.00	0.000
	After matching	0.264	0.264	0.0		−0.01	0.988
Central Jiangsu	Before matching	0.096	0.105	−3.0	94.7	−2.16	0.031
	After matching	0.096	0.096	−0.2		−0.09	0.929
Southern Jiangsu	Before matching	0.592	0.668	−15.7	97.1	−11.57	0.000
	After matching	0.592	0.594	−0.5		−0.24	0.809

Table 6. Variable joint significance test before and after elementary school matching.

Matching method		Pseudo R^2	LR Chi^2	P>Chi^2
Radius matching (0.001)	Before matching	0.019	692.91	0.000
	After matching	0.000	0.26	1.000
Radius matching (0.005)	Before matching	0.019	692.91	0.000
	After matching	0.000	0.18	1.000
Kernel matching (0.001)	Before matching	0.019	692.91	0.000
	After matching	0.000	0.2	1.000
Kernel matching (0.005)	Before matching	0.019	692.91	0.000
	After matching	0.000	0.23	1.000

the relationship between eating breakfast and student cognitive development in mainland China is insufficient. Given that China is a developing country with a large population, strengthening the study of Chinese samples will provide representative empirical evidence from China for other countries, especially developing countries, around the world. Therefore, this study is very meaningful to exploring more diverse and effective ways to promote students' cognitive development. Meanwhile, compared with previous studies, the data of this study have the advantages of better sampling methods, large volume, and wide coverage. At the same time, to solve selection bias and causal inference problems that traditional analytical techniques cannot address, this study used the PSM method and a robustness test to ensure the accuracy of the conclusions. To be more specific, through the analysis in this study, the results of OLS and PSM were presented: the ATT of the PSM analysis was slightly smaller than the coefficient of the OLS regression (absolute value), indicating that the OLS overestimated the effect of not eating breakfast on academic performance. Regardless, it is clear that regularly eating breakfast helps students improve their performance; without eating breakfast, students are at a disadvantage. This conclusion is consistent with the research conclusions of Xu et al. [38] and Fang [39]. Because our study used the PSM method to control selection bias and confounding variables, the conclusion is more robust. Compared to other interventions, such as tutoring,

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Table 7. Balance test of matching variables before and after middle school matching.

Covariate	Sample	Mean		bias (%)	% reduction in |bias|	t Test	
		Treatment group	Control group			t	p>|t|
Family socioeconomic status index	Before matching	45.764	49.533	−20.7	97	−27.85	0.000
	After matching	45.764	45.651	0.6		0.74	0.458
Only child	Before matching	0.453	0.525	−14.3	99.9	−19.65	0.000
	After matching	0.453	0.453	0.0		−0.01	0.993
Male	Before matching	0.505	0.552	−9.4	88.1	−12.92	0.000
	After matching	0.505	0.511	−1.1		−1.29	0.197
City	Before matching	0.624	0.639	−3.1	94	−4.28	0.000
	After matching	0.624	0.623	0.2		0.22	0.829
County town	Before matching	0.317	0.304	2.8	96.4	3.85	0.000
	After matching	0.317	0.317	0.1		0.11	0.909
Central Jiangsu	Before matching	0.137	0.165	−7.9	96.0	−10.65	0.000
	After matching	0.137	0.138	−0.3		−0.37	0.709
Southern Jiangsu	Before matching	0.492	0.485	1.4	92.2	1.96	0.051
	After matching	0.492	0.492	−0.1		−0.13	0.898

Table 8. Variable joint significance test before and after middle school matching.

Matching method		Pseudo R^2	LR Chi^2	P>Chi^2
Radius matching (0.001)	Before matching	0.011	1244.09	0.000
	After matching	0.000	2.79	0.904
Radius matching (0.005)	Before matching	0.011	1244.09	0.000
	After matching	0.000	6.18	0.519
Kernel matching (0.001)	Before matching	0.011	1244.09	0.000
	After matching	0.000	2.89	0.895
Kernel matching (0.005)	Before matching	0.011	1244.09	0.000
	After matching	0.000	9.20	0.238

breakfast is undoubtedly cheaper and easier to implement. The significance of this study's results is that they provide a strategic choice by which parents can improve their children's nutritional status and thus their children's performance, with low input and high efficacy. This is especially meaningful for disadvantaged families. Compared with the cost of tutoring classes, Kleiman-Weiner et al. found, using randomized experiments, that chewable vitamins, costing only 0.4 CNY per day, increased mathematics scores for students in poor areas [40].

Eating breakfast every day is a universally recognized part of a healthy lifestyle. For children and young children who are in a stage of rapid growth of mind and body, eating a sufficient, regular, and nutritious breakfast is especially important for physical and mental development. However, most students do not eat breakfast every day [41,42], as was found in the present study. Jiangsu is a province with a relatively well-developed social economy; therefore, no shortage of breakfast due to poverty is expected. Even so, many students did not have breakfast every day. In middle school, nearly 30% of students have irregular eating behavior. We speculate that this may be related to reasons such as students' lack of sleep and thus lack of time for breakfast, and the fact that adolescent students deliberately do not eat breakfast due to lack of physical control [43]. Regardless, families and schools need to pay more attention to the issue of student breakfast, especially for middle school students.

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Table 9. Estimation of the effect of elementary school not eating breakfast based on PSM model.

Matching method	Dependent variable: student achievement				
	Treatment group (skipping breakfast)	Control group (eat breakfast every day)	Average treatment effect (ATT)	Standard error	t value
Radius matching (0.001)	489.616	520.851	–31.235	1.246	–25.08***
Radius matching (0.005)	489.616	521.003	–31.387	1.245	–25.22***
Kernel matching (0.001)	489.616	520.912	–31.296	1.246	–25.12***
Kernel matching (0.005)	489.616	520.987	–31.371	1.245	–25.2***
Average effect			–31.322		

***, **, and * represent significance at 1%, 5%, and 10% level, respectively.

Table 10. Estimation of the effect of no-meal breakfast in the middle school based on the PSM model.

Matching method	Dependent variable: student achievement				
	Treatment group (skipping breakfast)	Control group (eat breakfast every day)	Average treatment effect (ATT)	Standard error	t value
Radius matching (0.001)	480.813	512.252	–31.439	0.647	–48.62***
Radius matching (0.005)	480.813	512.095	–31.282	0.646	–48.43***
Kernel matching (0.001)	480.813	512.179	–31.366	0.646	–48.53***
Kernel matching (0.005)	480.813	512.067	–31.254	0.646	–48.35***
Average effect			–31.335		

***, **, and * represent significance at 1%, 5%, and 10% level, respectively.

Students' skipping breakfast is due to many factors. Our results (Table 4) show that the better the family background, the less likely it is that students do not eat breakfast, especially if the student is an only child. Gender differences also occur: elementary school boys have a higher probability of not eating breakfast, but in middle school, girls are more likely to not eat breakfast. Students living in urban and rural areas also differ, and regional variables have an impact on students' behavior of not eating breakfast. This result reminds us that students miss breakfast due to complex reasons. In particular, because family background has a significant effect on the student's breakfast behavior, more attention must be paid to children of poor families during the breakfast intervention, so that they can better form the habit of regularly eating breakfast and obtain adequate nutritional support for physical and mental development. A limitation of this study is that we could not analyze the impact of breakfast food composition on performance due to lack of available data. More comprehensive research data in the future is thus needed.

Conclusions

Based on the analysis of large-scale academic monitoring data in Jiangsu Province, China, the most important conclusions of this paper are as follows: breakfast has a very positive effect on students' cognitive development. In primary school, students who eat breakfast every day in a week scored 31.322 points higher in academic performance than those who did not eat breakfast every day. In middle school, students who had breakfast every day had significantly better academic performance 31.335 points higher than those who did not regularly eat breakfast (Tables 9, 10). The results also show that skipping breakfast is still widespread among elementary and middle school students. This means that both the government and the family need to do more to make each student develop a good breakfast-eating habit and get better nutritional benefits to promote their cognitive development.

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References:

1. Alderman H, Hoddinott J, Kinsey B: Long term consequences of early childhood malnutrition. Oxf Econ Pap, 2006; 58(3): 450–74
2. Victora CG, Adair L, Fall C et al: Maternal and child undernutrition Study: Consequences for Adult health and human capital. Lancet, 2008; 371: 340–57
3. Adelman SW, Gilligan DO, Lehrer K: How effective are food for education programs? A critical assessment of the evidence from developing countries. Washington: International Food Policy Research Institute Publishers, 2008
4. Snilstveit B, Stevenson J, Phillips D et al: Interventions for improving learning Outcomes and access to education in low- and middle- income countries: A systematic review, 3ie Systematic Review 24. London: International Initiative for Impact Evaluation (3ie), 2015
5. United States Department of Agriculture. The School Breakfast Program Fact Sheet. 2010. Available from: URL: *http://www.fns.usda.gov/cnd/Breakfast/AboutBFast/SBPFactSheet.pdf*
6. United States Department of Agriculture. Supplemental Nutrition Assistance Program Participation and Costs. 2014. Available from: URL: *http://www.fns.usda.gov/sites/default/files/pd/SNAPsummary.pdf*
7. Bhattacharya J, Currie J, Haider SJ: Breakfast of champions? The School Breakfast Program and the nutrition of children and families. J Hum Resour, 2006; 41(3): 445–66
8. Frisvold DE: Nutrition and cognitive achievement: An evaluation of the School Breakfast Program. J Public Econ, 2015; 124: 91–104
9. Hinrichs P: The effects of the National School Lunch Program on education and health. J Policy Anal Manage, 2010; 29(3): 479–505
10. Adolphus K, Lawton CL, Champ CL, Dye L: The effects of breakfast and breakfast composition on cognition in children and adolescents: A systematic review. Adv Nutr, 2016; 7(3): 590S–612S
11. Edefonti V, Bravi F, Ferraroni M: Breakfast and behavior in morning tasks: facts or fads. J Affect Disord, 2017; 224: 16–26
12. Hau KT: [Have breakfast rather than wasting money on tutorials.] Hong Kong: The Chinese University of Hong Kong, 2016 [in Chinese]
13. Kristjansson EA, Gelli A, Welch V et al: Costs, and cost-outcome of school feeding programs and feeding programmes for young children. Evidence And recommendations. Int J Edu Dev, 2016; 48: 79–83
14. Dahl GB, Lochner L: The impact of family income on child achievement: Evidence from the earned income tax credit. Am Econ Rev, 2012; 102(5): 1927–56
15. Leos-Urbel J, Schwartz AE, Weinstein M, Corcoran S: Not just for poor kids: The impact of universal free school breakfast on meal participation and student outcomes. Econ Edu Rev, 2013; 36: 88–107
16. Powell CA,Walker SP, Chang SM, Grantham-McGregor SM: Nutrition and education: A randomized trial of the effects of breakfast in rural elementary school children. Am J Clin Nutr, 1998; 68: 873–79
17. McEwan PJ: The impact of Chile's school feeding program on education outcomes. Econ Edu Rev, 2013; 32: 122–39
18. Gagne RM: The Conditions of Learning. 4th ed. New York: Holt Rinehart & Winston Publishers, 1985
19. Farkas G: Cognitive skills and noncognitive traits and behaviors in stratification processes. Annu Rev Sociol, 2003; 29: 541–62
20. Frisvold DE. Nutrition and cognitive achievement: An evaluation of the School Breakfast Program. J Public Econ, 2015; 124: 91–104
21. Hoyland A, Dye L, Lawton CL: A systematic review of the effect of breakfast on the cognitive performance of children and adolescents. Nutr Res Rev, 2009; 22: 220–43
22. Ma G, Hu X, Gao S et al: [Effect of energy intake at breakfast on school performances.] Wei Sheng Yan Jiu, 1999; 28(5): 286–88
23. Zhao X, Zhang N, Tao T: [Association between the breakfast status and learning efficiency of senior high school students.] Chin J Sch Health, 2017; 38(9): 1303–6 [in Chinese]
24. Rosenbaum PR, Rubin DB: The central role of the propensity score in observational studies for causal effects. Biometrika, 1983; 70(1): 41–55
25. Rosenbaum PR, Rubin DB: Constructing a control group using multivariate matched sampling methods that incorporate the propensity score. American Statistication, 1985; 39(1): 33–38
26. Yang Z: [The intermediary factors of family background affects the students' development.] Edu Econ Rev. 2018;3(3): 61–82 [in Chinese]
27. Marks GN: Are father's or mother's socioeconomic characteristics more important influences on student performance? Recent international evidence. Social Indicators Research, 2008; 85(2): 293–309
28. Li C: Prestige stratification in the contemporary China: Occupational prestige measures and socioeconomic index. Socio Stud, 2005; 2: 74–102
29. Lu X: [Analysis of the top ten strata in contemporary Chinese society.] Stud Pract, 2002; 3: 55–63 [in Chinese]
30. Li S: [Research on the "Boy Crisis" from the boy perspective.] Res Edu Dev. 2010; 30(Z2): 48–52 [in Chinese]
31. Li W, Sun Y: [Reflections on the status quo and causes of academic backwardness of male students in China.] Edu Res, 2012; 33(9): 38–43 [in Chinese[
32. Caliendo M, Kopeinig S: Some practical guidance for the implementation of propensity score matching. J Econ Surv, 2008; 22(1): 31–72
33. Guo S, Fraser MW: Propensity score analysis: Statistical methods and applications. Thousand Oaks(CA): Sage Publications, 2009
34. Leuven E, Sianesi B: PSMATCH2: Stata module to perform full Mahalanobis and propensity score matching, common support graphing, and covariate imbalance testing. Boston College Department of Economics, Statistical Software Components. 2003. Available from: URL: *http://ideas.repec.org/c/boc/bocode/s432001.html*
35. Abadie A, Drukker D, Herr JL, Imbens GW: Implementing matching estimators for average treatment effects in Stata. Stata Journal, 2004; 4(3): 290–311
36. Becker SO, Ichino A: Estimation of average treatment effects based on propensity scores. Stata Journal, 2002; 2(4): 358–77
37. Lin DY, Psaty BM, Kronmal RA: Assessing the sensitivity of regression results to unmeasured confounders in observational studies. Biometrics, 1998; 54(3): 948–63
38. Xu H, Hu X, Zhang Q et al: [Analysis of the correlation between breakfast frequency and students' scores in poor areas.] Chi J Sch Health, 2014; 35(12): 1788–90 [in Chinees]
39. Fang C: [An empirical study of the effects of breakfast on students' achievements.] J Shanghai Edu Res, 2018; 8: 15–18 [in Chinese]
40. Kleiman-Weiner M, Luo R, Zhang L et al: [Eggs versus chewable vitamins: Which intervention can increase nutrition and test scores in rural China?] Chi Econ Rev, 2013; 24: 165–76 [in Chinese]
41. Gao S, Zhai F, Ma G, Ge K: [Analysis of breakfast skipping of Chinese primary and secondary school students.] Chi J Sch Health, 2001; 22(2): 109–11 [in Chinese]
42. Hu X, Fan Y, Hao L et al: [Survey of breakfast behaviors among primary and secondary students in seven cities of China.] Acta Nutrimenta Sinica, 2010; 32(1): 39–42 [in Chinees]
43. Liu Z, Guo X, Fu Y et al: Breakfast consumption among primary and secondary school students in Beijing. Chi J Sch Health, 2016; 37(01): 20–22

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