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Children's education and parents' dietary nutrient intake: an empirical study based on rural China

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This paper, taking the middle-aged and elderly parents in rural families of China as the subject, studies the impact of children's education on parents' dietary nutrient intake. After analyzing the data in China Health and Nutrition Survey (CHNS) 2011, this study discovers that China's rural children's higher educational level exerts a significant positive impact on the improvement of parents' food consumption, nutrient intake and diet quality. This indicates that the improvement of rural education can be an effective approach to increase dietary nutrient intake of China's rural population. The policy implication of this study is to further develop rural basic education, consolidate the coverage of compulsory education, and incorporate nutrition education into national education system.

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Introduction

A good intake of dietary nutrition is fundamental to good health and influences health throughout the life course and reduces the likelihood of developing some common diseases (such as obesity, diabetes, hypertension, coronary heart disease, etc.) (Neuhouser et al. 2022; Sharkey et al. 2002). The World Health Organization Working Group has identified nutrition as a key component of disease prevention, indicating that "a balanced and varied diet, composed of a wide range of nutritional and Tasty foods, adds years to life and life to years" (WHO 2021). Poor diet can lead to poor health and is a recognized and modifiable risk factor for the development of non-communicable diseases, which are the leading cause of death worldwide (Leech et al. 2015). The importance of nutrition, as an integral part of the solution to many societal, environmental, and economic challenges facing the world, has just started to be fully appreciated (Ohlhorst et al. 2013).

Education is an important influencing factor in improving dietary nutrition intake, and related education includes both education level and nutrition education. Studies in developed countries have found that improving one's education level is a key factor in improving dietary behavior and dietary nutrition intake. Higher education was associated with higher diet quality (Kang et al. 2019). Research has shown that the most important influencing factor for the improvement of dietary nutrition intake is the increase in educational attainment rather than income (Popkin et al. 2003). Education can affect individuals' perceptions of health care and living habits. People with high levels of education are more likely to choose healthier lifestyles, such as a balanced and healthy diet (Mackenbach 2021), greater self-control (Barker et al. 2009), a wider variety of food consumption (Beck et al. 2020), and more intake of vegetables and fruits (Phulkerd et al. 2020). Lower level of education is a predictor of poorer dietary patterns (Thorpe et al. 2019). School education has a positive impact on nutritional intake, with advantages in terms of coverage, structure and cost effectiveness (Graziose et al. 2017; Cotton et al. 2020). Nutrition education can also play a role in improving dietary intake, and numerous studies have shown that well-organized and implemented nutrition education and interventions are effective in improving dietary health and behavior (Dhandevi and Jeewon 2015) Education efforts must be emphasized to eliminate disadvantages in diet quality (Popkin et al. 2003).

Since the Opening of China, the country's economy has continuously and rapidly improved. Various economic, educational, and health policies have been implemented to shape the development of society, which may have greatly affected the Chinese diet and related malnutrition issues (Huang et al. 2021). Although the dietary quality of rural residents in China has been significantly improved, the economic development levels and food consumption groups between urban and rural areas are still unequal (Zhang et al. 2023). Their dietary quality is poorer than that of Chinese urban residents (Hu et al. 2022). The incidence of malnutrition, suboptimal health, and mortality is prevalent among rural residents (Ren et al. 2018). Rural residents are also more likely to fall victim to over-nutrition or under-nutrition than urban residents (Han et al. 2016). The Outline of Healthy China 2030 formulated by the Chinese government points out, the improving dietary health of urban and rural residents plays an important role in improving national health and it is also a basic requirement for building a healthy China (Li 2020). Beside income, the lack of nutritional knowledge is a major factor affecting the dietary nutrient intake of Chinese rural residents. In particular, the low educational level of middle-aged and elderly people in rural China has become an important obstacle of improving their dietary nutrient intake. Therefore, the improvement of dietary health of Chinese rural residents is an important guarantee for China to achieve "universal health", and the improvement of dietary nutrient intake of rural residents is an important social issue.

Education can improve dietary health, but it is obviously impossible for middle-aged and elderly residents in rural China to improve dietary nutrient intake by raising their own educational level. It is rather difficult to improve dietary nutrition intake through public health education due to a large middle-aged and elderly population in rural China. In addition, the sparsely populated rural areas, the relatively small villages, and the large distance between different villages lift the cost of health education. However, dietary nutrient intake can be improved through raising children's educational level. The spending power of a household or individual is not only constrained by the budget, but also by the scientific and cultural level of the family members or the individual, which determines the level and quality of the household or individual consumption. Existing studies suggest that education has an upward spillover effect, and the well-educated children can exert a significant positive impact on their parents' health in a variety of ways (Ma 2019).

The contribution of this study is that it explores the upward spillover effect of education on dietary nutrient intake, i.e., children's higher educational level impacts parents' dietary nutrient intake. China, the largest developing country in the world, has scored fast economic growth. Meanwhile, it has witnessed wide education popularization and rapid development, which has led to huge intergenerational differences in educational levels. Thus, children who receive better education may have an impact on their parents' dietary nutrient intake. Different from studies on the impact of education on dietary nutrient intake in developed countries, the analysis on the unique problem in China can enrich the research on the impact of education on dietary nutrient intake. It is urgent to explore the evidence of improving nutrition and health of rural population from non-economic fields when the nutritional health problem is prominent in rural China. The study of the influence of children's education on parents' dietary nutrient intake can provide an accurate direction for making public policies.

In addition, dietary nutrient intake is taken as an exogenous variable in existing studies, but it may be an endogenous variable because there may be unobserved variables that affect both children's educational level and parents' dietary nutrient intake. Furthermore, the interaction mechanism between children's educational level and parents' dietary nutrient intake cannot be removed. In order to eliminate the endogeneity problem in OLS estimation, this paper takes the implementation of compulsory education as an instrumental variable. In addition, this paper differs from previous studies in sample selection. The data of CHNS survey in 2011 are used in this paper, including all middle-aged and elderly parents in rural China, different from many studies in which young parents were selected as samples.

The rest of the paper is designed as follows: "Literature review" overviews existing literature regarding the relationship between education and dietary nutrient intake, education's spillover effect on dietary nutrient intake; section "Research methods" presents the data utilized for our research and empirical model; section "Results" presents the findings obtained from the empirical analyses; section "Discussion of the results" discusses the results; and section "Conclusion and policy recommendations" concludes and provides policy suggestions.

Literature review

Education has a significant impact on dietary nutrient intake. Existing studies, especially in developed countries, have shown

that educational level is an important factor in improving dietary nutrition quality and dietary nutrient intake. Moreover, education still has an impact on dietary nutrient intake when income is taken into account (Roos et al. 2001). More-schooled individuals tend to have better health outcomes and health-related behavior (Amin et al. 2013). More educated individuals are more likely to make healthy lifestyle choices, such as a balanced diet and healthy eating habits (Gao et al. 2013; Patel et al. 2020).

Vitamin intake is directly proportional to education, but carbohydrate, fat and iron intake decreases with the higher educational level of household heads (Adrian and Daniel 1976). Empirical studies in the USA have shown education level a strong correlate of both household income and diet quality (French et al. 2019), and that the higher educational level of female heads of households will lead to the higher nutrient intake (Ramezani and Roeder 1995). Studies in Australia have indicated that the more educated an individual is, the wider the range of foods they consume on a regular basis (Nikodijevic et al. 2020), for example, more educated people consume more nuts (Guan et al. 2022). Individuals with higher education, both males and females, consume significantly more types of food than other individuals, and there is a significant association between higher education level and regular consumption of a greater variety of foods (Worsley et al. 2004). Based on the survey of European countries, it is found that there is a significant difference in fruit and vegetable intake between the most and least educated men, and the difference is also significant among women (De et al. 2000). Participants with higher educational status have better nutritional intakes, particularly within lower GDP countries (Rippin et al. 2020). The well-educated people in the UK eat less meat, more salads, and fewer cakes and desserts than less educated people (Fraser et al. 2000). As educational attainment increases, there is a shift towards the consumption of healthier foods such as wholewheat bread rather than white bread (Cole et al. 2020). Data from the Dutch National Food Consumption Survey between 2007 and 2010 show that the more educated group has a healthier diet, consuming more fruits, vegetables and fish and significantly less meat than the less educated group (Van Bussel et al. 2020).

Chinese families are experiencing a remarkable nutrition improvement and a dramatic dietary change (Ren et al. 2019). Higher education and income levels have significantly higher fruit intake (Liu and Grunert 2020; Li et al. 2022). Besides the income factor, female educational level has a significant impact on food consumption pattern and nutrient intake (calories, protein and fat) (Bhandari and Smith 2000). Based on household survey data collected in China's 11 cities, the higher the wives' educational level, the higher the family's healthy diet index (Wang 2017). As the wife's education level increases, the household Eating Healthy Index score will increase for all foods (Wang et al. 2019). A survey in Tianjin shows that there is a significant difference in daily food consumption among people with different income levels and educational levels. The least educated consume more cereals, and the most educated consume more fruit, milk and meat. Due to differences in food consumption, the intake of protein, fat, riboflavin, calcium, selenium, zinc and Vitamin E increases with the higher educational level, while the intake of carbohydrates and manganese decreases with the higher educational level (Yang et al. 1998).

Education has a spillover effect on dietary nutrient intake, and parents' higher educational level can significantly improve children's dietary nutrient intake. The children whose parents are more educated have higher frequency and intake of milk (Stenhammar et al. 2007), fruit and vegetables (Yung et al. 2010; Groele et al. 2019). The children whose mothers are highly educated are less likely to eat chocolate, potato chips and white bread and more likely to eat graham bread, fruit and fruit juices, and the intake of non-starch polysaccharides and most vitamins and minerals increases significantly with mothers' higher educational level (Rogers and Emmett 2003). The diets of the children with well-educated mothers are closer to the recommended intake of folic acid, Vitamin C and iodine (Navia et al. 2003). Mothers' higher educational level significantly increases the protein intake and improves nutrition status of their children over 6 months of age (Dang and Yan 2007). The higher the mother's education level, the higher is the intake of DHA in children (Woźniak et al. 2022). The children whose fathers have lower educational level will have lower intake of total fat and fat energy (Martinchik et al. 1997). In addition, parents' nutritional knowledge has a positive correlation with their children's intake frequency of eggs, legumes, fruits, nuts and supplements, and has a negative correlation with the intake of carbonated beverages and Western fast foods. Parents' knowledge of nutrition varies significantly depending on their education level, which in turn has an impact on their children's diet (Mahmood et al. 2021; Flores-Barrantes et al. 2022). Parents' nutritional education can improve children's nutritional status at the population level (Woźniak et al. 2022).

To sum up, educational level exerts a positive impact on dietary nutrient intake. In addition, education has a downward spillover effect on dietary nutrient intake, i.e., parents' higher educational level can improve children's dietary nutrient intake. Although it is clear that education can improve dietary nutrient intake and there is a downward spillover effect, does education have an upward spillover effect? In other words, whether children's educational level has an impact on parents' dietary nutrient intake? Most of the existing studies focus on the effect of education on one's own nutritional intake or the effect of parents' education on their children's dietary intake, but there are few studies on the effect of children's education on their parents' dietary intake. Considering that dietary knowledge can be spread, and it will affect the dietary health of other people (Marshak et al.1998), this study attempts to analyze whether children's higher educational level in rural China has an impact on their parents' dietary nutrient intake in the context of the rapid development of education in China.

Research methods

Data sources. To make an empirical analysis on the impact of children's education on their parents' dietary nutrient intake, this paper uses the data from the CHNS. The selected provinces in the Survey basically cover all China's regions with different features in geographical locations, economic development, public resources and health index, including Beijing, Hebei, Shanghai, Chongqing, Guangxi, Guizhou, Heilongjiang, Henan, Hunan, Jiangsu, Liaoning and Shandong, which to some extent reflects China's overall situation.

CHNS data are well suited for studies related to intergenerational family relationships. The Survey investigates various information of heads of households and children, which avoids selection bias of the samples. Individual information covers a wide range of aspects such as educational level, incomes and health condition. In diet quality, the CHNS makes a detailed and comprehensive record of food consumption and nutritional status. Diet surveys include household diet surveys and individual diet surveys. The 24-h recall method is adopted in individual diet survey, and respondents are asked to recall the diet variety, amount, time, location and cooking methods of food within one day.

Based on the CHNS in 2011, all the samples of rural families are first selected. Considering that young parents have higher educational level and their children are younger, their children's educational level cannot exert an impact on parents' dietary nutrient intake. Then the middle-aged and elderly people at the

age of 45 or above are selected to study the impact of children's education on parents' dietary nutrient intake in rural China. Finally, the samples with missing variables are removed, and 1194 parent samples are finally reserved for formal data analysis.

In addition, the Chinese Dietary Guidelines 2007 (CDG) and China Food Composition Table 2004 are from the website of Chinese Nutrition Society (hinese Nutrition Society 2004, 2007). The data of educational development in all provinces are from the China Statistical Yearbook. The variable of food consumption is set based on the food classification standards of the CDG, the variable of nutrient intake is set based on the China Food Composition Table 2004, and the instrumental variable, i.e., the educational development status of each province, is set according to the proportion of the population with junior high school education in the total population of each province in China Statistical Yearbook of previous years.

Measures. Food consumption is set based on the food classification standards of China Food Composition Table 2004. Nine food types are studied in this paper, including cereals, beans and bean products, vegetables, fruit, livestock meat, poultry, milk, eggs, fish and shrimp and other aquatic products.

Nutrient intake is set based on China Food Composition Table 2004. We converted food consumption into nutrient intake, and selected calories and three major macronutrients that are closely related to health for analysis. The three macronutrients are carbohydrates, protein and fat.

Although the nutrient-based Dietary Quality Index (DQI) can reflect dietary quality more comprehensively, the measurement of this index is very specialized and complex. Therefore, we chose the Dietary Balance Index (DBI) to measure dietary quality by referring to the method of the Institute of Nutrition and Food Safety of the Chinese Center for Disease Control and Prevention. Considering the characteristics and problems of Chinese residents' diets, we selected relevant indicators based on the core entries in the Chinese Dietary Guidelines 2007 to construct DBI-2007, and defined the method of taking each indicator according to the recommended amounts of various foods in the CDG and Food Guide Pagoda as well. Therefore, the DBI-2007 can reflect both insufficient and excessive intake problems.

Since there are few statistics on edible oil in the CHNS, and the condiments are consumed at the family level, the DBI-2007 index is measured from the following foods, including cereals, vegetables, fruit, dairy products, beans, animal meat (red meat, poultry and game), aquatic products (fish and shrimp), eggs and diet variety, while condiments, edible oil, and water intake are not included, given the availability of data. Rice and rice products, flour and flour products, corn, coarse cereals and starch are classified as cereals, dark-color vegetables and light-color vegetables are classified as vegetables.

DBI-2007 indexes include: High Bound Score (HBS), Low Bound Score (LBS) and Diet Quality Distance (DQD). The three indexes reflect excessive dietary intake, inadequate dietary intake and dietary imbalance respectively. HBS: The absolute value of the sum of positive scores in all indexes reflect the degree of excessive dietary intake. The score ranges from 0 to 32. 0 indicates no excessive intake; 1–6, slightly excessive intake; 7–13, low-level excessive intake; 14–19, medium-level excessive intake; over 19, high-level excessive intake. LBS: The absolute value of the sum of negative scores in all indexes ranges from 0 to 72. 0 indicates no inadequate intake; 1–14, slightly inadequate intake; 15–29, low-level inadequate intake; 30–43, medium-level inadequate intake; over 43, high-level inadequate intake. DQD: The sum of the absolute value of the scores of all indexes comprehensively reflects the problems in a particular diet. Due to the lack of data related to drinking water in this study, DQD score ranges from 0 to 72. 1–14 indicates slight diet intake; 15–29, low-level diet imbalance; 30–43, medium-level diet imbalance; over 43, high-level diet imbalance.

As mentioned above, educational level is an important factor affecting dietary nutrient intake, so educational level is controlled in the model of this paper. In addition, existing studies have proved that gender is a factor affecting dietary nutrient intake, and there are significant differences in food consumption between different genders (Galiè et al. 2019). Age is also a factor affecting dietary nutrient intake. The older persons often pay more attention to dietary nutrient intake (Michalczyk et al. 2020; Choi et al. 2021). Family income will significantly affect food consumption of a family (Drescher et al. 2009; Morseth et al. 2017). Studies have found that the higher the family income is, the higher the family's dietary nutrient intake level will be (Tafreschi 2015; Gao et al. 2020). On this basis, demographic variables in this paper include age, gender, marital status, educational level, family income, and Body Mass Index (BMI) (Ridoutt et al. 2016; Bharti et al. 2021). Other control variables include weekly hours of light physical labor, moderate physical labor, and heavy physical labor. These variables are set based on "How many hours you spend on the following physical labor in your weekly working hours" to reflect individual potential demand for food consumption, nutrient intake and diet quality.

Table 1 shows the 24-h average dietary nutrient intake of the parents whose children are under different educational levels (no schooling, primary school, junior middle school, senior high school, secondary technical school or vocational school, bachelor degree, master degree or above). According to the CDG and Balanced Diet Pagoda for Chinese Residents issued by the Chinese Nutrition Society in 2011, the intake of food per person per day is as follows: cereals, 250–400 g; vegetables and fruit, 300–500 g and 200–400 g; animal food such as fish and shrimp (125–225 g), livestock meat and poultry (50–75 g), eggs (25–50 g); dairy products (300 g) and beans and bean products (50 g). The weight of various types of food is not the weight of a specific food, but the total amount of one type of food. It can be seen that in rural China the consumption of cereals exceeds the standard, while the consumption of vegetables basically reaches the standard and the consumption of fruit is inadequate. The total consumption of animal food is inadequate although livestock meat and poultry are consumed in higher quantities. Consumption of dairy products is seriously inadequate, and consumption of beans is high.

The comparison of the recommended amount of the CDG and Balanced Diet Pagoda and the food consumption of the parents whose children are of different educational levels shows that parents in different groups in consuming each type of food are very different. The groups with the higher educational level consume fewer cereals, and fewer vegetables and fruit. The consumption of animal food such as fish, poultry, meat and eggs as well as dairy products sharply increases, but the consumption of beans has no big difference. This suggests that the dietary status of the parents with more educated children is better than that of those with less educated children.

According to the requirements on daily reference intake of macronutrients in Chinese Dietary Reference Intakes (2011), the energy supply percentage of energy-yielding nutrient in adult diet is 50–65% carbohydrates, fat, 20–30%, and protein, 10–15%. According to the National Program for Food and Nutrition Development (2014–2020), the average daily intake of energy per person is 2200 to 2300 kcal, the proportion of cereal intake is no less than 50%, the proportion of fat intake is no more than 30 percent, and the average daily protein intake is 78 g. Based on the above two nutrient intake standards and the conversion

Table 1 Average dietary nutrient intake of the parents with children of different educational levels.

	None	Graduated from primary school	Lower middle school degree	Upper middle school degree	Technical or vocational degree	University or Master's degree or higher	Unit
Cereals	465.631	439.054	455.344	375.816	346.267	346.198	g
Beans	82.252	78.926	79.734	80.524	64.020	82.812	g
Vegetable	322.748	370.151	316.926	287.849	270.842	251.664	g
Fruit	35.315	80.659	64.766	61.683	98.865	92.767	g
Livestock meat	52.568	61.922	63.865	82.026	91.450	93.150	g
Poultry	13.063	9.341	16.642	20.438	25.992	34.145	g
Dairy products	2.252	5.814	3.036	12.753	13.669	15.507	g
Eggs	12.324	19.461	23.466	27.538	28.921	32.783	g
Aquatic products	12.252	17.667	24.954	34.298	35.224	46.135	g
Heat	2402.232	2379.346	2332.919	2212.986	2159.545	2125.351	kcal
Carbohydrates	391.163	384.738	370.775	355.875	335.520	295.289	g
Protein	47.389	59.656	61.407	63.622	65.508	71.592	g
Fat	59.460	60.415	65.106	69.136	71.374	73.968	g
HBS	6.865	6.049	5.918	5.346	4.956	4.696	
LBS	26.676	25.965	24.853	23.524	22.519	21.789	
DQD	33.541	31.314	31.071	28.870	28.176	27.784	

coefficients of major energy-yielding nutrients, the conversion coefficients of carbohydrates, fat and protein are 4 kcal/g, 9 kcal/g and 4 kcal/g, respectively. It can be concluded that the daily macronutrient reference intakes of Chinese adults are 2200–2300 kcal of energy, 287.5–373.8 g of carbohydrates, 48.9–76.7 g of fat and 55–86.3 g of protein.

Table 1 shows that the per capita daily calorie intake of each group basically meets the requirement of the daily reference intake, but carbohydrate intake is significantly higher than the reference intake, especially in the group whose children have low educational level (no schooling and primary school graduates). Fat and protein intake is significantly lower than the reference intake, even in the group with the most educated children. On the whole, with the higher educational level of their children, parents reduce the intake of calorie and carbohydrates, but increase the intake of protein and fat. The change of the diet structure to some extent indicates that children's higher educational level improves parents' nutritional status.

Based on the score range of the DBI–2007 indexes, in terms of diet quality, the HBS of each group is basically in the appropriate range of 1 to 6, indicating no excessive intake. The LBS of each group is in the range of 15 to 29, indicating that there is inadequate dietary intake. The DQD of most groups is in the low dietary imbalance range of 15 to 29, and only the DQD of the group with the lowest educational level (no schooling) is in the medium-level inadequate intake. The comparison of different groups shows that the higher educational level gradually decreases the diet balance index, proving that children's higher educational level improves parents' nutritional status.

Empirical model and method. In order to verify that children's higher educational level may have an impact on their parents' dietary nutrient intake, this paper constructs the following empirical model:

$$F_{\mathrm{ik}} = \sigma_0 + \sigma_1 CEdu_{ik} + \Delta\sigma_2 X_{ik} + \mu_{ik} \quad (1)$$

Equation (1) is a linear regression equation of the influence of children's educational level on parents' dietary nutrient intake. In the equation, F_{ik} denotes the food consumption, nutrient intake and diet quality of individual parent i residing in Province k. $CEdu_{\mathrm{ik}}$ denotes the educational level of their children. X_{ik} denotes other demographic variables that influence food consumption, nutrient intake, and diet quality. μ_{ik} is a random error term.

Model (1) may have endogeneity problems due to omitted variables or reverse causality. Endogeneity refers to the estimation of regression equations in which one or more explanatory variables in the model are correlated with random disturbance terms, resulting in biased parameter estimates (Cameron and Trivedi 2005). There are two reasons for the endogeneity problem: first, omitted variables, as despite the inclusion of as many control variables as possible in the regression model, there are still unobservable factors that can affect both children's educational attainment and parents' dietary intake; and second, reverse causality, as parents with higher levels of dietary intake are likely to be in a better socioeconomic situation and are more likely to invest more in their children's education, resulting in higher educational attainment. These two problems will lead to inaccurate model estimation, which makes it difficult to draw an objective conclusion. Therefore, this paper adopts the IV method to improve the accuracy of causality identification, and takes "the implementation of the Compulsory Education Law (CEL) in rural China" as an instrumental variable of children's educational level (Lundborg and Majlesi 2018; De Neve and Fink 2018; Ma 2019). In 1986, China promulgated the Compulsory Education Law of the People's Republic of China, clearly stipulating that "all children who have reached the age of six, regardless of gender, ethnic group or race, shall attend school and receive compulsory education for a specified period of time". Thus, the implementation of 9-year compulsory education in China to a large extent increases the access of rural children to education, but exerts no impact on the length of schooling of other groups, and has no relation with parents' dietary nutrient intake. Thus, the implementation of compulsory education can be used as an instrumental variable of rural children's educational level.

This paper refers to the strategy of Haines et al. (1988). Two-stage least square method (2SLS) is used for instrumental variable estimation. Equations (2) and (3) are the first and second stage estimation models of 2SLS respectively:

$$CEdu_{\mathrm{ik}} = \alpha_0 + \alpha_1 X_{ik} + \alpha_2 \left(Expose_{ijk} * \mathrm{Infl}_k \right) + \alpha_3 \mathrm{Expose}_{ijk} + \varepsilon_{\mathrm{ik}} \quad (2)$$

$$F_{\mathrm{ik}} = \beta_0 + \beta_1 CEdu_{ik} + \Phi\beta_2 X_{ik} + \mu_{ik} \quad (3)$$

In the first stage estimation (Eq. 2), the impact of the implementation of compulsory education in China on the educational level of rural individuals is estimated. In Eq. (2), $CEdu_{ik}$ is the educational level of child i whose registered

residence is in Province K. $Expose_{ijk}$ is whether the compulsory education is implemented in Province K, the registered residence of child i in year j. The CEL was released in 1986, but compulsory education law was not implemented at the same time across different provinces. The commencement of compulsory education in the provinces covered by the CHNS were Beijing (1986), Liaoning (1986), Heilongjiang (1986), Shanghai (1993), Jiangsu (1986), Shandong (1986), Henan (1986), Hubei (1987), Hunan (1991), Guangxi (1991), Guizhou (1988), and Chongqing (1986). This paper holds that if the samples were at the age of 16 or above when the province started to implement the CEL, it means that the samples had completed the compulsory education and were not impacted by the CEL. If the samples were below 16 years old, it means that the samples were affected by the policy. The samples who were at the age of 7 or below had not been enrolled in school, so $Expose_{ijk}$ is valued as 9, and $Expose_{ijk}$ of the individuals between 8 and 15 is valued between 8 and 1 in descending order, demonstrating the period impacted by the CEL is from 8 years to 1 year.

Due to the varied educational development among different provinces, the impact of the CEL is different in different provinces. This paper adopts the same assumption of Jackson (2016), i.e., the impact of the CEL on different provinces depends on the educational development of each province before the implementation of the policy. The provinces with better educational development would be less impacted by the CEL. Thus, this paper uses the ratio of the population having received junior secondary education to the total population of each province in China Statistical Yearbook of 1986 as an index. The higher proportion means the higher educational development level of the province. The value of $Infl_k$ is the proportion of the population having received junior secondary education to the total population of the province. $Expose_{ijk}$*$Infl_k$ and $Expose_{ijk}$ are used to construct the impact of the CEL on individual educational level.

Results

First, this paper makes an empirical test of the impact of children's educational level on parents' food consumption in rural China, including cereals, beans, vegetables, fruit, livestock meat, poultry, milk, eggs and aquatic products. Second, based on the analysis of food consumption, this paper further explores the impact of children's educational level on parents' nutrient intake, mainly including intake of calorie, heat, protein and fat. Finally, the empirical result of the impact of children's educational level on parents' diet quality is presented, including HBS, LBS and DQD.

Impact of children's educational level on parents' food consumption. In order to eliminate the possible endogeneity problem due to omitted variables and reverse causation, this paper uses the two-stage least square method for instrumental variable estimation with China's education policy as the instrumental variable. Table 2 shows the IV estimation result of the impact of children's educational level on parents' food consumption in rural China. The dependent variables are cereals, beans, vegetables, fruit, livestock meat, poultry, milk, eggs and aquatic products.

The result shows that in all models, the Cragg-Donald Wald F statistic is more than 10, indicating that the instrumental variables selected in this paper are appropriate and there is no problem of weak instrumental variables. In rural China, children's educational level exerts a significant negative impact on their parents' consumption of cereals and vegetables, with the coefficients of −251.021 and −622.201, and the impact is statistically significant at the level of $p < 0.01$. This suggests that parents with better educated children in rural China consume fewer cereals and vegetables. The impact of children's educational level on parents' fruit consumption is not very obvious. In contrast, Chinese rural children's educational level has a significant positive impact on the consumption of livestock meat, poultry, milk, eggs and aquatic products, with coefficients of 240.017, 54.070, 122.874, 66.087, and 30.103, respectively, and the impact is statistically significant at the level of $p < 0.01$, $p < 0.05$, $p < 0.05$, $p < 0.01$, and $p < 0.1$, indicating that the parents whose children have higher educational level consume more meat, poultry, milk, eggs and aquatic products.

According to the CDG, from the perspective of the relationship between food and health, an important feature of the balanced dietary pattern of Chinese residents is that cereals take up a large part. Rich in carbohydrates, cereals are used to be the most economical and important food source for Chinese residents to obtain energy. However, ultra-high proportion of carbohydrates in the diet and ultra-low protein and fat intake will lead to excessive intake of calories, resulting in weight gain and various chronic diseases. Dairy and bean products play an important role in improving nutrition of the Chinese people, especially the poor. In the CDG, vegetables, fruit, dairy products and beans are among the top recommended food types. Aquatic products, poultry, eggs and lean meat are rich in protein, lipid, Vitamin A, B vitamins, iron, zinc and other nutrients, and they are an important part for a balanced diet and an important source of human nutrition. However, the livestock meat rich in fat and saturated fatty acid is no good for preventing cardiovascular and cerebrovascular diseases, overweight, obesity and other diseases.

Thus, children's higher educational level exerts a more significant impact on parents' consumption of all kinds of food, including a significant increase in consuming animal protein food, and a reduction in consuming cereals, meaning the rural parents whose children have the higher educational level enjoy better nutrient intake. The consumption of beans and fruits was not significantly affected, while the consumption of vegetables decreased significantly, but this is not a bad phenomenon for rural China. For a long time, most of beans, vegetables and fruit have been consumed by the rural population. The traditional nutrition concept holds that animal food is more nutritional, which causes the significant decrease of vegetables, but exerts no significant positive impact on the consumption of beans and fruit.

The regression result of other control variables shows that parents' food consumption decreased significantly with age, male's food consumption is higher than female's, parents with higher educational level consumed fewer cereals and more animal protein food, and the families with higher income consume more animal protein food. In addition, the persons with longer heavy physical labor hours consume more cereals, and the persons with higher BMI have a lower consumption of various types of food.

Impact of children's educational level on parents' nutrient intake. Table 2 shows that rural children's higher educational level has a significant impact of improving parents' food consumption. Furthermore, it is necessary to discuss whether rural children's higher educational level will actually improve nutrient intake. Thus, this paper analyzes the impact of children's educational level on parents' nutrient intake in rural China. As the change of food consumption will lead to the structure change of source of nutrition, this paper also analyzes the nutrients from different sources besides the analysis of total nutrient intake, including calories, protein and fat from plant-based food and calories, protein and fat from animal food.

Table 2 Impact of children's educational level on parents' food consumption.

	Cereals	Beans	Vegetables	Fruit	Livestock meat
Children's educational level	−251.021*** (90.345)	38.655 (47.410)	−622.201*** (134.046)	49.038 (76.275)	240.017*** (61.106)
Control variable	Yes	Yes	Yes	Yes	Yes
Constant term	2453.328*** (321.838)	201.719 (171.467)	2992.001*** (452.365)	762.937*** (246.491)	1044.865*** (205.933)
F value at first stage	21.946	21.946	21.946	21.946	21.946
Observations	1194	1194	1194	1194	1194
	Poultry	Dairy products	Eggs	Aquatic products	
Children's educational level	54.070** (21.444)	122.874** (51.458)	66.087*** (18.824)	30.103* (22.900)	
Control variable	Yes	Yes	Yes	Yes	
Constant term	250.635*** (71.757)	−215.824** (109.231)	−158.931** (64.448)	115.808 (71.476)	
F value at first stage	21.946	21.946	21.946	21.946	
Observations	1194	1194	1194	1194	

The data in the bracket are heteroskedasticity standard errors.
Standard errors in parentheses $*p < 0.1$, $**p < 0.05$, $***p < 0.01$.

Table 3 Impact of children's educational level on parents' nutrient intake.

	Heat	Carbohydrates	Protein	Fat
Children's education	−722.858** (312.553)	−60.565*** (18.844)	6.176* (3.748)	24.351* (10.673)
Control variable	Yes	Yes	Yes	Yes
Constant term	5766.231*** (1273.139)	556.278*** (64.230)	106.223*** (12.381)	351.221*** (129.785)
Observations	1194	1194	1194	1194

The data in the bracket are heteroskedasticity standard errors.
Standard errors in parentheses $*p < 0.1$, $**p < 0.05$, $***p < 0.01$.

Table 3 shows that rural children's higher educational level has a significant negative impact on their parents' intake of calories and carbohydrates, but exerts a significant positive impact on their parents' intake of fat and protein. One possible reason is that the parents whose children have higher educational level will pay more attention to the rational nutrition structure under the influence of their children, tend to control the intake of carbohydrates and calories, and increase the intake of fat and protein due to the increase of animal food consumption. According to the data of CHNS from 2010 to 2012, in rural China, the proportion of the intake of cereals, animal food and fat is 58.8, 12.5, and 29.7%, respectively. Compared with developed countries, Chinese rural residents have a relatively high carbohydrate energy supply, while the proportion of protein and fat energy supply is low. Thus, according to the results in Table 3, the increase in children's education is associated with the improvement of their parents' nutritional intake, which is shown as a decrease in the intake of calories and carbohydrates and an increase in the intake of fat and protein.

While exerting an impact on parents' food consumption structure, rural children's higher educational level also has a corresponding impact on parents' nutrient intake structure. The empirical result is shown in Table 4. The regression result shows that rural children's higher educational level has a significant negative impact on parents' intake of energy and protein from plant food, but has a significant positive impact on intake of plant fat, animal calories, animal protein and animal fat. This indicates that parents are more likely to choose animal food with their children's higher educational level. According to the CDG, animal food can provide high-quality protein needed by human body, but animal oil has a higher proportion of saturated fatty acids. Vegetable oil is rich in unsaturated fatty acids. Increased intake of high quality protein and unsaturated fat means more reasonable internal structure of the two nutrients such as protein and fat. At present, residents in rural China still take plant food as the staple diet and animal food as a supplement. Therefore, in terms of the main nutrient intake structure, rural children's higher educational level improves parents' intake structure of main nutrients.

Impact of children's educational level on parents' diet quality. The evidence of the improving effect of rural children's education on parents' dietary nutrient intake has been provided in the previous part from the perspective of food consumption and nutrient intake. Furthermore, to overcome the one-sided impact of one food or one nutrient on measuring the rationality of diet structure, this paper will analyze parents' dietary structure from the perspective of overall diet quality to obtain more evidence that can prove that rural children's educational level improves parents' nutrient intake.

Diet quality is to measure dietary behaviors from the rationality of nutritional structure of food. Dependent variables of the model include three diet balance indexes of HBS, LBS and DQD that are adopted to reflect the problem of excessive and inadequate dietary intake. HBS reflects the degree of excessive dietary intake, and the higher score means higher degree of excessive dietary intake. LBS reflects the degree of inadequate dietary intake, and the higher score means higher degree of inadequate dietary intake. DQD, measured with the sum of the absolute value of scores of all indexes, reflects diet imbalance of a certain food, and the higher score means a higher degree of diet imbalance.

Table 5 shows the brief results of OLS and IV estimation of the impact of rural children's educational level on parents' diet quality, indicating that children's higher educational level exerts a significant impact on improving parents' diet quality. Children's higher educational level significantly lowers the scores of the three indexes such as HBS, LBS and DQD, showing children's higher

Table 4 Impact of children's educational level on parents' intake structure of major nutrients.

	Plant heat	Plant protein	Plant fat
Children's education	−956.965*** (131.718)	−3.159*** (1.378)	3.823*** (1.284)
Control variable	Yes	Yes	Yes
Constant term	3087.681*** (437.188)	77.923*** (11.220)	−2.520 (3.898)
Observations	1194	1194	1194
	Animal heat	Animal protein	Animal fat
Children's educational level	225.699*** (60.993)	9.637*** (3.564)	19.286*** (5.367)
Control variable	Yes	Yes	Yes
Constant term	1236.417*** (211.359)	59.210*** (12.044)	109.846*** (18.719)
Observations	1194	1194	1194

The data in the bracket are heteroskedasticity standard errors.
Standard errors in parentheses $^{*}p < 0.1$, $^{**}p < 0.05$, $^{***}p < 0.01$.

Table 5 Impact of children's educational level on parents' diet quality.

	HBS	LBS	DQD
Children's educational level	−1.463* (0.760)	−0.242** (0.935)	−1.221** (1.117)
Control variable	Yes	Yes	Yes
Constant term	12.580*** (2.481)	24.653*** (3.084)	37.232*** (3.597)
Observations	1194	1194	1194

The data in the bracket are heteroskedasticity standard errors.
Standard errors in parentheses $^{*}p < 0.1$, $^{**}p < 0.05$, $^{***}p < 0.01$.

educational level significantly lowers the degrees of parents' excessive dietary intake, inadequate dietary intake and dietary imbalance. In other words, parents' diet quality has been improved.

Heterogeneity. In traditional Chinese culture, sons often have the duty to care for parents, especially in rural China. Sons have always provided their parents with economic support and care of everyday lives. In addition, as it is common for rural families to prefer sons to daughters, especially when parents are getting old, sons have a higher status and have a bigger say in the family, and they also have a greater influence on their parents. Thus, this paper proposes the hypothesis that sons may have a greater influence on parents' dietary nutrient intake than daughters. The heterogeneity of children's educational level on parents' nutrient intake is analyzed based on whether parents live with their children or not in the CHNS survey.

Table 6 shows the different impact of sons' and daughters' higher educational level on parents' health. First, from the perspective of food consumption, sons' higher educational level significantly reduces parents' consumption of cereals and vegetables, and significantly increases the consumption of livestock meat, poultry, milk, eggs and aquatic products. Daughters' educational level significantly reduces parents' consumption of vegetables, and significantly increases the consumption of livestock meat, poultry, milk and egg food, but the influence coefficient is lower than that of son group. Second, from the perspective of nutrient intake, sons' higher educational level has a significant negative impact on parents' calorie and carbohydrate intake, but has a significant positive impact on the intake of fat and proteins. However, daughters' higher educational level only has a significant negative effect on parents' calorie and carbohydrate intake, but has no significant effect on other nutrient intake. Finally, from the perspective of diet quality, sons' higher educational level significantly reduces the scores of the three indexes such as HBS, LBS and DQD; daughters' higher educational level has no significant effect on diet quality. Based on the above results, it can be found that sons' higher educational level has a greater impact on parents' food consumption, exerts a significant impact on parents' nutrient intake, and significantly lowers the degrees of parents' excessive dietary intake, inadequate dietary intake and dietary imbalance. In other words, parents' diet quality has been improved.

In traditional Chinese rural families, fathers play the role of master and have absolute authority, while their wives and sons are subordinate and subject to their leadership. As they get older, fathers will gradually delegate their power in the family to their sons. However, fathers still have a high status in the family, and the influence of children on fathers is relatively weak. Thus, this paper proposes the hypothesis that children's impact on fathers' dietary nutrient intake may be weaker than that of mothers.

Table 6 tests the impact of children's educational level on dietary nutrient intake of fathers and mothers. In terms of food consumption, children's higher educational level significantly reduces fathers' consumption of vegetables, but significantly increases consumption of livestock meat, dairy products and eggs; children's higher educational level significantly reduces mothers' consumption of cereals and vegetables, but significantly increases consumption of livestock meat, poultry, dairy products, eggs and aquatic products. In terms of nutrient intake, children's higher educational level only has a significant negative impact on fathers' carbohydrate intake. However, children's higher educational level significantly reduces mothers' calorie and carbohydrate intake, but increases their fat and protein intake. The similar result is drawn in terms of diet quality. Children's higher educational level exerts no significant impact on fathers' three indexes such as HBS, LBS and DQD, but significantly reduces the degree of mothers' excessive dietary intake, inadequate dietary intake and dietary imbalance. In other words, mothers' diet quality has been improved. Thus, when children's educational level is higher, the mothers' dietary nutrient intake is more affected in a comprehensive way, while fathers are less affected.

Mechanism analysis. In order to further explore the impact channels of rural children's higher educational level on parents' dietary nutrient intake, this paper analyzes the possible transmission mechanisms. Dietary knowledge can be spread, and it will exert an impact on diet health of other people (Marshak et al. 1998). Furthermore, nutritional knowledge is an important predictor of dietary intake, for single nutrient or food group, or dietary nutrient intake index (Hendrie et al. 2008). Therefore, when children's educational level is higher, it is possible to influence their parents' dietary knowledge through spreading health and nutrition knowledge, so as to improve their parents' dietary nutrient intake.

Table 6 Test results of different sample groups.

	Children group		Parent group	
	Son sample	Daughter sample	Father sample	Mother sample
Food				
Cereals	−254.973** (104.010)	−252.273* (107.976)	−129.987 (122.643)	−324.952*** (124.957)
Beans	99.171 (60.878)	−102.463 (130.338)	37.437 (71.558)	56.101 (61.291)
Vegetables	−584.660*** (139.183)	−631.464* (469.121)	−571.738*** (184.517)	−644.751*** (181.434)
Fruit	52.957 (74.505)	41.634 (64.816)	48.526 (112.437)	49.750 (102.082)
Meat	285.992*** (67.392)	196.424** (70.292)	184.257** (75.733)	283.685*** (89.413)
Poultry	67.079** (23.014)	49.326* (97.564)	53.844 (33.152)	49.884** (25.445)
Dairy products	130.231** (36.940)	96.515* (39.493)	93.442* (48.582)	142.565* (84.184)
Eggs	77.459*** (19.221)	52.639* (78.108)	51.076** (24.382)	78.360*** (27.695)
Aquatic products	31.096* (23.114)	25.154 (38.743)	16.342 (36.065)	41.036* (28.086)
Energy				
Heat	−683.546** (326.303)	−257.182* (391.650)	−559.589** (404.098)	−801.444* (428.115)
Carbohydrate	−50.005*** (18.769)	−42.203* (51.324)	−52.793* (27.972)	−64.211*** (23.515)
Protein	5.798** (3.579)	2.612 (21.355)	2.897 (5.261)	8.685* (5.094)
Fat	53.122** (32.486)	23.618 (26.611)	44.513 (39.630)	56.623** (41.944)
Nutritional balance				
HBS	−1.489* (0.865)	−0.807* (2.044)	−0.486 (1.054)	−2.117** (1.067)
LBS	−0.260** (0.995)	−0.096* (4.189)	−0.045 (1.328)	−0.296** (1.288)
DQD	−1.549** (1.243)	−0.903* (4.862)	−0.441 (1.615)	−1.821** (1.503)

The data in the bracket are heteroskedasticity standard errors.
Standard errors in parentheses *$p < 0.1$, **$p < 0.05$, ***$p < 0.01$.

Based on the above theoretical analysis, this paper takes the change of China's education policy as an instrumental variable to carry out two-stage instrumental variable estimation results and analyzes the impact of children's educational level on parents' dietary knowledge. This paper further classifies the questions related to dietary knowledge in the CHNS questionnaire into three types such as food consumption, nutrient intake and diet quality. The questions in food consumption include: "The diet habit of eating a lot of staple food (rice, wheat and their products) is bad for health", "It's good for health to eat beans and bean products", "The diet habit of eating a lot of fresh fruit and vegetables is very good for health", "It's good for health to eat a lot of meat products (such as fish, poultry, eggs, lean meat)", and "It's good for health to drink milk and eat dairy products". The questions in nutrient intake include: "Vegetables contain more starch than staple food (rice or flour)", "It is good for health to eat high-fat food", and "eggs and milk are important sources of high-quality protein". The questions in diet quality include: "It is good for health to eat less fat and animal fat", "Lard is healthier than vegetable oil", "Refined rice and refined flour contain more vitamins and minerals than coarse grains and brown rice", and "It is good for health to eat different kinds of food". Respondents' answers to the above questions are valued as follows: Strongly disagree = 1, Disagree = 2, Neutral = 3, Agree = 4, Strongly agree = 5. The IV regression in Table 7 shows that the impact based on dietary knowledge is basically consistent with the above conclusion. Children's higher educational level can significantly increase parents' dietary knowledge, and make parents agree more on the knowledge related to food consumption, nutrient intake and diet quality.

Discussion

More and more studies had found that there was an upward spillover of human capital from children, and that children's education could potentially have an impact on their parents' health (De Neve and Fink 2018; Ma 2019). China, the largest developing country in the world, has scored fast economic growth. Meanwhile, it has witnessed wide education popularization and rapid development, which has led to huge intergenerational differences in educational levels. Thus, children who receive better education may have an impact on their parents' dietary nutrient intake. Different from studies on the impact of education on dietary nutrient intake in developed countries, the analysis on the unique problem in China can enrich the research on the impact of education on dietary nutrient intake. This differed from some studies in developed countries because mechanisms such as social support and resource access might be more prominent in China as a developing country than in developed countries (Friedman and Mare 2014). Children were part of their parents' social network, so their socioeconomic status might have an independent influence on their parents in many behavioral processes (Berkman et al. 2000; Rowa-Dewar et al. 2014).

In terms of food consumption, rural children's higher educational level significantly improved parents' food consumption structure, which significantly reduced the consumption of cereals and vegetables, and significantly increased the consumption of livestock meat, poultry, dairy products, eggs and aquatic products. This was because better educated children acquired more health knowledge, which in turn had an impact on their parents (Cutler and Lleras-Muney 2010). Children shared the health knowledge gained in school with their parents, thus increasing their parents' health knowledge and improving their perceptions of dietary health (Ferrini et al. 1994; Berniell et al. 2013).

In terms of nutrient intake, rural children's higher educational level improved parents' nutrient intake. Children's higher educational level had a significant negative impact on parents' energy and carbohydrate intake, and had a significant positive impact on their fat and protein intake. From the perspective of nutrient intake structure, rural children's higher educational level had a significant negative impact on parents' intake of energy and protein from plant food, but had a significant positive impact on intake of plant-based fat, animal calories, animal protein and animal fat. Well-educated children also had more financial means to provide material assistance to their parents, thereby improving the quality of their parents' meals (Friedman and Mare 2014). The result of diet quality showed that children's higher educational level significantly lowered the degrees of parents' excessive

Table 7 Impact of children's educational level on parents' dietary knowledge.

	IV
It is not good for health to eat a lot of staple food (cereals).	0.072* (0.205)
It is good for health to eat beans and bean products.	0.409*** (0.145)
It is very good for health to eat a lot of fresh fruit and vegetables.	0.261 (0.154)
It is good for health to eat a lot of meat products (such as fish, poultry, eggs, lean meat) every day.	0.459** (0.191)
It is good for health to drink milk and eat dairy products.	0.557*** (0.216)
Vegetables contain more starch than staple food (rice or flour)	−0.581*** (0.178)
It is good for health to eat high-fat food.	0.911*** (0.288)
Eggs and milk are important sources of high-quality protein.	0.440** (0.201)
It is good for health to eat less fat and animal fat.	−0.981*** (0.283)
Lard is healthier than vegetable oil.	0.955*** (0.263)
Refined rice and refined flour contain more vitamins and minerals than coarse grains and brown rice.	0.336 (0.242)
It is good for health to eat different kinds of food.	0.028** (0.154)

The data in the bracket are heteroskedasticity standard errors.
Standard errors in parentheses *$p < 0.1$, **$p < 0.05$, ***$p < 0.01$.

dietary intake, inadequate dietary intake and dietary imbalance. In other words, parents' diet quality had been improved.

Related studies had indicated that there is a significant gender difference in the impact of children's educational level on parents' dietary nutrient intake (Lee et al. 2017; Lundborg and Majlesi 2018; Wei et al. 2022). The heterogeneity analysis in this paper showed, there was also a gender difference between sons and daughters, but sons' higher educational level had a greater impact on parents' dietary intake, while the impact of daughters was relatively small, which is slightly different from the findings of existing studies (Lundborg and Majlesi 2018). One possible reason is that China's rural areas are deeply influenced by traditional culture. In the traditional concept of raising sons as an insurance against the insecurity of old age, sons in rural families take the responsibility of supporting their parents. Moreover, sons have a greater say in the family and have a greater impact on their parents' dietary nutrient intake. In addition, it was found that there was a big difference between the influence of fathers and mothers. When children's educational level was higher, the mothers' dietary nutrient intake was more affected in a comprehensive way, while fathers' was less affected. This conclusion is similar to the studies of Berniell et al. (2013) and Lundborg and Majlesi (2018). The possible reason is that fathers are reluctant to accept their children's dietary and nutritional advice owing to their higher status in China's rural families, but mothers are more likely to follow their children's advice, thus improving their dietary nutrient intake.

Social network theory (Berkman et al. 2000) suggested that by using the family as a social network, children with more education would pass on more health knowledge gained in school to their parents, thus changing their health perceptions and physical activity behaviors. Therefore, we analyzed the possible transmission mechanism, which was due to the fact that health perception might be one of the most important factors (Lundborg and Majlesi 2018). Results showed that higher levels of education among children significantly improved parents' dietary knowledge and led to greater parental agreement with knowledge related to food consumption, nutrient intake, and diet quality, as was the research of Xie et al. (2021).

Conclusion and policy recommendations

The lack of nutritional knowledge is a major factor affecting the dietary nutrient intake of Chinese rural residents. In particular, the low educational level of middle-aged and elderly people in rural China has become an important obstacle of improving their dietary nutrient intake. This paper explored the impact of children's educational level on parents' dietary nutrient intake in rural China. The results revealed that China's rural children's higher educational level exerts a significant positive impact on the improvement of parents' food consumption, nutrient intake and diet quality. In other words, education has an upward spillover effect on dietary nutrient intake. This indicates that the improvement of rural education can be an effective approach to increase dietary nutrient intake of China's rural population.

This result includes some important policy implications. Firstly, the problem of inadequate nutritional intake has been largely solved with the continuous development of China's rural economy, and the effect of income increases on the nutritional intake of China's rural population is now less significant. Increases in income do not solve the problems of dietary imbalances caused by a lack of dietary knowledge, and therefore policy measures that rely solely on income increases to eliminate dietary intake problems are incomplete. The findings of this study show that improved education of children can increase parents' dietary knowledge, improve their dietary structure and reduce their dietary imbalances, thereby significantly improving the quality of their diets, which is evidence that education plays an important role in improving dietary intake. However, it is impossible to raise the educational level of the middle-aged and elderly people and it is hard to implement universal nutrition education in rural China. Based on the result in this paper, it is an effective approach to improve dietary nutrient intake of China's rural population through raising their children's educational level.

Secondly, the compulsory education system implemented in China can not only raise the educational level of rural residents, but also have strong externalities in health and dietary nutrition. Thus, education can be used as an important means to improve the human capital of rural residents in China. The Chinese government needs to further develop rural basic education, constantly improve conditions in rural schools, and improve the quality of teaching.

Finally, the government needs to strictly implement compulsory education in rural areas, prevent dropouts due to various reasons, and consolidate achievements in popularizing compulsory education. The government needs to improve urban enrollment policies and create conditions for rural children to study and live in cities with their parents. Second, the Chinese government needs to extend the compulsory education period and gradually includes high school education in the compulsory education, which will be an effective means to further improve China's human capital, especially in rural China. In addition, more health education activities should be carried out in school education. In particular, it is suggested that health education, especially nutrition education, should be included in the national

education system. Health and nutrition education should be taken as an important part of compulsory education, and health education promotion mechanism should be established in schools.

One limitation warrants cautious interpretations of our findings. Individuals may report their food consumption inaccurately because of various reasons such as memory, knowledge, and the interview situation, thus CHNS is unable to include all foods consumed in the records.

Data availability

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

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Competing interests

The authors declare no competing interests.

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