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RESEARCH ARTICLE

SHIFTING TO A RECOMMENDED DIETARY PATTERN COULD PROMOTE SUSTAINABLE DEVELOPMENT OF THE ENVIRONMENT AND HUMAN HEALTH

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KEYWORDS

CHNS data, cluster analysis, dietary patterns, sustainable development

HIGHLIGHTS

- Shifting from the existing dietary patterns to the alternative recommended dietary pattern could enhance the sustainable development of environment and human health.
- Shifting to the Planet Healthy Pattern is more effective than the Chinese Dietary Pattern.
- Measures and efforts to induce balanced dietary behavior are necessary.

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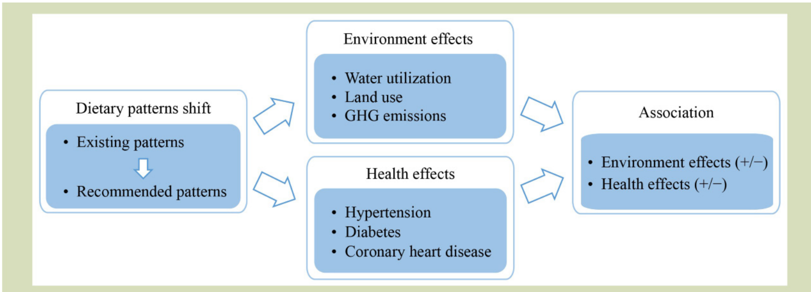
GRAPHICAL ABSTRACT



ABSTRACT

With the rapid development of China's economy, Chinese people tend to eat foods rich in fat, sugar and protein. This change in dietary pattern has brought double challenges to China's sustainable development of environment and human health. So it has become urgent for the nation to shift to a healthy and sustainable dietary pattern. Based on the China Health and Nutrition Survey database, this study used K-means cluster analysis to classify China's existing dietary patterns into quasi-southern, quasi-northern and quasi-western patterns. Two alternative recommended dietary patterns, Chinese dietary and planet health patterns, were selected to compare the effects of environment and health. The results show that a shift from the three existing dietary patterns to two alternative dietary patterns could enhance sustainable development of environment, especially for the quasi-western pattern shifting to the planet health pattern. Also, a shift would have of great benefits for human health, effectively reduce the relative risks of diseases such as hypertension, type 2 diabetes and coronary heart disease. The greatest benefits would come from shifting the quasi-western pattern benefits to one of the two alternative dietary patterns in terms of environment effects, and the quasi-southern pattern benefits most in terms of health effects. Shifting to the planet health pattern is more effective than the Chinese dietary pattern both in environment and human health. This paper provides policy recommendations to vigorously advocate dietary balance, scientifically promote dietary patterns, and change consumer dietary behavior.

1 INTRODUCTION

Following economic reforms and increased globalization, dietary patterns of Chinese people have undergone great changes. With the continuous improvement of China's income and urbanization, diets are shifting from a traditional diet, based on cereal consumption, to a diversified diet based on food consumption rich in fat, sugar and protein. For example, Chinese annual per capita consumption of livestock and poultry meat has increased more than twofold, while the annual per capita consumption of grains and vegetables has declined to varying degrees from 1997 to 2019[1].

Diets inextricably link environmental sustainability and human health. Such structural changes in diet have had a significant impact on China's sustainable development of environment and health. In environmental terms, China's existing dietary patterns have brought severe challenges to China's environment from greenhouse gas (GHG) emissions, water utilization and land use. For example, GHG emissions are on the rise. According to the report on 2021 China and Global Food Policy, carbon emissions from China's agricultural food system increased from 940 Mt in 1997 to 1.16 Gt in 2012, with an upward trend. The urgency of water utilization and land use has increased[2], with per capita food water consumption increasing from 255 $m^3 \cdot yr^{-1}$ in 1961 to 860 $m^3 \cdot yr^{-1}$ in 2003[3], and the current arable land area may not meet the food consumption needs for Chinese people, making China the largest net importer of virtual arable land in recent years[4]. In health terms, the increasing food consumption and changing dietary structure contribute to an improvement in nutrition and health status of Chinese people. However, dietary imbalance has prompted Chinese people to face the problems of coexistence of malnutrition, insufficient trace elements and multiple diet-related diseases[5]. For example, according to the data from National Center for Cardiovascular Diseases of China, the prevalence of coronary heart disease among Chinese adults increased from 4.6% in 2003 to 10.2% in 2013, and the number of mortality and deaths from coronary heart disease continues to increase. Concurrently, the prevalence of diet-related chronic diseases has gradually increased, with the prevalence of hypertension among adults reaching 27.5% and diabetes reaching 11.9% in 2018. In summary, China urgently needs to build a healthy and sustainable food system[6].

Shifting to a healthy dietary pattern is one of the important ways to achieve a healthy and sustainable food system. Many exploratory studies have been done on this topic, mainly focusing on the following three aspects. (1) Assessment of environment effects of dietary patterns such as GHG emissions[7], water utilization[8] and land use[9]. (2) Assessment of the health effects of dietary patterns. For example, Fung et al. found a significantly lower risk of coronary heart disease and stroke if a Mediterranean dietary pattern was maintained[10]. Also, some scholars evaluated the effects of dietary patterns on the environment and on health. For example, Tilman and Clark found that three alternative diets, Mediterranean, fish-vegetarian and all-vegetarian, have reduced total all-cause mortality by 0% to 18% compared to existing diets. Shifting to these three healthy alternative diets will significantly reduce GHG emissions and agricultural land demand[11]. (3) Proposal of healthy and sustainable dietary patterns. Some scholars take human health as the main goal. For example, Li puts forward some suggestions on food consumption for Chinese urban residents based on the perspective of nutrient intake[12]. Some scholars take the environment as the main goal. For example, Lin et al. proposed sustainable consumption pattern in China with high ecological carrying level as the main goal for optimization[13].

However, there are still some shortcomings in the current research. Firstly, with respect to research focus, most studies analyze the existing dietary patterns in various countries, or common dietary patterns such as the Mediterranean dietary pattern[14] and the vegetarian dietary pattern[15]. Few studies evaluate the latest proposed dietary pattern from the perspectives of environment and health effects. In addition, among the analyses on health effects, few studies have conducted analyses from the perspective of dietary-related diseases such as hypertension. Dietary pattern analysis has emerged as an alternative, holistic approach that summarizes complex dietary data to explore more practical information than data on individual foods or nutrients for investigating dietary-disease relationships[16]. Secondly, with respect to research area, most of the existing studies analyze the dietary patterns in developed countries such as the USA[17], the UK[18] and Spain[19], and few studies analyze the dietary patterns in developing countries such as China. China's consumer market has become the fastest growing market among the major economies so that it is worthy of study. Also, compared with the dietary pattern of western developed countries, the Chinese dietary is much more complex, so it is important to explore dietary status and existing dietary patterns[16]. Thirdly, with respect to research data, most studies use macro-data such as food consumption data released by the National Bureau of Statistics[1], and few studies use micro-data such as China Health and Nutrition Survey (CHNS) to explore environment and health effects of dietary pattern. And CHNS has nearly 2000 types of food, including the amount consumed away-from-home, which could be used to analyze environment and health effects more precisely.

Thus, based on the CHNS database, this study evaluated the environment and health effects under different dietary patterns, aiming to explore whether a shift to an alternative dietary pattern could promote sustainable development of environment and health. This study first analyzes the dietary status of Chinese residents, and explores the existing dietary patterns of Chinese residents through K-means cluster analysis. Additionally, this study selected two alternative recommended dietary patterns, the Chinese dietary pattern (CDP) proposed by the Chinese Nutrition Society and the planet health pattern (PHP) proposed by EAT-Lancet, and evaluates environment and health effects under different existing and alternative dietary patterns. By focusing on CDP, this study could provide clear understanding of the eastern dietary pattern and provide reference for developing countries to develop healthy dietary patterns. Finally, we provide policy recommendations to help China to build a healthy and sustainable food system.

2 DATA AND METHODOLOGY

2.1 Data source and preprocessing

2.1.1 Data source

This study used the CHNS database. CHNS, an ongoing open cohort, international collaborative project between the Carolina Population Center at the University of North Carolina at Chapel Hill and the National Institute for Nutrition and Health at the Chinese Center for Disease Control and Prevention, was designed to examine the effects of the health, nutrition and family planning policies, and programs implemented by national and local governments and to see how the social and economic transformation of Chinese society is affecting the health and nutritional status of its population. Initiated with a partial sample in 1989, the full survey of CHNS runs from 1991 to 2015. The sample began with eight provinces and added a ninth, Heilongjiang, in 1997 and three cities, Beijing, Shanghai and Chongqing, in 2011 and three provinces, Zhejiang, Shaanxi and Yunnan, in 2015. Since the data on food consumption in the CHNS database are currently only released until 2011, this study used the CHNS-2011 for subsequent calculation and analysis.

2.1.2 Data preprocessing

Based on the food consumption data, CHNS covers nearly 2000 kinds of food. To meet the research needs, food needs to be classified according to the following steps. Firstly, over 1000 kinds of food were allocated into 36 food subgroups such as rice, wheat, corn, pork and beef. Secondly, these 36 food subgroups were allocated to 11 food groups according to the relevant literature i.e., grains, tubers, vegetables, fruits, meat, aquatic products, egg, dairy, nuts, legumes, oil and sugar[20]. Given that oil and condiment data were at the household level, this study obtained the family-member three-day meal times, total meal times and meal times ratio according to the three-day meal times of the household survey, in order to calculate oil and condiment intake of each family member[21]. Finally, we estimate the average daily intake of each food for Chinese residents.

The basic characteristics of residents, such as age, gender, urban and rural areas, provinces, height, weight and body mass index, were combined with the individual daily food consumption. Since CHNS separates the adult survey from the childhood survey, and the contents of the two surveys are not completely consistent, this study explored the dietary pattern for Chinese adults and obtaining basic data on characteristics and daily food consumption for Chinese adults.

Missing data and outliers had to be addressed. For missing values, all missing values in food consumption were treated as 0 in this study because residents might not be able to eat all kinds of food during the survey period. For outliers, samples with negative food consumption and beyond three standard deviations of the mean were excluded as outliers. The final sample size of data was 5080.

2.2 Research method

2.2.1 K-means cluster analysis

Cluster analysis is a method for examining dietary patterns, being a statistical method for classification according to the characteristics of individuals. In the case of unclear overall classification, clustering can be used to explore the classification of individuals[22]. Given the extensive territory and culture diversity of China, dietary patterns are complex. Thus, this study used K-means clustering analysis to explore the dietary patterns of Chinese adults and classified the sample individuals with similar diets using the following steps. (1) The optimal clustering number, namely clustering center of gravity center, was determined. The maximum number of clusters was set, and the optimal number of clusters was determined according to the increase of the number of clusters combined with the change of the squared error and sum of squares for error (SSE). (2) Samples were then classified according to the clustering center of gravity. The Euclidean distance between each sample and each center of gravity center was sequentially calculated, and samples were put into a class with the smallest distance. The mean vector of the new class was replaced with the center of gravity of the new class, and the process was repeated until all samples were classified. (3) The average level of food consumption was calculated to describe the characteristics of dietary patterns for each class. These steps were all performed using Stata statistical analysis software.

2.2.2 Calculation of environment effects

Environment effects were attributed to water utilization, land use and GHG emissions linked to the initial agricultural production.

According to Food and Agriculture Organization, food is lost or wasted throughout the supply chain, from initial agricultural production down to final household consumption. When calculating the environment effects of food consumption, food loss and waste need to be taken into account so that the estimated environment effects are more reasonable. In this analysis we used food lose and waste ratios reported by the Food and Agriculture Organization[23] (Table S1) and obtained the amount of production (C_i) required for each food consumption.

Water utilization in this study mainly referred to surface water and groundwater resources, i.e., blue water utilization. Water utilization (W) was taken as equal to the sum of the products of individual food production (C_i) and blue water coefficient (BW_i), according to Eq. (1). Blue water coefficient of foods were sourced from Mekonnen and Hoekstra[24,25] which gives the blue water coefficients of major crops and farm animals at the national level from 1996 to 2005. Since our food consumption data was based on 2011, we used the method of Ali et al.[26] to update the water coefficient ($m^3 \cdot t^{-1}$).

$$W = \sum_{i=1}^{n} C_i \times BW_i \tag{1}$$

Land use was mainly based on the concept of ecological footprint, which refers to the productive land area needed to meet the needs of people for consumption of products and disposal of waste[27]. Land use (L) was taken as equal to the sum of the products of the individual food production (C_i) and the land use coefficient (EF_i), according to Eq. (2). Since FAOSTAT provides the harvest field and the production of the main crops produced in each country, and we took the ratio of these values to be the unit annual land occupation for these products. Also, we obtained the land use coefficient (10^{-5} $km^2 \cdot kg^{-1}$) through the land occupation and yield of various types of food.

$$L = \sum_{i=1}^{n} C_i \times EF_i \tag{2}$$

GHG emissions (G) were taken as the sum of the products of the individual food production (C_i) and the carbon emission factor (CE_i) calculated as Eq. (3). The GHG emission coefficient ($kg \cdot kg^{-1}$ CO_2 eq) of each crop was obtained by averaging the collected lifecycle assessment studies as used in other research[28]. For the GHG emissions, the coefficient ($kg \cdot kg^{-1}$ CO_2 eq) of main farm animals was obtained from the 2011 FAOSTAT database.

$$G = \sum_{i=1}^{n} C_i \times CE_i \tag{3}$$

More details about coefficients on blue water, land use and GHG emissions are available at supplementary materials (Table S2) and description of calculation method at supplementary methods.

2.2.3 Calculation of health effects

In health effect terms, this study focused on three diseases closely related to diet: hypertension, type 2 diabetes and coronary heart disease. The results of other systematic evaluation and meta-analysis on food group of hypertension[29], diabetes[30] and coronary heart disease[31] were used for calculation of health effects. The advantages of systematic evaluation and meta-analysis are that a large number of cohort studies in medical science are included, and relevant factors such as gender and age are controlled, so that the medical results can be widely applied[32]. Those study provide nonlinear relationships between food groups and diseases, and these relationships were divided as positive, negative or not correlated.

Based on the dose–response relationship between different food groups and diseases (Tables S3–S5), we first calculate the relative risk (RR) change for each dietary pattern compared with non-consumption. Specifically, the potential of dietary patterns to reduce the risk of each disease was calculated by multiplying the RR by selecting risk-reducing foods noted as $RRreduced_i$ ($RRreduced$ means the value is < 1) and risk-increasing foods noted as $RRincreased_i$ ($RRincreased$ means the value is > 1). In this way, RR change was calculated as:

$$RRchange = \left(\sum_{i=1}^{n} RRreduced_i \times \sum_{i=1}^{n} RRincreased_i\right) - 1 \tag{4}$$

Secondly, we calculated RR reduction for a shift from an existing dietary pattern to an alternative dietary pattern. Given that the RR reduction values for different dietary patterns relative to non-consumption were calculated in step 1, the RR reduction for a shift from an existing dietary pattern to an alternative dietary pattern was based that value (See supplementary materials for more details of the calculation of health effects).

2.2.4 Calculation of estimated energy requirement

Different dietary patterns need to be compared at the same energy level, so it is necessary to calculate the estimated energy requirement (EER), which is the average dietary energy intake that is predicted to maintain energy balance in healthy, normal-weight individuals of a defined age, gender, weight, height and level of physical activity consistent with good health. EER_i was calculated using the formula of Tabata et al.[33]:

$$EER_i = R_i \times Weight_i \times PAL_i \quad (5)$$

where, EER_i is the estimated energy requirement (kcal per day) for each adult i and R_i is the energy requirement of 1 kg bodyweight per person per day, which is divided according to gender and age. For males, this was 22.7 kcal for 18–49 years old, 21.5 kcal for 50–65 years old, 21.4 kcal for 66–80 years old, and 21.5 kcal for 80 years old and above. For females, it was 21.4 kcal for those aged 18–49 and 20.1 kcal for those aged 50 and above (Table S6). $Weight_i$ is the bodyweight of each individual investigated from CHNS data, where the bodyweights of overweight and underweight adults are adjusted to a critical normal weight according to the definition of EER, based on a relevant study[28]. Also, the EER_i was then adjusted by inflating this basic energy need with the physical activity level (PAL_i). PAL_i is a non-dimensional factor, and a higher PAL_i indicates more intensive physical activities and higher energy demand. For this purpose we applied estimate of this value according to the labor intensity given in the CHNS questionnaire[28], where no, very light and light work physical activities categories in the CHNS questionnaire were assigned 1.5, moderate physical activities was assigned 1.75, and heavy and very heavy work physical activities was assigned 2 (Table S7; See supplementary materials of calculating estimated energy requirement for more details).

3 RESULTS

3.1 K-means cluster analysis of dietary pattern

The three kinds of dietary patterns are classified by conducting K-means clustering analysis on existing samples using the standardized daily individual intake of 14 food subgroups (Fig. 1). The average daily intake of rice and vegetables in dietary pattern 1 is much higher than the other two dietary patterns and the average daily intake of wheat in dietary pattern 2 is much higher than others. But the average daily intake of fruits, meat and milk in dietary pattern 3 is the highest among the three dietary patterns. In view of the regional cultural characteristics and related dietary clustering studies[22], we designated these three patterns as quasi-southern, quasi-northern pattern and quasi-western patterns, respectively.

3.2 Per capita daily food intake under different dietary patterns

This study selected two alternative dietary patterns were used to evaluate the environment and human health effects. These

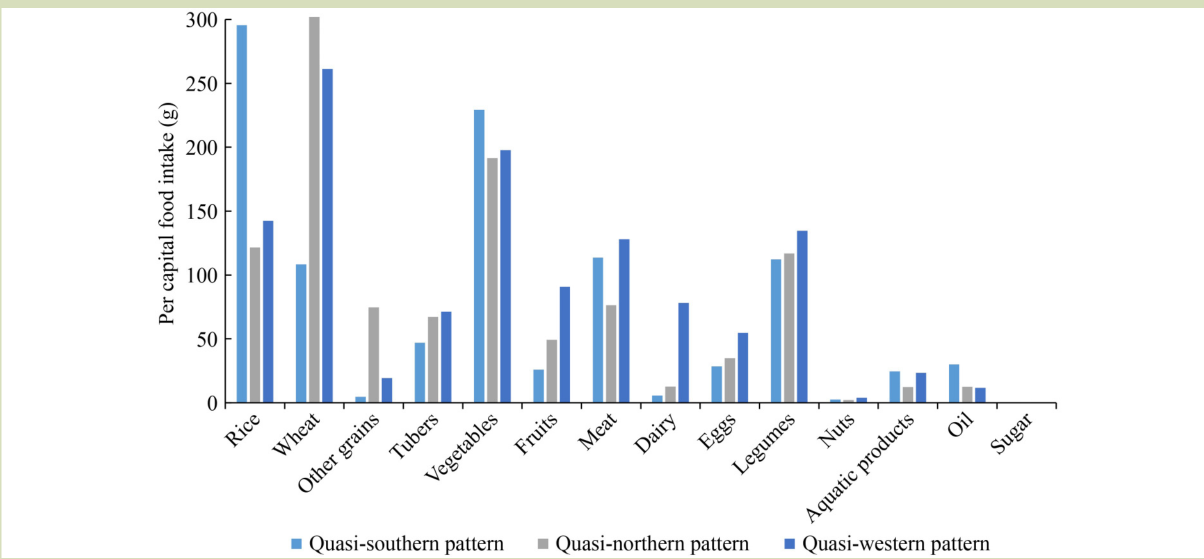


Fig. 1 Per capita daily food intake under three clustering dietary patterns (quasi-southern, quasi-northern and quasi-western patterns).

were selected as being a novel dietary pattern for China and one applicable to Chinese adults. The first was CDP proposed by the Chinese Society of Nutrition and the second was the PHP proposed by EAT-Lancet. These alternative dietary patterns have different emphases, with the former focusing on nutritional health and the latter on resource environment. Therefore, it is necessary to conduct a comprehensive evaluation on the environment and health effects of these alternative dietary patterns, and compare them with the existing dietary patterns.

The daily food intake of different dietary patterns at the same energy level varies significantly (Table 1). Compared to the three existing dietary patterns, CDP and PHP require less intake of cereals, meat and sugar, and more intake of vegetables, fruits, dairy and nuts. In addition, the two alternative dietary patterns also have their own emphasis on food consumption. For example, in terms of vegetable and eggs intake, the CDP is much higher than the PHP, while in terms of nut intake, the PHP is significantly higher than the CDP.

3.3 Environment effects of different dietary patterns

Shifting to alternative dietary patterns might not necessarily deliver environmental sustainability (Fig. 2). With respect to water utilization, among the three existing dietary patterns (quasi-southern, quasi-northern and quasi-western patterns) the quasi-southern pattern has the least water consumption, while the quasi-western pattern has the most water consumption, mainly due to the fact that the consumption of meat and dairy products in the quasi-western pattern is higher than that in the quasi-southern pattern. If people changed from the quasi-southern and quasi-northern patterns to two alternative dietary patterns, the daily water consumption would increase mainly because of an increased intake of dairy. A change from the quasi-western pattern to the CDP, would decrease the daily water consumption by about 14% whereas a change to the PHP would only give a reduction of about 5%. The main reason for this water saving would be the reduction in meat consumption. With respect to land use, if people change from the existing dietary patterns to the CDP, only for the quasi-western pattern would there be a reduction (−14%) in land use. However, if the change was to the PHP, land use would decrease for the three existing patterns (quasi-southern, quasi-northern and quasi-western pattern) by about 11%, 9% and 28%, respectively. The main reason for these saving would be a reduction in meat consumption, which would contribute by more than half of the land use saving[11]. With respect to GHG emissions, if people changed from the three existing dietary patterns to one of alternative dietary patterns, all but the quasi-northern pattern would contribute to reductions in GHG emissions, with similar benefits for changes from both the quasi-southern and quasi-western patterns.

In summary, with respect to environment effects, a shift from the three existing dietary patterns to either of the alternative dietary patterns, a change from the quasi-western pattern would provide the most benefits, where as a shift from the other two existing patterns might be neutral or even

Table 1 Daily food intake (g) of different dietary patterns at 2000 kcal level

Food group	QSP	QNP	QWP	CDP	PHP
Grains and tubers	455.5	565.3	494.2	275	250
Vegetables	229.3	191.4	197.7	450	300
Fruits	26.0	49.2	90.7	300	200
Meat	113.5	76.4	128.1	50	43
Aquatic products	24.5	12.2	23.3	50	28
Eggs	28.5	34.9	54.7	50	13
Dairy	5.6	12.7	78.1	300	250
Legumes	112.3	116.9	134.6	65	75
Nuts	2.5	2.2	3.9	10	50
Oil	29.9	12.5	11.8	25	20
Sugar	0.1	0.4	0.2	0	0

Note: The intake of 11 food groups in the table was calculated by combining consumption of 36 food subgroups. Comparing different dietary patterns required these to be at the same energy level. According to the research method, the estimated energy requirement of each Chinese adult is about 2000 kcal per day. QSP, quasi-southern pattern; QNP, quasi-northern pattern; QWP, quasi-western pattern; CDP, Chinese dietary pattern; and PHP, planet health pattern.

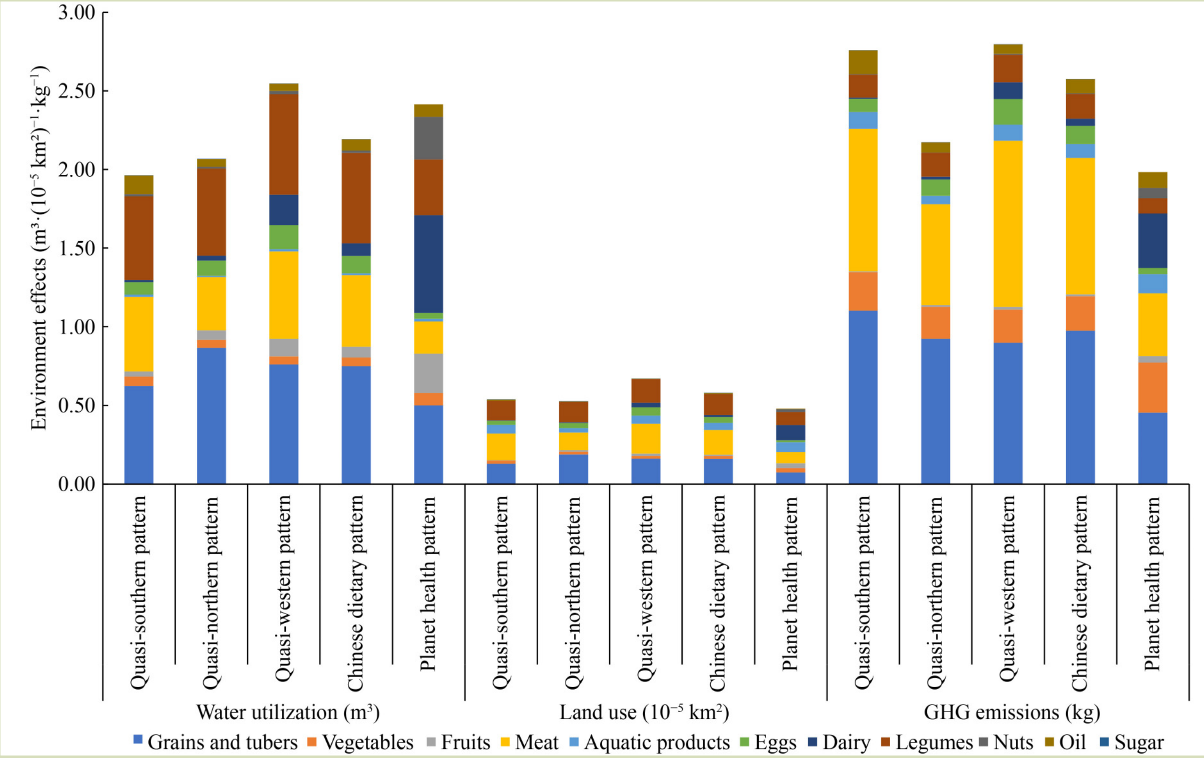


Fig. 2 Environment effects (water utilization, land use and GHG emissions) of different dietary patterns (quasi-southern, quasi-northern, quasi-western, Chinese dietary and planet health patterns).

detrimental in the case of a shift from the quasi-northern pattern. Importantly, the PHP appears to be more resource-friendly than the CDP.

3.4 Health effects of different dietary patterns

Shifting to either of the alternative dietary patterns would significantly reduce the relative risk of three diet-related diseases (Fig. 3). With respect to hypertension, among the three existing dietary patterns (quasi-southern, quasi-northern and quasi-western patterns), a shift to the PHP reduced the relative risk (39%, 33% and 37%, respectively) which was more than a shift to the CDP (30%, 23% and 28%, respectively). The main reason for this risk reduction is that under the alternative dietary patterns, decreasing consumption of red meat would help reduce the risk of hypertension[29]. With respect to type 2 diabetes, among the three existing dietary patterns, the quasi-western pattern was more beneficial than the other existing patterns. Shifting to the CDP or PHP might reduce the relative risk of diabetes about 38% and 47%, respectively, mainly due to the increasing whole grain consumption and reducing of red meat consumption[30]. With respect to coronary heart disease, among the three existing dietary patterns, the quasi-southern pattern was more beneficial than the other existing patterns. Shifting to the CDP or PHP might reduce the relative risk of coronary heart disease by about 33% and 41%, respectively, mainly due to the increasing whole grain and fruit consumption[31].

In summary, in terms of the relative risk for the three diet-related diseases, a shift to either of two alternative dietary patterns could be beneficial for Chinese adults, with the health benefits of the PHP the most pronounced.

3.5 Benefits of shifting different dietary patterns

The benefits of shifting from each the three existing dietary patterns to either of the alternative dietary patterns varied (Fig. 4). We benchmark the environment and health effects of shifting from the quasi-southern pattern to the CDP so that we could visually compare the effects of shifting from existing dietary patterns to alternative patterns. Three environment effects (water utilization, land use and GHG emissions) and three nutritional health effects (relative risk of hypertension, type 2 diabetes and coronary heart disease) were used as benchmarks, each of which was assigned a value of 1 so that the

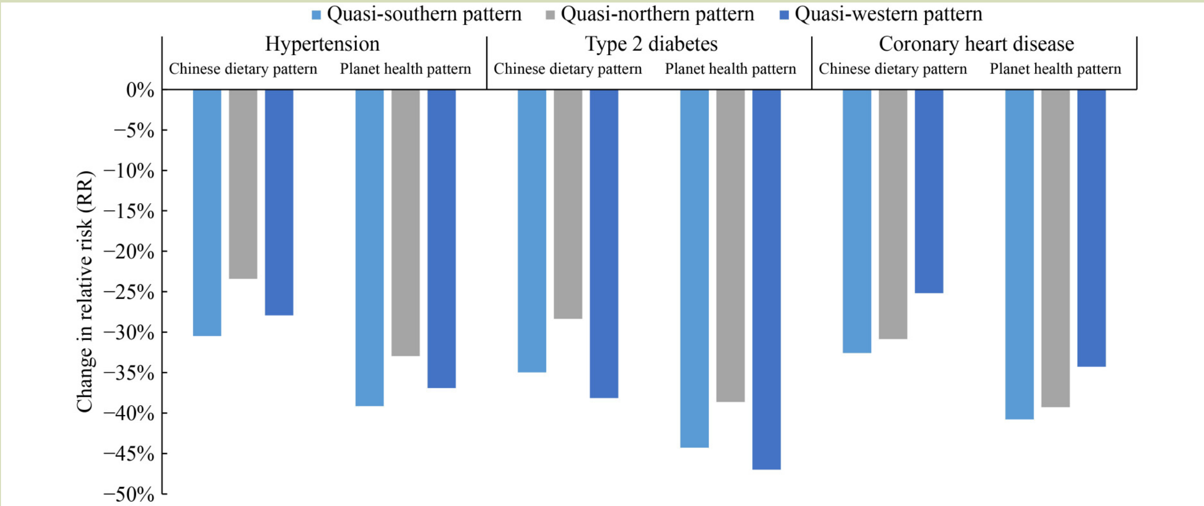


Fig. 3 Changes in relative risk of three diseases after shifting from three existing dietary patterns (quasi-southern, quasi-northern and quasi-western patterns) to alternative dietary patterns (Chinese dietary and planet health patterns).

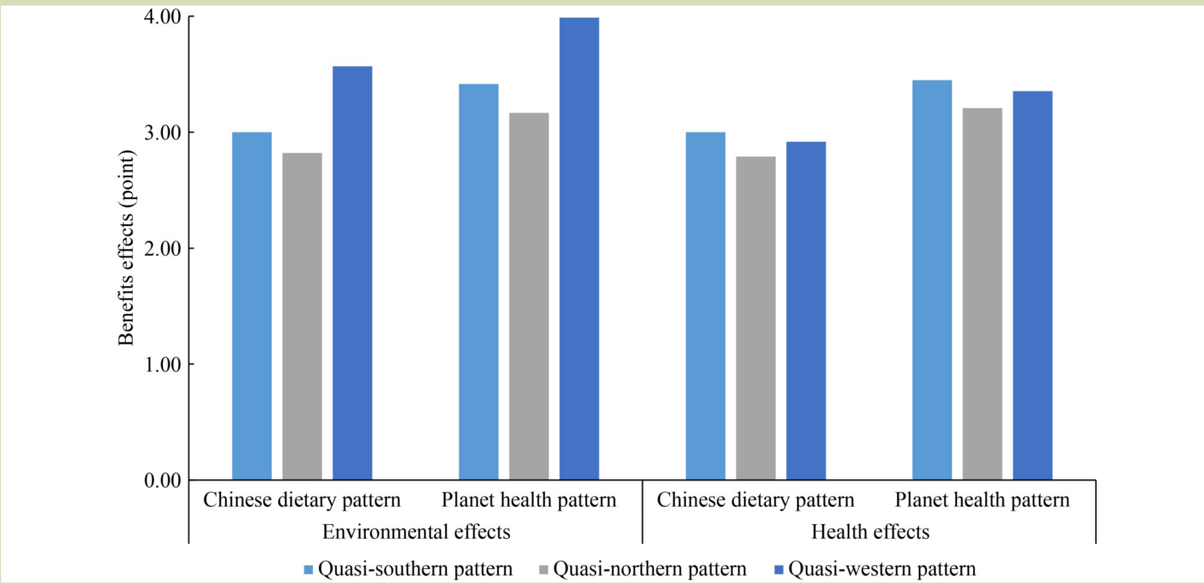


Fig. 4 Benefits of environment and health effects shifting from three existing dietary patterns (quasi-southern, quasi-northern and quasi-western patterns) to an alternative pattern (Chinese dietary or planet health patterns).

benefits of shifting dietary pattern could be calculated. It was evident that a shift from the quasi-western pattern to an alternative pattern could provide the most environmental benefits, and from the quasi-southern pattern for the health benefits, indicating that Chinese residents following the quasi-western or quasi-southern patterns should actively shift to CDP or PHP. Importantly, it was evident that PHP could be more beneficial than CDP for the environment and health.

4 CONCLUSIONS AND POLICY RECOMMENDATIONS

Based on CHNS data, this study explored the environment and health effects of different dietary patterns. The main conclusions are as follows: (1) Daily per capita food consumption varies across dietary patterns at the same energy level. Taking dairy as an example, the daily per capita consumption of dairy under the quasi-southern, quasi-northern and quasi-western patterns was about 5.6, 12.7, 78.1 g, respectively. (2) A shift to an alternative dietary pattern could deliver increased environmental sustainability compared to some existing dietary patterns, with a shift to the PHP more environmentally-friendly than to the CDP. (3) A shift to alternative dietary pattern could be greatly beneficial to the health of Chinese adults. Shifting to either of the two alternative dietary patterns appeared effectively reduce the relative risk of hypertension, type 2 diabetes and coronary heart disease. (4) The benefits of shifting from the each of the existing dietary patterns to an alternative dietary pattern differ, with a shift to the PHP being potentially more beneficial than as shift to the CDP for both the environment and human health. Therefore based on findings of this study, PHP would be our recommended pattern.

The results of this study support several policy recommendations: (1) Active promotion of a balanced diet. At present, dietary imbalance has become an important risk factor for chronic diseases such as obesity, cardiovascular and cerebrovascular diseases, and type 2 diabetes[34]. Therefore, the government should vigorously promote knowledge of the benefits of balanced diets through various media, so that the concept of a balanced diet can be deeply rooted in people's thinking. (2) Scientifically promotion of improved dietary patterns. The government should promote different dietary patterns based on the sustainable development of environment and health goals, combining the dietary habits and economic conditions of Chinese residents, in order to deliver benefits for both the environment and human health. (3) Encouragement of a shift in consumer dietary behavior. The government and other relevant departments should seek to change consumer behavior through various means, including food labeling, food quantity regulation and provision of nutritional information, in order to reduce the consumption of some foods, such as red meat, and effect a change in the food supply from by changing demand, thus promoting the sustainable development for humans and nature. These recommendations do not apply only to China, but other governments globally should also consider these policy recommendations.

Supplementary materials

The online version of this article at https://doi.org/10.15302/J-FASE-2023489 contains supplementary materials.

Compliance with ethics guidelines

Maoran Zhu and Jian Zong declare that they have no conflicts of interest or financial conflicts to disclose. This article does not contain any studies with human or animal subjects performed by any of the authors.

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