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Original article

# Association between dietary patterns, cadmium intake and chronic kidney disease among adults

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S U M M A R Y

*Background & aims:* Almost one in ten Chinese adults has chronic kidney disease (CKD). However, the link between dietary patterns, dietary cadmium intake and CKD has not been studied in China.
*Method:* Adults (n = 8429) in the China Health and Nutrition Survey who had at least one 3-day 24 h food record in combination with household food inventory in 1991, 1993, 1997, 2000, 2004, 2006, and 2009 and estimated glomerular filtration rate (eGFR) measured in 2009. Dietary pattern was identified using factor analysis. CKD was defined as eGFR <60 mL/min/1.73 m$^2$.
*Results:* There were 641 (7.6%) cases of CKD in the sample. After adjustment for demographic, lifestyle factors (i.e. smoking, alcohol drinking, physical activity) and chronic conditions, the odds ratio (OR) for CKD was 4.05 (95%CI 2.91–5.63, p for trend <0.001) for extreme quartiles of estimated cumulative cadmium intake. A traditional southern dietary pattern (high intake of rice, pork, and vegetables, and low intake of wheat) was associated with more than four times increased prevalence of CKD (comparing extreme quartiles, OR 4.56, 95%CI 3.18–6.56). A modern dietary pattern (high intake of fruit, soy milk, egg, milk and deep fried products) was inversely associated with CKD (for extreme quartiles, OR 0.5, 95% CI 0.36–0.71). The association between dietary patterns and CKD were attenuated by cadmium intake.
*Conclusion:* Traditional southern dietary pattern is positively associated, and modern dietary pattern is inversely associated, with CKD among Chinese adults. However, these associations can be partly attributed to cadmium contamination in parts of the food supply.


Chronic kidney disease (CKD) affects 8–16% of the population worldwide [1]. It is associated with poor health outcomes, including cardiovascular disease (CVD) and increased mortality [1]. In China, about one in ten adults have CKD [2], with the known risk factors including diabetes, hypertension, obesity and use of nephrotoxic medications [1].

The role of diet in the development of CKD is largely unknown although a low protein intake and low dietary acid load has been shown to be beneficial in the management of CKD [3]. There have been suggestions that dietary phosphorus intake [4], sugar intake [5] and, uncommonly, high dietary oxalate [6] is associated with the development of CKD. Most of the studies on dietary patterns and CKD were conducted in Western countries. A Western dietary pattern (high intake of red and processed meats, saturated fats and sweets) is positively associated (mostly odds ratio (OR) < 2 for high intake vs low intake), while a diet with high intake of vegetables, fruits and whole grains is inversely associated with CKD [7–9]. No study in China has assessed the association between dietary intake and CKD in the general population, although based on the regional difference in the prevalence of CKD and meat intake, it has been hypothesized that red meat consumption is positively linked to CKD [2]. Although white rice intake increases the risk of diabetes [10], a risk factor for CKD, it is inversely associated with weight gain and blood pressure in the Chinese population [11]. The association between a rice based dietary pattern and CKD remains unknown.

Cadmium is a well-known nephrotoxic heavy metal. Low level exposure to cadmium has been shown to increase the risk of CKD in

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USA [12]. In the general population, dietary sources are considered to be the most significant route of cadmium exposure. Food contamination with cadmium is also suspected to be related to CKD in certain regions of Sri Lanka [13]. Although cadmium contamination of food has attracted a lot of concern in recent years in China [14,15], no study has assessed the association between dietary cadmium intake and CKD.

This study aimed to assess the association between dietary patterns, intake of cadmium from foods and CKD among Chinese adults who participated in the Chinese Health and Nutrition Survey (CHNS).

## 1. Method

### 1.1. Study sample

The CHNS study is an ongoing open prospective household-based cohort study that includes nine provinces in China (representing 553 million people). Nine waves of data collection (i.e. 1989, 1991, 1993, 1997, 2000, 2004, 2006, 2009, and 2011) have been conducted. The survey uses a multistage random-cluster sampling process to select samples in both urban and rural areas. All the members in the selected household were invited to participate in the study, however dietary intake in 1989 only involved middle aged adults. Blood samples were collected only in the 2009 survey. The survey was approved by the institutional review committees of the University of North Carolina and the National Institute of Nutrition and Food Safety.

In 2009, 9551 of the 18887 (50.6%) participants had blood measurements to assess renal function. After excluding those below 18 years of age, without dietary information in 2009, pregnant women and those with an extreme energy intake (men: >6000 kcal or <800 kcal; women: >4000 or <600 kcal), the final sample included in the analysis was 8429 (Fig. 1).

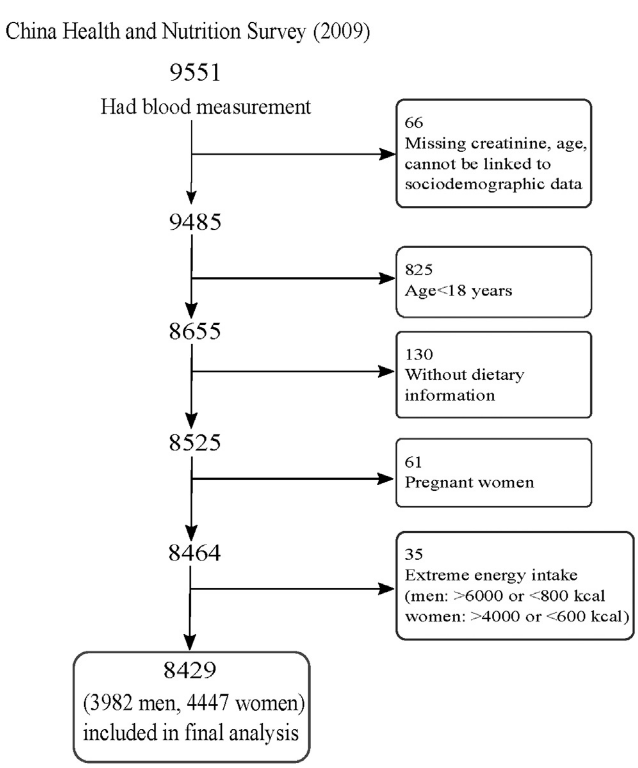


**Fig. 1.** Sample description.

### 1.2. Outcome variable: eGFR and CKD

Kidney function was evaluated by the estimated glomerular filtration rate (eGFR). In 2009, fasting blood was collected by venepuncture. Serum creatinine was measured using Jaffe's kinetic method (Hitachi 7600 automated analyser, Hitachi Inc., Tokyo, Japan). eGFR was calculated by adaptation of the Modification of Diet in Renal Disease (MDRD) equation on the basis of data from Chinese CKD patients [16]:

$$\text{eGFR}\ (\text{mL}/1.73\ \text{m}^2) = 175 \times \text{Serum creatinine}\ (\text{ml/dL})^{-1.234} \times \text{age(years)}^{-0.179}\ [\text{women} \times 0.79]$$

CKD was defined as eGFR less than 60 mL/min/1.73 $m^2$.

In sensitivity analysis, we also used CKD-EPI creatinine equation to estimate eGFR [17].

### 1.3. Exposure variables: dietary patterns and cadmium intake

At each wave, all foods and condiments in the home inventory, purchased from markets or picked from gardens, and food waste, were weighed and recorded by interviewers at the beginning and end of the three-day food consumption survey. Individual dietary intake data were collected by a trained investigator conducting a 24 h dietary recall on each of 3 consecutive days. The dietary recall was supported by dietary records kept by the individual with the final dietary data including the type and amount of food, the type of meal and the place of consumption. Cooking oil and condiments consumption for each individual in the household was estimated using weighted household intake (by individual energy intake). Detailed description of the dietary measurement has been published elsewhere [18]. Food consumption data were analysed using the Chinese Food Composition Table.

Food categories were collapsed into 35 food groups based on similar nutrient profiles or culinary use, and average food intake for individuals (gram/day) calculated for each wave. The food groups are similar to the food items used in a validated food frequency questionnaire used in a 2002 Chinese national nutrition survey. Dietary patterns (main independent variables) across the seven waves (1991–2009) were identified by factor analysis, using the standard principal component analysis method. Factors were rotated with an orthogonal (varimax) rotation to improve interpretability and minimize the correlation between the factors. The number of factors retained from each food classification method was determined by eigenvalue (>1), scree plot, and factor interpretability by each factor. Labelling of the factors was primarily descriptive and based on our interpretation of the pattern structures.

Factor loadings are equivalent to simple correlation between the food items and the factor. Higher loadings (absolute value) indicate that the food shares more variance with that factor. The sign of the loading determines the direction of the relationship of each food to the factor. Factor loadings were graphically presented.

At each wave, participants were assigned pattern-specific factor scores. Scores for each pattern were calculated as the sum of the products of the factor loading coefficients and standardized daily intake of each food group associated with that pattern. Cumulative scores were added across seven waves (1991–2009), a cumulative mean score was calculated for each factor, and participants were classified into quartiles according to the cumulative mean factor scores.

Cadmium intake was estimated using food composition tables from published literature in China [14]. The estimated food cadmium composition (mg/kg) in these tables was based on cadmium measurements in 2629 food samples randomly purchased from

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