The Burden of Coronary Heart Disease and Cancer From Dietary Exposure To Inorganic Arsenic in Adults in China, 2016

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The burden of coronary heart disease and cancer from dietary exposure to inorganic arsenic in adults in China, 2016

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Abstract

Objective: The inorganic arsenic (iAs) could cause a wide range of health damage, including coronary heart disease (CHD) and lung, bladder, and skin cancer. Although dietary iAs intake is the primary source of iAs, the burden of CHD and cancers from dietary iAs exposure in Chinese adults has not been well known. **Methods:** To estimate the iAs exposure level in Chinese adults' dietary, we systematically collected food-specific iAs concentrations in China from Chinese and English literature databases during 2000-2020. Food consumption was extracted from two nationwide food and nutrition surveys in China. The population attributable fraction (PAF) was calculated based on the dose-response relationship between iAs and CHD risk. Combining the 2016 Chinese tumor registry data, we calculated the annual incidence of cancer from dietary iAs exposure to measure the disability-adjusted life year (DALY). **Results:** The total amount of daily foodborne iAs intake was 0.55 μg/kg bw/d among Chinese adults. The DALY of foodborne iAs-associated CHD was 3,017,510 DALYs, which accounted for 10.18% of total CHD DALYs in Chinese adults. Moreover, the carcinogenic DALYs for lung cancer, bladder cancer, and skin cancer of Chinese residents related to dietary iAs were 314.24, 9.89, and 167.32 thousand, accounting for 2.05%, 1.70%, and 35.5% of the respective total cancer burden. **Conclusions:** Our findings suggested that dietary iAs exposure causes a substantial disease burden in Chinese adults. More efforts for foodborne iAs control are critical to reducing the disease burden of CHD and cancer in China and other countries with similar dietary patterns.

Keywords: Dietary; inorganic arsenic; Burden of disease; Cardiovascular heart disease; Cancer; Disability-adjusted life year

1. Introduction

Arsenic (As) is a metalloid, which is widely distributed in the environment, in inorganic and organic forms via natural and anthropogenic activities. The potential routes of As cumulation in food supply include soil, contaminated water, and pesticide applications[1]. Diet has been considered an essential intake source for general populations [2]. In recent years, the health effects of inorganic As (iAs) intakes from food have been concerned[3, 4]. Grain food (e.g., rice/flour/coarse cereal) in the Asian diet constitutes a potential source of iAs intake for people.

Epidemiological studies have indicated that the intake iAs have adverse effects on human health, especially on cardiovascular disease (CVD) and cancers. The iAs and its compounds were classified as a group I carcinogen by the International Agency for Research on Cancer (IARC) [5]. Epidemiologic studies have shown the relationship between arsenic exposure level and lung, bladder, and skin cancer risk [6-8]. Besides its carcinogenicity, iAs also contributes to cardiovascular disease risk (CVD)[9, 10]. There was a common misperception about early studies conducted in high-level iAs contaminations that iAs contributed to CHD risk only in those populations with high iAs exposure [11, 12]. However, growing evidence has been reported for the association between iAs exposure and the risk of CHD at low-moderate levels (< 100μg/L) [13, 14]. Several studies indicated the increase of CHD risk due to the daily dietary iAs consumption [14]. Currently, studies on iAs-associated CHD risk due to dietary exposure are limited at present[15]. The contribution of foodborne iAs exposure to the burden of CHD and cancer is an essential issue of concern.

Nowadays, there is an increasing concern about the burden of disease caused by iAs. In 2016, the World Health Organization (WHO) launched an initiative to estimate the foodborne burden of diseases including arsenic intake[16, 17]. The European Food Safety Authority Panel on Contaminants in the Food Chain has assessed foodborne As-related human health risks in European countries [18]. With its high iAs content, rice is a primary food in the Chinese dietary pattern. Cardiovascular disease and cancer have been the leading cause of the disease burden in 2016[19]. However, up till now, little is know about the burden of foodborne iAs-induced CHD and cancer in China. And it is necessary to quantitatively assess the CHD and cancer disease burden due to dietary iAs.

Here, the present study estimated the nation-level concentration of iAs in daily food in Chinese by systematic literature search. Then, the dietary iAs exposure in Chinese adults was evaluated by combining the consumption data from the national level surveys and concentration of iAs in daily food. Furthermore, the burden of CHD and cancer attributable to food iAs were estimated by counterfactual analysis proposed by WHO. This study provided the estimation for the impact of iAs intake on the health of Chinese adults to improve the public health policies and supervision in food contaminants in China and other regions or countries with similar dietary patterns.

2. Methods

2.1. Data source of food type-specific iAs concentrations

Data on iAs concentrations (mg/kg) in different food types were obtained by searching three Chinese databases (The General Library of Chinese Academic Journals (CNKI), Wan fang Data-academic Journal Full Text library (WAN FANG), and Chinese Biomedical Literature Database (CBM)) and three English databases (PubMed, Embase, and Ovid Medline) for relevant studies published from January 2000 to July 2019. The keywords for different database retrieval strategies are shown in Supplement Table S1. All literature reporting iAs concentrations in various food types in Mainland China were included. Details for literature searching and excluding are illustrated in Supplement Figure 1. Sample-size weighted arithmetic means of iAs concentrations were calculated for each of the food types in studies using the following formula:

$$C_k = \sum_{m=1}^{m=n}(N_m \times M_m) \,/\, \sum_{m=1}^{m=n} N_m \quad (1)$$

Where C_k means the weighted iAs concentration in the food k (mg/kg), N_m means the sample size of food k, and M_m means the iAs concentration of the food k in the original study, n is the number of the articles searched of food k, as shown in Table S3.

2.2. Data source of food consumption frequency

Specific food type consumption frequency (gram per reference man per day, g/d) was obtained from two surveys (Supplement Table S2 and Table S5). One was the 5th China Total Diet Study (TDS) conducted in 20 provinces from 2009 to 2013 [20]. The other one was the 2015 China Household Survey Yearbook, which provided relevant data of the other 11 provinces [21]. A household food weighing method and 24-hour dietary recall over three consecutive days were used in these two monitoring surveys to investigate dietary patterns of Chinese adults. Details for the two studies were mentioned before [22]. We categorized the food types into nine categories: grains (rice and other grains), Potatoes, Legumes/Nuts, Vegetables, Fruits, Meat, Dairy products, Eggs, and Aquatic products.

2.3. The Estimated amount of daily foodborne iAs intake

The amount of daily foodborne iAs intake (DI, μg/day) and the estimated daily foodborne iAs intake by body weight (EDI, μg/kg body weight/day) were calculated by summing up the products of each type of food's daily consumption frequency and the corresponding iAs concentration according to the following equations:

$$DI_j = \sum_k (C_k \times F_{kj}) \tag{2}$$

$$EDI_j = \sum_k (C_k \times F_{kj}) \,/\, BW_j \tag{3}$$

where DI_j (μg/ day) and EDI_j (μg/kg body weight/day) means the total daily foodborne iAs intake of j province in China; C_k means the iAs concentration in the food k (mg/kg), F_{kj} means the daily consumption rate of the food k (g/d), and BW_j means the average body weight (kg) in j province. The average body weight (BW_j) of residents in regions of China was obtained from the China National Nutrition and Health Survey 2010[23].

2.4. Dose-response relationship between iAs exposure and CHD risk

To date, no meta-analysis study reported the relationship between dietary iAs exposure and risks of CHD in the databases PubMed and Embase. Thus, we referred to a study of more than four hundred thousand subjects worldwide to obtain the relative risks (RRs) of CHD in response to iAs exposure in drinking water [14]. The study demonstrated a significant association between iAs intake amount and the CHD incidence and mortality in drinking water. It regarded 10 μg/L of inorganic arsenic in drinking water as the reference exposure. Hence, there is an assumption that the iAs absorbed by the individual through food can be converted into a certain amount of water containing iAs. Based on the log-linear dose-response association model of this meta-analysis and the converted water arsenic concentration level [14, 24], the incidence and mortality of RRs for 31 provinces can be obtained. The formulas were as follows:

$$C_{water} = (DI_j \times Bio_{food})/(Bio_{water} \times M_{water}) \quad (4)$$

$$RR_{incidence} = 0.1826 \times \ln(C_{water}) + 0.568 \quad (5)$$

$$RR_{mortality} = 0.2992 \times \ln(C_{water}) + 0.278 \quad (6)$$

where C_{water} means the converted iAs concentration and Bio_{food} and Bio_{water} refer bioavailability of iAs through diet and drinking water[25]; M_{water}, the daily intake of water for an adult in China is 1.85 L/day [26]; $RR_{incidence}$ and $RR_{mortality}$ mean the relative risk of foodborne iAs intake induced CHD incidence and mortality.

2.5. Estimation burden of CHD attributed to foodborne iAs intake

The DALYs is a metric used to evaluate the burden of a particular disease, estimated as the sum of corresponding Years of Lived with Disability (YLD) and premature death-related Years of Life Lost (YLL) caused by the disease [27]. A 2-stage approach was adopted to calculate the DALYs of CHD attributed to foodborne iAs exposure. First, the representative RR mentioned in section 2.4 was converted into the population attributable fraction (PAF)[28], defined as the percentage of outcomes reduced if exposure to a risk factor was reduced to the counterfactual level of minimum theoretical risk [29]. The conversion equation was as follows:

$$PAF_{incidence} = (RR_{incidence} - 1) \,/\, RR_{incidence} \tag{7}$$

$$PAF_{mortality} = (RR_{mortality} - 1) \,/\, RR_{mortality} \tag{8}$$

Then the deaths or prevalent cases-related YLLs, YLDs, and DALYs (in thousands) and age-standardized mortality or prevalence-related YLL, YLD, and DALY rates (per 100,000) of CHD attributed to foodborne iAs intake were calculated in the second stage. Liu et al. [19] reported the CHD burden in 2016 in all 33 province-level administrative units in China. CHD was referred to the I20–I25.9 coded diseases in the International Statistical Classification of Diseases and Related Health Problems, Tenth Revision (ICD-10). We calculated the estimators for foodborne iAs exposure-related CHD burden according to the following equations:

$$A\text{-}YLL = PAF_{mortality} \times YLL \tag{9}$$

$$A\text{-}YLD = PAF_{incidence} \times YLD \tag{10}$$

$$A\text{-}DALY = A\text{-}YLL + A\text{-}YLD \tag{11}$$

$$PAF_{total} = A\text{-}DALY/DALY_{\text{-}CHD} \tag{12}$$

The *A-YLL, A-YLD*, and *A-DALY* meant the YLLs, YLDs, and DALYs or corresponding age-standardized rates attributed to the foodborne iAs exposure. $PAF_{mortality}$ and $PAF_{incidence}$ meant the proportion of mortality and incidence of CHD due to foodborne iAs exposures. PAF_{total} refers to the proportion of DALY related to foodborne iAs.

2.6. Estimation of carcinogenic risk and cancer disease burden from dietary iAs exposure

Annual count (AC) is an indicator to evaluate the estimated carcinogenic risk of dietary exposure to iAs[30]. It is calculated as in equation (13).

$$AC = (N_{pop}*y*SF)/LE_{pop} \tag{13}$$

Where, N_{pop} is the total number of people exposed; y refers to the lifetime average daily iAs intake from dietary source; LE_{pop} is the life expectancy for exposed populations. SF refers to slope factor, which is calculated as described below. Based on the Meta-regression coefficients of lung and bladder cancers caused by iAs exposure through the drinking water route, the SF values of lung and bladder cancers caused by dietary exposure to iAs in China were obtained by combining the cancer data and demographic characteristics of China[31, 32].

$$SF = IR*(e^{\beta}-1)*W/Q \tag{14}$$

In the equation (14), IR is the cumulative lifetime incidence of cancer in the population, for which data were obtained from the 2016 Chinese tumor registry data[33];

β is the meta-regression coefficients of lung and bladder cancers; W is the average body weight of the Chinese population, with a value of 60 kg; Q is the average daily water consumption of the Chinese population. According to the US EPA's IRIS database, the SF value for skin cancer is 0.0015 $(\mu g \cdot kg^{-1} \cdot d^{-1})^{-1}$.

$$DALY_{iAs} = AC*DALY_{ave/case} \tag{15}$$

Combining the number of cases of the three cancers in 2016 and the disease burden of cancer in each province of the country, the average DALY per case of lung, bladder, and skin cancer can be obtained. Therefore, the disease burden of the three cancers due to dietary iAs exposure is calculated as shown in Equation 15.

3. Results

We established a database including all retrieved eligible data of iAs concentrations in related food types (Table 1 and Supplement Table S3). The retrieving was independently completed by two individuals (Wenjing S and Jialin L), and the flow chart was shown in Supplement Figure 1. The numbers of studies in various periods were shown in Supplement Table S4. A total of 52 studies with 45 296 unique iAs data points from 26 (municipalities or autonomous) provinces/cities were involved in our study. Grain was the most frequently reported food category, followed by aquatic products. The details of the results were shown in Supplement materials.

We pooled all data, and Table 1 presents iAs concentrations from 9 food groups. The concentration of iAs in rice is similar in the northern and southern regions; however, the concentration of iAs in flour is a little higher in the north. Vegetables and Meat reported the same mean iAs concentration (0.016 mg/kg), which was slightly higher than in Eggs (0.013 mg/kg). The lowest iAs concentrations were found in Fruits and Dairy products (0.011 mg/kg).

The estimated average daily intakes (EDIs) of iAs for residents in China and a specific province were shown in Table 2. The total daily iAs intake was estimated to be 0.55 μg/kg bw/d (34.14 μg/d) among Chinese individuals, which was above the RfD of 0.3 μg/kg bw/d for iAs intake set by the USEPA [34] (Table 2). The northeast region has the highest value of EDI compared with the other six regions of China. Jilin province in the northeast region reported the highest EDI of iAs (0.94 μg/kg bw/d), about 2.2 times higher than Guangdong province in the south of China. The primary source of foodborne iAs was Rice accounting for 46.83% of the total, followed by Other grains accounting for 16.30% of the total, and Vegetables accounting for 16.23% of the total (Figure 2).

Burdens of CHD attributed to foodborne iAs intake were estimated, referring to the mortality and prevalence in China in 2016, results of which were shown in Table 3, Figure 3, and Supplement Table S6. The number of DALYs attributed to foodborne iAs intake was 3,017,510 among Chinese, and the age-standardized DALY rate was 261.8 per 100,000 individuals (Table 3). The Liaoning, Hunan, and Hebei provinces had the top three most enormous DALYs numbers caused by foodborne iAs-related CHD. The Qinghai, Hainan, and Tibet provinces were among the bottom three. With age-standardized, the DALY rate related to foodborne iAs intake in Jilin province was more than 900.00 per 100,000 individuals. The DALY rate in Liaoning province, Xinjiang province, and Heilongjiang province was also more than 500.00 per 100,000 individuals. Notably, Guangdong province had the lowest age-standardized DALY rate of only 27.47 per 100,000 individuals, about 33-fold lower than Jinlin province. It is clear to see that the age-standardized DALY rate of foodborne iAs induced CHD were more massive in the Northern, Northeast, Northwest, compared with the East, South coast provinces, and Southwest of China, as shown in Figure 3.

Jilin province has the highest PAF of incidence and mortality (0.156 and 0.224, respectively), approximately 9-15 times higher than the lowest PAFs (0.018 and 0.015, respectively) in Guangdong province (Table 3). After evaluating the DALY rates and age-standardized YLL/YLD rates related to foodborne iAs intake, the average proportion of DALYs related to foodborne iAs was 10.18% in China, 1.55% (Guangdong province) to 22.26% (Jilin province) among 31 provinces/cities. The mortality or prevalence was also estimated in Supplement Table S6.

The SF values for dietary iAs-induced lung and bladder cancer incidence were 0.001717 and 0.000139 $(\mu g \cdot kg^{-1} \cdot d^{-1})^{-1}$ (Supplement Table S7). In 2016, the carcinogenic DALY of Chinese residents exposed to iAs through diet was 491.46 thousand, of which the DALYs for lung cancer, bladder cancer, and skin cancer were 314.24, 9.89, and 167.32 thousand, respectively (Table 4). In China, iAs exposure via dietary route will cause a loss of 35.54 years of healthy life for every 100,000 people. The DALY rate of cancers related to dietary iAs in Hebei Province, Inner Mongolia, Jilin Province, Liaoning Province, Hunan Province, and Sichuan Province is higher than the national average in China.

4.Discussion

This study estimated the national level of iAs exposure from dietary and its contribution to CHD and cancer-related DALYs in Chinese adults. The average foodborne iAs intake was 34.14 μg/d and 0.55 μg/kg bw/d among the Chinese. Rice/flour/coarse cereal contributed the most significant proportion (63.13%) of iAs intake, and there were significant regional differences in the intake of iAs. The foodborne iAs intake-related CHD burden was quantified with DALY number and age-standardized DALY rate, equaling 3,017,510 and 261.8 per 100,000 persons, respectively. Furthermore, the carcinogenic DALYs for lung cancer, bladder cancer, and skin cancer of Chinese residents related to dietary iAs were 314.24, 9.89, and 167.32 thousand, accounting for 2.05%, 1.70%, and 35.5% of the respective total cancer burden.

Dietary iAs exposure has been considered an important issue and there has been an increasing trend in recent years. Previous studies have demonstrated that diet is the primary source of iAs exposure for people living in areas with a low iAs level in drinking water [2, 35]. The dietary iAs exposure in Chinese residents was 27.7 μg/d, range 10.8-44.6 μg/d in The Fifth China Total Diet Study (in 2009-2013), which was lower than the results study[20]. Meantime, our result was similar to previous exposure assessment in India, which indicated that the iAs exposure via rice of individuals in the three regions was 0.3 to 0.84 μg/kg bw/day[36]. Moreover, a dietary survey in Japan showed that iAs intake was 0.446 μg/kg bw/day[37].

Food is susceptible to contamination from natural and anthropogenic elements [38]. Grains, capable of accumulating during growth, are the primary staple food among Chinese people, resulting in grains being a primary source for foodborne iAs intake. Since Rice/Flour/Coarse cereal contributed most to foodborne iAs intake, limits of iAs contents in such food types may reduce iAs exposure among the Chinese. In the meanwhile, the contribution of vegetables should not be ignored. Although the iAs concentration in vegetables was low, the iAs intake via vegetables ranked second for the high daily consumption. Our results demonstrated the critical role of Rice/Flour/Coarse cereal consumption in foodborne iAs exposure, suggesting less Rice/Flour/Coarse cereal intake in the daily diet may effectively reduce the iAs intake.

Our study indicated that the burden of CHD attributable to dietary iAs is not negligible. The elevated risk of CHD in response to low-moderate to high iAs in drinking water has been studied in a systematic review and meta-analysis [14]. However, the epidemiological evidence for the association between foodborne iAs exposure and CHD was less documented [39]. Under the assumption of a log-linear relationship between iAs and the risk of CHD, we used DALY, which is an internationally accepted method of measuring disease burden created by the WHO, as an indicator to calculate the disease burden from dietary iAs.[40] A previous study reported that dietary iAs caused, on average, 669 DALYs per 100,000 among CHD patients in 13 GEMS around the world, which indicated that dietary iAs intake caused significant but avoidable diseases of burden. Hence, it is noted that a reduction in dietary iAs intake should be implemented to improve quality of life. In this study, the age-standardized DALYs rate of dietary iAs intake-induced CHD was 261.8 per 100,000 in China, lower than 676 DALYs per 100,000 for the disease burden of iAs-associated CHD in Western Pacific (WPR B, including China)[24].

In addition, our findings suggested that dietary iAs exposure causes a substantial cancer disease burden in Chinese adults. It is assumed that iAs in food and drinking water would produce the same carcinogenic risk. Furthermore, The cancer disease burden from dietary inorganic arsenic assessed in this study in China was similar to that calculated by members of a previous FERG working group[24]. In the assessment, it was found that Jilin, Hunan, and Sichuan provinces have the highest standardized cancer disease burden, which may be due to high rice consumption. Although many previous studies on arsenic have been based on drinking water intake, dietary intake of iAs is close to that of drinking water intake in areas with low iAs concentrations in water[41]. Therefore, although the complexity of measuring foodborne arsenic exposure and the controversial linear dose-response relationships for arsenic-associated cancers make the assessment process uncertain, it remains necessary to quantify the disease burden caused by each arsenic pathway.

Although our findings provided a nationwide estimation for foodborne iAs-associated CHD and cancer burden, several limitations should be mentioned in this study. First, some iAs concentrations in various food types were referred to published literature for journals, with a publication bias process. Also due to missing data, it is not implementable to obtain the concentration of various foods at the provincial level. Second, the health effect risk may be underestimated in this study. Dietary iAs intake was not accounted for for some other food types (e.g., oil, sugar, pastry) due to unavailable data. Similarly, the iAs exposure from drinking water was not included in the present study since it is more difficult to quantify the amount of water consumed through the diet. In addition, the latest version of the disease burden data for CHD and cancer were not used, as the lack of data for YLL and YLD. Finally, in this study, it was assumed that the risk of disease from iAs in the diet and iAs in drinking water was the same to calculate the attributable disease burden. Therefore, it is expected that more studies on dietary iAs and disease risk are conducted in the future to reduce the uncertainty in the calculation of the attributable disease burden.

5. Conclusions

In summary, our study provided a nation-level estimation for the burden of disease by foodborne iAs in China. Our results indicated that dietary iAs exposure causes a significant burden of disease, especially in those higher Rice/Flour/Coarse cereal consumption areas. More attention to control dietary iAs intake in policy is necessary for China and other regions or countries with similar dietary patterns.

List of abbreviations

iAs: inorganic arsenic; CHD: Coronary Heart Disease; PAF: Population Attributable Fraction; DALY: Disability-Adjusted Life Year; YLL: Years of Life Lost;

YLD: Years Lived with Disability; CVD: Cardiovascular Disease; IARC: International Agency for Research on Cancer; WHO: World Health Organization; TDS: Total Diet Study; RR: relative risk.

Declarations

Ethics approval and consent to participate

Not applicable.

Consent for publication

Not applicable.

Availability of data and materials

The datasets used in this study are available as supplementary materials.

Competing interests

The authors declare they have no actual or potential competing financial interests.

Authors' contributions

Jialin Liu and Wenjing Song: Methodology, Software, Formal analysis, Writing- original draft, Writing- editing. Jialin Liu and Wenjing Song contributed equally to this work. Qi Wang, Yibaina Wang, and Sheng Wei: Conceptualization, Methodology, Supervision, Project administration, Funding acquisition, Writing-review & editing. Yiling Li, Jiao Huang and Yuan Cui: Methodology, Software, Formal analysis.

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Table 1. Estimators of food type-specific inorganic arsenic (iAs) concentrations in China[a].

Food types		No. of samples		Mean (mg/kg)	
		North	South	North	South
Cereals	Rice	336	8501	0.094	0.085
	Other (except rice)	2041	1979	0.042	0.02
Legumes/Nuts		3009	3009	0.02	0.02
Potatoes		2880	2880	0.019	0.019
Meat		5105	5105	0.016	0.016
Eggs		4394	4394	0.013	0.013
Dairy products		3547	3547	0.011	0.011
Aquatic products		5035	5035	0.039	0.039
Vegetable		4533	4533	0.016	0.016
Fruit		3893	3893	0.011	0.011

[a]Sample size-weighted estimators were calculated.

Table 2. The average of estimated daily foodborne inorganic arsenic (iAs) intake in 31 provinces in China.

Province/City	foodborne iAs intake (μg/d)	foodborne iAs intake (μg/kg bw/d)[b]	Province/City	foodborne iAs intake (μg/d)	foodborne iAs intake (μg/kg bw/d)[b]
China	34.14	0.55			
North			Hubei	42.66	0.69
Beijing	41.03	0.60	Hunan	40.52	0.69
Hebei	35.57	0.54	**South**		
Inner Mongolia	35.32	0.53	Guangdong	24.51	0.42
Shanxi	24.71	0.38	Guangxi	39.53	0.70
Tianjin	30.43	0.45	Hainan	28.24	0.51
Northeast			**Southwest**		
Heilongjiang	37.24	0.57	Chongqing	34.31	0.59
Jilin	61.17	0.94	Guizhou	31.40	0.55
Liaoning	51.44	0.78	Sichuan	38.00	0.64
East			Tibet	28.34	0.50
Anhui	28.69	0.46	Yunnan	31.84	0.55
Fujian	44.48	0.75	**Northwest**		
Jiangsu	26.06	0.41	Gansu	35.13	0.56
Jiangxi	32.85	0.57	Ningxia	42.92	0.67
Shandong	29.09	0.44	Qinghai	33.80	0.53
Shanghai	40.25	0.63	Shaanxi	33.47	0.56
Zhejiang	54.81	0.90	Xinjiang	40.21	0.63
Central					
Henan	32.39	0.51			

[b]The average body weight (bw) of residents in regions of China was obtained from the China National Nutrition and Health Survey 2010.

Table 3. Estimation of burden of coronary heart disease (CHD) attributed to foodborne inorganic arsenic (iAs) intake in 31 provinces in China in 2016.

Provinces	Incidence-PAF	Mortality-PAF	YLLs (in thousands) (95% UI)	Age-standardized YLL rate (per 100,000) (95% UI)	YLDs (in thousands) (95% UI)	Age-standardized YLD rate (per 100,000) (95% UI)	DALY (in thousands) (95% UI)	Age-standardized DALY rate (per 100,000) (95% UI)	Proportion of DALY related to foodborne iAs (%)
China	7.28%	10.30%	2931.8(2833.38-3025)	254.36(245.82-262.44)	85.72(59.21-117.07)	7.44(5.14-10.16)	3017.51(2892.6-3142.07)	261.8(250.96-272.6)	10.18%
North									
Beijing	10.08%	14.52%	53.7(46.19-61.77)	277.28(238.53-318.95)	2.39(1.66-3.28)	12.32(8.58-16.94)	56.08(47.86-65.05)	289.6(247.11-335.89)	14.25%
Hebei	7.92%	11.28%	233.51(204.47-261.51)	383.37(335.69-429.34)	5.31(3.64-7.29)	8.71(5.98-11.97)	238.82(208.11-268.8)	392.08(341.66-441.31)	11.17%
Inner Mongolia	7.81%	11.11%	85.62(75.11-97.9)	389.63(341.81-445.52)	2.02(1.4-2.77)	9.21(6.37-12.59)	87.64(76.51-100.67)	398.84(348.17-458.11)	11.00%
Shanxi	1.91%	1.78%	15.6(13.66-17.52)	50.05(43.84-56.23)	0.61(0.41-0.84)	1.94(1.32-2.69)	16.2(14.08-18.36)	52(45.16-58.92)	1.78%
Tianjin	5.44%	7.44%	26.43(22.74-30.13)	189.89(163.37-216.47)	0.86(0.6-1.19)	6.2(4.33-8.56)	27.29(23.34-31.32)	196.09(167.7-225.03)	7.36%
Northeast									
Heilongjiang	8.63%	12.35%	180.4(157.34-203.38)	527.92(460.46-595.17)	3.82(2.66-5.18)	11.17(7.79-15.15)	184.21(160.01-208.56)	539.09(468.24-610.32)	12.24%
Jilin	15.61%	22.44%	216.57(193.42-240.89)	907.2(810.21-1009.05)	4.18(2.89-5.78)	17.5(12.12-24.21)	220.75(196.31-246.67)	924.7(822.33-1033.26)	22.26%
Liaoning	13.30%	19.19%	261.17(226.98-294.41)	667.55(580.16-752.51)	7.81(5.44-10.75)	19.96(13.91-27.48)	268.98(232.42-305.16)	687.52(594.07-779.99)	18.95%
East									
Anhui	4.47%	5.91%	68.12(61.39-75.2)	133.31(120.14-147.18)	2.28(1.57-3.11)	4.46(3.07-6.08)	70.39(62.95-78.31)	137.77(123.21-153.26)	5.85%
Fujian	11.26%	16.25%	63.06(55.58-71.09)	199.22(175.6-224.59)	3.04(2.07-4.18)	9.6(6.53-13.21)	66.1(57.65-75.27)	208.81(182.12-237.8)	15.93%
Jiangsu	2.84%	3.29%	28.82(25.5-32.4)	41.77(36.96-46.96)	2.06(1.42-2.81)	2.99(2.06-4.08)	30.88(26.92-35.22)	44.75(39.02-51.04)	3.26%

Jiangxi	6.67%	9.36%	66.14(58.99-74.02)	182.82(163.08-204.63)	2(1.37-2.77)	5.54(3.8-7.65)	68.14(60.37-76.79)	188.37(166.88-212.27)	9.25%
Shandong	4.70%	6.27%	151.86(135.28-167.85)	183.81(163.73-203.16)	4.44(3.1-6.08)	5.37(3.75-7.36)	156.3(138.37-173.93)	189.18(167.48-210.52)	6.22%
Shanghai	9.80%	14.10%	29.91(25.92-34.04)	136.81(118.59-155.73)	2.42(1.67-3.33)	11.06(7.64-15.22)	32.32(27.59-37.37)	147.87(126.24-170.95)	13.65%
Zhejiang	14.16%	20.41%	96.81(84.84-110.56)	198.93(174.34-227.21)	6.17(4.21-8.49)	12.68(8.64-17.45)	102.98(89.05-119.06)	211.62(182.99-244.66)	19.89%
Central									
Henan	6.45%	9.02%	219.37(198.12-241.8)	290.54(262.4-320.24)	5.19(3.62-7.14)	6.87(4.79-9.46)	224.55(201.74-248.94)	297.41(267.19-329.7)	8.93%
Hubei	10.65%	15.36%	164.48(148.16-182.09)	330.68(297.86-366.09)	4.98(3.42-6.87)	10.01(6.89-13.81)	169.46(151.58-188.96)	340.69(304.74-379.9)	15.16%
Hunan	9.89%	14.24%	241.62(216.75-275.06)	432.98(388.42-492.91)	5.76(3.96-7.86)	10.32(7.09-14.09)	247.38(220.71-282.92)	443.3(395.51-506.99)	14.10%
South									
Guangdong	1.77%	1.54%	23.72(21.06-26.41)	25.9(23-28.84)	1.43(0.98-1.97)	1.56(1.07-2.15)	25.15(22.05-28.38)	27.47(24.08-30.99)	1.55%
Guangxi	9.53%	13.70%	139.3(123.66-156.35)	366.1(325.01-410.91)	3.4(2.32-4.69)	8.93(6.1-12.34)	142.7(125.99-161.04)	375.03(331.12-423.24)	13.56%
Hainan	4.21%	5.49%	9.12(8.02-10.37)	123.95(109.02-140.98)	0.28(0.19-0.38)	3.8(2.62-5.17)	9.4(8.22-10.76)	127.74(111.64-146.15)	5.44%
Southwest									
Chongqing	7.36%	10.42%	48.04(42.31-54.43)	186.42(164.19-211.2)	1.84(1.25-2.53)	7.12(4.86-9.81)	49.88(43.57-56.96)	193.54(169.05-221.01)	10.26%
Guizhou	5.95%	8.24%	56.18(48.42-64.77)	203.3(175.23-234.42)	1.49(1.02-2.05)	5.4(3.68-7.4)	57.67(49.44-66.82)	208.7(178.91-241.82)	8.16%
Sichuan	8.93%	12.81%	175.95(154.04-200.29)	253.41(221.86-288.47)	6.13(4.18-8.37)	8.83(6.02-12.05)	182.08(158.22-208.66)	262.24(227.88-300.52)	12.62%
Tibet	4.27%	5.59%	3.46(2.98-4.09)	137.61(118.64-162.63)	0.06(0.04-0.09)	2.48(1.66-3.43)	3.52(3.02-4.18)	140.09(120.3-166.06)	5.56%
Yunnan	6.17%	8.59%	76.04(67.54-86.02)	198.05(175.93-224.05)	1.76(1.19-2.46)	4.58(3.11-6.4)	77.79(68.74-88.47)	202.63(179.05-230.45)	8.51%
Northwest									
Gansu	7.73%	10.99%	59.37(52.88-66.74)	273.94(243.99-307.96)	1.49(1.02-2.04)	6.88(4.73-9.41)	60.86(53.9-68.78)	280.83(248.71-317.37)	10.88%

Ningxia	10.74%	15.49%	24.35(21.21-27.66)	446.23(388.67-506.74)	0.56(0.39-0.78)	10.27(7.06-14.27)	24.91(21.6-28.43)	456.5(395.73-521.01)	15.34%
Qinghai	7.12%	10.06%	13.19(11.49-14.95)	277.07(241.42-314.14)	0.27(0.18-0.37)	5.66(3.88-7.81)	13.46(11.68-15.33)	282.73(245.29-321.95)	9.98%
Shaanxi	6.97%	9.82%	94.42(83.02-107.41)	290.76(255.66-330.76)	2.02(1.39-2.77)	6.21(4.29-8.53)	96.44(84.42-110.18)	296.96(259.95-339.29)	9.74%
Xinjiang	9.78%	14.07%	102.54(90.72-115.56)	551.91(488.29-621.98)	1.52(1.05-2.09)	8.18(5.63-11.25)	104.06(91.77-117.65)	560.09(493.92-633.23)	13.98%

Table 4. The burden of lung, bladder and skin cancer attributed to foodborne inorganic arsenic (iAs) intake in 31 provinces in China in 2016.

Provinces	Lung cancer (in thousands)	Bladder cancer (in thousands)	Skin cancer (in thousands)	Total(in thousands)	Total per 100,000
China	314.24(297.81-326.57)	9.89(9.32-11.42)	167.32(143.13-180.11)	491.46(450.26-518.1)	35.54(32.56-37.47)
North					
Beijing	3.09(2.53-3.66)	0.08(0.06-0.1)	0.81(0.53-1.18)	3.99(3.12-4.94)	18.37(14.37-22.71)
Hebei	18.9(15.67-22.37)	0.69(0.53-0.93)	27.38(19.13-35.17)	46.97(35.33-58.47)	62.88(47.29-78.27)
Inner Mongolia	5.62(4.73-6.64)	0.2(0.16-0.24)	7.11(5.31-8.72)	12.92(10.21-15.6)	51.29(40.5-61.89)
Shanxi	6.21(4.94-7.56)	0.17(0.13-0.22)	5.99(4.53-7.45)	12.37(9.61-15.23)	33.58(26.09-41.37)
Tianjin	2.31(1.95-3.86)	0.07(0.05-0.08)	0.62(0.48-0.88)	2.99(2.48-4.82)	19.16(15.86-30.84)
Northeast					
Heilongjiang	14.36(11.94-17.03)	0.32(0.26-0.39)	5.15(4.15-6.78)	19.83(16.35-24.19)	52.21(43.03-63.68)
Jilin	10.83(8.77-12.79)	0.35(0.27-0.42)	25.8(17.15-33.37)	36.98(26.2-46.58)	135.32(95.86-170.43)
Liaoning	15.44(12.84-18.37)	0.44(0.33-0.53)	7.33(5.41-8.93)	23.21(18.58-27.83)	53.02(42.43-63.58)
East					
Anhui	13.4(11.27-16)	0.49(0.41-0.6)	5.66(4.47-6.71)	19.55(16.14-23.31)	31.55(26.06-37.62)
Fujian	13.07(10.78-15.8)	0.39(0.31-0.52)	5.03(3.97-6.54)	18.49(15.06-22.86)	47.73(38.87-59.01)
Jiangsu	14.75(12.28-17.52)	0.47(0.38-0.57)	4.5(3.39-5.55)	19.72(16.06-23.64)	24.65(20.07-29.56)
Jiangxi	12.58(10.71-14.81)	0.45(0.37-0.57)	7.8(6.33-9.3)	20.83(17.42-24.68)	45.37(37.93-53.75)
Shandong	20.02(16.73-23.73)	0.61(0.51-0.75)	11.02(8.85-13.63)	31.66(26.1-38.11)	31.83(26.23-38.31)
Shanghai	2.82(2.31-3.42)	0.09(0.06-0.11)	0.82(0.52-1.06)	3.73(2.9-4.59)	15.41(11.97-18.99)
Zhejiang	15.81(12.99-18.97)	0.54(0.43-0.65)	4.13(3.04-5.39)	20.48(16.47-25.01)	36.63(29.46-44.75)
Central					

Henan	21.89(18.3-25.83)	0.87(0.69-1.32)	17.17(13.99-20.78)	39.93(32.98-47.93)	41.89(34.6-50.28)
Hubei	20.08(16.79-23.82)	0.61(0.5-0.73)	7.99(6.53-10.05)	28.67(23.81-34.61)	48.72(40.47-58.81)
Hunan	24.85(20.83-30.04)	1(0.79-1.4)	24.45(18.5-29.98)	50.31(40.13-61.42)	73.74(58.82-90.03)
South					
Guangdong	17.53(14.64-20.85)	0.49(0.41-0.62)	4.35(3.28-5.61)	22.37(18.33-27.09)	20.34(16.66-24.63)
Guangxi	14.79(12.43-17.76)	0.51(0.4-0.82)	6.99(5.73-8.66)	22.3(18.56-27.24)	46.09(38.37-56.3)
Hainan	1.65(1.32-2.06)	0.06(0.04-0.08)	0.7(0.52-1.03)	2.41(1.89-3.17)	26.26(20.63-34.6)
Southwest					
Chongqing	7.14(5.71-8.9)	0.23(0.18-0.3)	2.85(2.23-3.83)	10.22(8.13-13.03)	33.52(26.66-42.75)
Guizhou	6.3(5.18-7.53)	0.31(0.25-0.38)	9.54(7.09-12.03)	16.15(12.52-19.94)	45.42(35.23-56.1)
Sichuan	31.13(25.2-36.57)	1.15(0.91-1.4)	21.68(17.49-25.99)	53.96(43.59-63.96)	65.31(52.77-77.41)
Tibet	0.54(0.44-0.65)	0.04(0.03-0.07)	0.85(0.66-1.08)	1.43(1.14-1.79)	43.13(34.3-54.19)
Yunnan	10.05(8.47-12.02)	0.38(0.32-0.48)	7.46(5.74-9.12)	17.89(14.52-21.62)	37.5(30.44-45.31)
Northwest					
Gansu	5.03(4.19-6.01)	0.16(0.13-0.2)	2.27(1.88-2.66)	7.46(6.2-8.86)	28.58(23.77-33.96)
Ningxia	1.69(1.37-2.06)	0.04(0.03-0.05)	0.34(0.28-0.41)	2.08(1.68-2.52)	30.76(24.92-37.37)
Qinghai	1.24(1.01-1.48)	0.05(0.04-0.07)	0.72(0.59-0.86)	2.01(1.64-2.41)	33.9(27.58-40.63)
Shaanxi	7.72(6.17-9.6)	0.29(0.23-0.4)	6.74(5.5-8.14)	14.75(11.9-18.14)	38.69(31.21-47.58)
Xinjiang	3.86(3.19-4.57)	0.12(0.09-0.19)	1.3(1.04-1.56)	5.29(4.32-6.32)	22.05(18.02-26.34)

Fig. 1 Flow chart of dietary inorganic arsenic (iAs) data retrieval from six databases both in Chinese and English.

Fig. 2 The proportion of inorganic arsenic contribution from different food groups in China.

Fig. 3 Map of age-standardized CHD DALY rate (per 100,000) induced by foodborne inorganic arsenic (iAs) intake in provinces of China.

Figures

Figure 1

Flow chart of dietary inorganic arsenic (iAs) data retrieval from six databases both in Chinese and English.

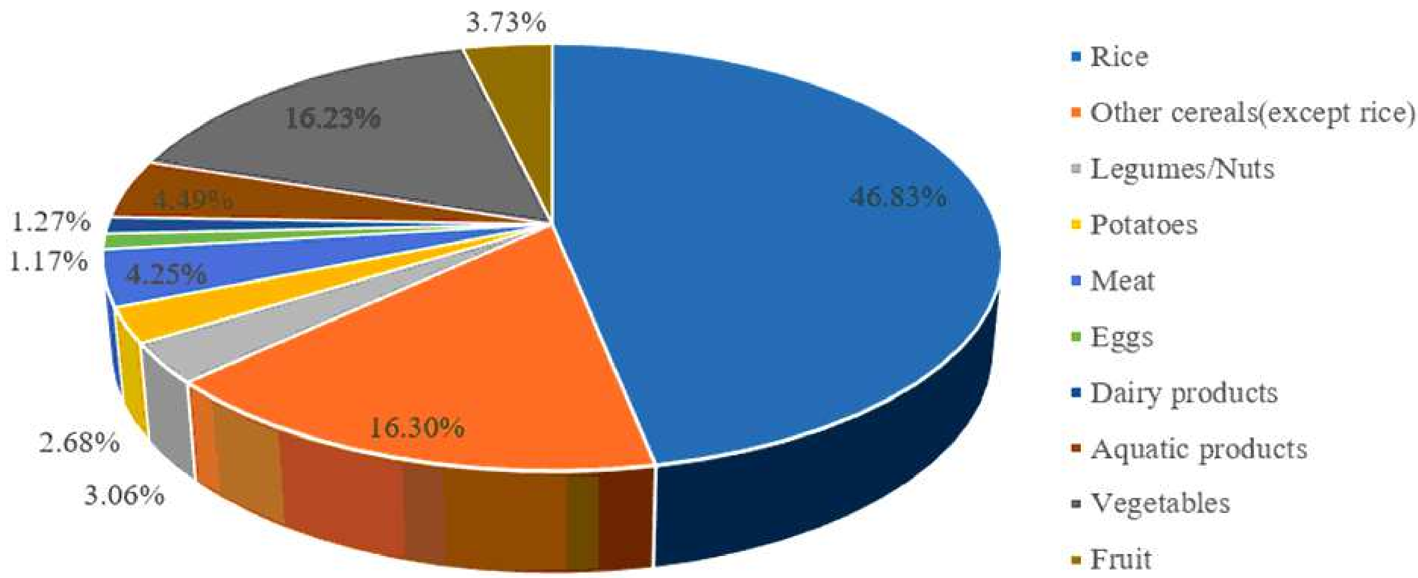

Figure 2

The proportion of inorganic arsenic contribution from different food groups in China.

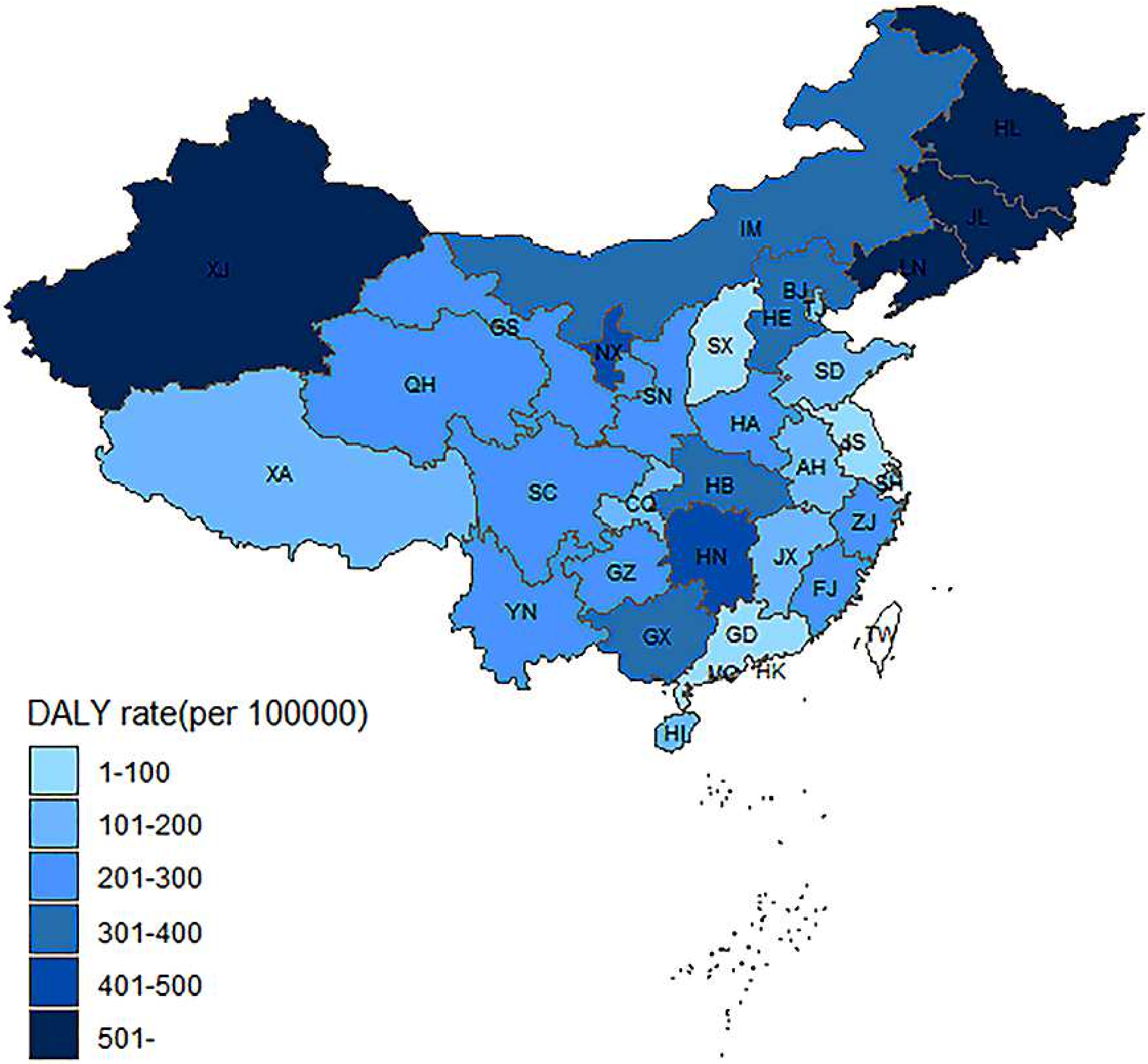

Figure 3

Map of age-standardized CHD DALY rate (per 100,000) induced by foodborne inorganic arsenic (iAs) intake in provinces of China.

Supplementary Files

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- Supplementmaterials.docx