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Summary

Background Few studies have used nationally representative data to describe dietary trends and the related cardiometabolic mortality burden in China. Thus, we aimed to characterise the trends in disease-related dietary factors as well as their associated disease burden among Chinese adults from 1982 to 2012.

Methods For this cross-sectional population-based study, we analysed a nationally representative sample of 204,802 adults aged 20 years or older, using data from the 1982, 1992, 2002, and 2010–12 China National Nutrition Surveys (CNNS). We did a comparative risk assessment, in which the effects of suboptimal intakes of 12 dietary factors, individually and collectively, on cardiometabolic mortality were estimated by calculating the population attributable fraction (PAF) to estimate the proportional reduction in cardiometabolic deaths that would occur if exposure to each dietary risk factor was reduced to an alternative optimal level.

Findings The overall PAF of mortality from cardiovascular disease and type 2 diabetes that was associated with suboptimal dietary quality was 62.2% in 1982, 57.9% in 1992, 56.2% in 2002, and 51.0% in 2010–12, which accounted for 21.8% of total mortality in China in 1982, 16.6% in 1992, 17.6% in 2002, and 20.8% in 2010–12. The estimated number of cardiometabolic deaths associated with suboptimal dietary intakes was 1.07 million in 1982, 0.93 million in 1992, 1.18 million in 2002, and 1.51 million in 2010–12. Of all 12 dietary factors examined, high sodium intake (17.3%), low fruit consumption (11.5%), and low marine omega-3 fatty acids (9.7%) were associated with the largest numbers of estimated cardiometabolic deaths in 2010–12.

Interpretation We observed an improvement in several dietary factors in China in the past few decades. However, current intakes of these dietary factors remain suboptimal. Poor diet quality is estimated to be associated with a substantial proportion of deaths from heart disease, stroke, and type 2 diabetes in China.

Funding Ministry of Health, China, and Ministry of Science and Technology, China.

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**Research in context**

**Evidence before this study**

We searched PubMed for studies published up to Jan 31, 2019, using the following key terms: ("stroke" or "diabetes" or "cardiovascular disease" or "heart disease"), and "mortality burden" and "China" and ("food" or "nutrition" or "diet"), with no language restrictions. We also searched references listed in the identified papers. Several papers, including our previous publications, examined the burden of diabetes or cardiovascular disease associated with the dietary transition in China. However, the samples in these studies were not nationally representative and did not consider population growth. Some of the studies we identified did estimate disease burdens associated with lifestyle factors at a national level; however, these studies examined burdens of total mortality and overall disability-adjusted life-years (DALYs), rather than the burden of cardiometabolic disease. The Global Burden of Disease Study indicated that dietary factors are the leading risk factor for morbidity and mortality in China, accounting for 16·3% of DALYs and 30·6% of all-cause deaths in 2010. However, there is scarce information about trends in the consumption of individual foods and nutrients and the cardiometabolic disease burden associated with these dietary factors, based on nationally representative data in China.

**Added value of this study**

Using a comparative risk assessment model and nationally representative dietary data from the China National Nutrition Surveys (CNNS), we comprehensively estimated the number of cardiometabolic deaths related to suboptimal dietary habits among Chinese adults in 1982, 1992, 2002, and 2010–12, taking into account population growth and ageing. We found that the population attributable fraction of a combination of 12 dietary factors associated with cardiometabolic mortality decreased from 62·2% in 1982 to 51·0% in 2010–12. However, the absolute number of cardiometabolic deaths increased substantially from 1982 to 2012. During the same time period, the population average BMI increased by 2·8 kg/m², which was associated with an estimated 0·33 million cardiometabolic deaths, and systolic blood pressure increased by 8 mm Hg, which was associated with an estimated 1·11 million cardiometabolic deaths. To the best of our knowledge, this cross-sectional study is the first population-level analysis of the association between cardiometabolic mortality and overall dietary patterns in China. This study is also the first to incorporate population ageing and growth in a time-trend analysis of the cardiometabolic mortality burden and to provide an updated description of Chinese adult dietary patterns based on the most recent nationally representative data available.

**Implications of all the available evidence**

Taken together, the available evidence indicates that dietary transitions are significantly associated with the chronic disease burden in China. Despite some modest improvements over the past few decades, diet quality is still suboptimal at a population level. Based on nationally representative data from 1982 to 2012, several dietary improvements occurred in the Chinese population, including decreased sodium intake and increased intake of fruits, nuts, marine omega-3 fatty acids, and polyunsaturated fatty acids; however, current consumption patterns for these dietary factors remain suboptimal. During the same time period, the Chinese diet underwent rapid westernisation, including increased consumption of red meat, processed meat, and sugar-sweetened beverages. Although the proportion of the cardiometabolic disease burden attributable to suboptimal diets has decreased during the past few decades, the burden remains alarmingly high, which underscores the need for public health nutrition and policy strategies to improve diet quality in China.

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Table 1: Sociodemographic distribution of participants in the 1982, 1992, 2002, and 2010–12 China National Nutrition Surveys

<table>
<thead>
<tr>
<th>Year</th>
<th>Total</th>
<th>1982</th>
<th>1992</th>
<th>2002</th>
<th>2010–12</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age group, years</td>
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<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>20–34</td>
<td>17 668 (45·3%)</td>
<td>22 436 (38·5%)</td>
<td>13 651 (26·0%)</td>
<td>8742 (15·9%)</td>
<td></td>
</tr>
<tr>
<td>35–49</td>
<td>10 178 (26·1%)</td>
<td>18 960 (32·5%)</td>
<td>18 584 (35·4%)</td>
<td>16 882 (30·7%)</td>
<td></td>
</tr>
<tr>
<td>50–64</td>
<td>7787 (20·0%)</td>
<td>11 807 (20·2%)</td>
<td>13 290 (26·3%)</td>
<td>18 806 (34·2%)</td>
<td></td>
</tr>
<tr>
<td>65–79</td>
<td>2995 (7·7%)</td>
<td>4484 (7·7%)</td>
<td>5835 (11·1%)</td>
<td>9444 (17·2%)</td>
<td></td>
</tr>
<tr>
<td>≥80</td>
<td>380 (1·0%)</td>
<td>629 (1·1%)</td>
<td>566 (1·1%)</td>
<td>1178 (2·1%)</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Sex</th>
<th></th>
<th></th>
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</tr>
</thead>
<tbody>
<tr>
<td>Male</td>
<td>19 386 (49·7%)</td>
<td>28 010 (48·0%)</td>
<td>24 709 (47·1%)</td>
<td>25 279 (45·9%)</td>
</tr>
<tr>
<td>Female</td>
<td>19 622 (50·3%)</td>
<td>30 036 (52·0%)</td>
<td>27 717 (52·9%)</td>
<td>29 773 (54·1%)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Living area</th>
<th></th>
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</tr>
</thead>
<tbody>
<tr>
<td>Urban</td>
<td>13 744 (35·2%)</td>
<td>17 633 (30·2%)</td>
<td>17 530 (33·4%)</td>
<td>27 471 (49·9%)</td>
</tr>
<tr>
<td>Rural</td>
<td>25 264 (64·8%)</td>
<td>40 683 (69·8%)</td>
<td>34 896 (66·6%)</td>
<td>27 581 (50·1%)</td>
</tr>
</tbody>
</table>

Data are number of participants (%).
Articles

Data collection and measurements

All four CNNS followed a similar framework of organisation and investigator training procedure (appendix). Dietary information was collected for 5 days in 1982 by trained investigators who weighed all available foods in participants’ homes at the beginning of the first day, recorded (and weighed if necessary) all new foods brought into the homes during the 5 days and weighed all leftover food at the end of the fifth day to calculate the total amount of food consumed by participants during those 5 days. In the 1992, 2002, and 2010–12 surveys, diet was assessed during 3 consecutive days (including two weekdays and one weekend) of 24-h dietary recall in addition to weighing of household cooking oil and condiments. For each dietary recall day, investigators went to participants’ homes and helped to record food intake during the past 24 h. Investigators also weighed the household cooking oil and condiments at the beginning and end of each 24 h dietary survey (appendix). Nutrient intakes were calculated with the China Food Composition Tables (FCTs), which are continuously updated with commonly consumed foods and changes in nutrient content.

### Table 2: Mean consumption of key dietary components among Chinese adults aged 20 years or older in the China National Nutrition Surveys from 1982, 1992, 2002, and 2010–12

<table>
<thead>
<tr>
<th>Dietary component</th>
<th>1982 (mean, SD)</th>
<th>1992 (mean, SD)</th>
<th>2002 (mean, SD)</th>
<th>2010–12 (mean, SD)</th>
<th>Mean change, 1982–2012 (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Energy intake, kcal per day</strong></td>
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<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2783 (22)</td>
<td>2638 (16)</td>
<td>2271 (23)</td>
<td>2064 (27)</td>
<td>–719 (–25·8%)</td>
<td></td>
</tr>
<tr>
<td><strong>Protein, % of total energy intake per day</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7·2%</td>
<td>9·6%</td>
<td>10·8%</td>
<td>11·8%</td>
<td>4·6 (63·9%)</td>
<td></td>
</tr>
<tr>
<td><strong>Fat, % of total energy intake per day</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>12·0%</td>
<td>16·0%</td>
<td>26·4%</td>
<td>32·3%</td>
<td>20·3 (169·2%)</td>
<td></td>
</tr>
<tr>
<td><strong>Carbohydrate, % of total energy intake per day</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>80·8%</td>
<td>74·4%</td>
<td>62·8%</td>
<td>55·9%</td>
<td>–24·9 (–30·8%)</td>
<td></td>
</tr>
</tbody>
</table>

**Dietary factors related to disease burden†**

- Sodium, g per day: 6·5 (0·2) 6·3 (0·1) 5·9 (0·1) 5·2 (0·1) –1·3 (–20·0%)
- Marine omega-3 fatty acids, mg per day: 12·0 (0·1) 20·0 (0·2) 25·0 (0·3) 30·0 (0·3) 18·0 (150·0%)
- Fruit, g per day: 17·0 (4·5) 22·0 (3·2) 27·0 (3·7) 32·0 (4·3) 25·0 (150·0%)
- Whole grains, g per day: 91·0 (11·9) 24·6 (3·3) 21·4 (3·3) 14·6 (3·1) –7·6 (–30·8%)
- Nuts, g per day: 1·2 (0·3) 3·2 (0·3) 3·2 (0·3) 3·2 (0·3) 2·0 (150·0%)
- PUFAs, % of total energy intake per day: 2·9% (0·1) 4·2% (0·1) 7·1% (0·2) 8·6% (0·2) 5·7 (150·0%)
- Total vegetables, g per day: 330 (16) 267 (7) 257 (7) 248 (5) –82 (–24·8%)
- Processed meat, g per day: 2·0 (0·6) 1·9 (0·2) 2·9 (0·5) 3·6 (0·3) 1·6 (80·0%)
- Red meat, g per day: 18·2 (1·6) 32·2 (1·6) 55·2 (2·7) 64·4 (2·7) 46·2 (252·8%)
- Refined grains, g per day: 407 (8) 388 (4) 323 (5) 304 (4) –103 (–25·5%)
- Low-fat dairy products, g per day: 0·0 (0·0) 0·0 (0·0) 0·0 (0·0) 0·0 (0·0) 0·0 (0·0)
- Sugar-sweetened beverages, g per day: 0·0 (0·0) 0·0 (0·0) 0·0 (0·0) 0·0 (0·0) 0·0 (0·0)
- Eggs, g per day: 4·2 (0·4) 11·5 (0·6) 23·8 (1·1) 25·3 (0·8) 19·3 (451·0%)
- Fish, shellfish, and other seafood, g per day: 4·4 (0·6) 26·0 (1·7) 31·5 (3·1) 23·0 (2·1) 18·6 (422·7%)
- Total dairy products, g per day: 16·8 (6·2) 10·5 (1·4) 20·7 (2·9) 23·1 (1·8) 6·3 (37·5%)
- Soybeans, g per day: 7·1 (0·7) 7·2 (0·5) 10·9 (0·7) 9·8 (0·4) 2·7 (38·0%)
- Dark coloured vegetables, g per day: 71·8 (6·7) 92·2 (4·7) 87·2 (4·8) 80·5 (3·4) 8·7 (12·1%)
- Saturated fatty acids, % of total energy intake per day: 3·3% (0·2) 4·4% (0·1) 6·6% (0·2) 7·4% (0·1) 4·0 (121·2%)
- Alcohol, g per day: 1·0 (0·2) 1·0 (0·2) 1·0 (0·2) 1·0 (0·2) 1·0 (0·2)
- Vegetable oil for cooking, g per day: 9·6 (0·6) 15·8 (0·6) 29·6 (1·2) 33·8 (1·0) 24·2 (252·1%)
- Animal fat for cooking, g per day: 0·4 (0·0) 0·6 (0·0) 0·4 (0·0) 0·4 (0·0) 0·3 (7·5%)

Data are mean (SD), unless otherwise indicated. PUFAs=polyunsaturated fatty acids. †Food groups selected on the basis of evidence from the most recent meta-analyses and systematic reviews and defined according to 2016 Chinese Dietary Guidelines. Food groups in the guidelines included fruit (fresh fruit, excluding canned fruit and dried fruit), whole grains (grain foods with fibre to carbohydrate ratio ≥0·1, such as white rice and refined wheat flour products), nuts (peanuts, tree nuts, and seeds), processed meat (bacon, ham, sausage, and meat processed outside household), red meat (pork, beef, and lamb), sugar-sweetened beverages (carbonated drinks, fruit drinks, and sweetened tea), low-fat dairy products (fat values per 100 g milk equivalence <2 g), and dark coloured vegetables (spinach, carrots, green peppers, and chives).

See Online for appendix
composition. Specifically, FCT-1981 was used for dietary data from the 1982 CNNS, FCT-2002 was used for dietary data from the 1992 and 2002 CNNS, and FCT-2009 was used for dietary data from the 2010–12 CNNS. We evaluated energy-adjusted dietary intakes for each dietary factor using the residual method of 2000 kcal per day, except for polyunsaturated fatty acids (PUFAs), which were calculated as a percentage of total energy intake. To estimate the proportion of participants meeting or exceeding national dietary recommendations, we applied the recommended criteria for food intakes (g per 1000 kcal) from the 2016 Chinese Dietary Guidelines and criteria of nutrients from the Chinese Dietary Reference Intakes (appendix).11 Fasting bodyweight, height, and blood pressure were measured by trained investigators (appendix).

Comparative risk assessments
We applied population-level comparative risk assessments12 to estimate the number and proportion of cardiometabolic deaths that would have been prevented in the analysis period if the distribution of exposure to a specific dietary risk factor had been changed to a hypothetical alternative distribution, while holding other risk factors constant. We examined the effects of suboptimal intakes of 12 dietary factors individually and collectively. For the analysis, we separated participants into 28 groups by sex, urbanisation (urban or rural), and age at measurement (20–29, 30–39, 40–49, 50–59, 60–69, 70–79, or ≥80 years). The method of comparative risk assessments is described in detail in the appendix.

Statistical analysis
All iterations of the CNNS were designed to provide accurate estimates of nutritional status in the Chinese population according to sex, age, and level of economic development. We calculated the mean (SD) of each risk factor by sex, age group, and urban or rural status for each CNNS year. Applying the post-stratification population sampling weights derived for the dietary surveys from the sampling probability of the 1980, 1990, 2000, and 2010 Chinese population aged 20 years or older (based on census data), we estimated nationally representative population levels for intakes of foods and nutrients. To quantify time trends of the risk factors, our regression models included the year of each survey as a continuous variable.

Assuming a causal relationship between each risk factor and cardiometabolic mortality, we calculated the population attributable fraction (PAF)12 to estimate the proportional reduction in cardiometabolic deaths that would occur if exposure to each risk factor was reduced to an alternative optimal level. These methods are described in detail in the appendix.

All statistical analyses were done with SAS software, version 9.4.

Role of the funding source
The sponsors of the study had no role in study design, data collection, data analysis, data interpretation, or writing of the report. YH and YL both had full access to all study data. All authors contributed to the research, commented on the manuscript drafts, and agreed to submit the final draft for publication. All lead authors and corresponding authors had final responsibility for the decision to submit for publication.

Results
Across the four CNNS, complete dietary intake data were available for 204,802 participants aged 20 years or older (table I). Compared to the 1982 survey sample, the
2010–12 sample consisted of higher proportions of older adults and urban residents and lower proportions of younger adults and rural residents, reflecting increasing patterns of ageing and urbanisation in China (appendix).

The average daily energy intake was 2783 kcal per day in the 1982 survey, compared with 2064 kcal per day in the 2010–12 survey. In 1982, carbohydrates contributed to 80.8% of the total energy intake of the study population, compared with 74.4% of total energy intake in the 1992 sample, 62.8% in the 2002 sample, and 55.9% in the 2010–12 sample, 62.8% in the 2002 sample, and 55.9% in the 2010–12 survey. In 1982, carbohydrates contributed to 80·8% of the total energy intake of the study population, compared with 74·4% of total energy intake in the 1992 sample, 62·8% in the 2002 sample, and 55·9% in the 2010–12 sample (table 2). Meanwhile, energy contribution from fat was 12·0% in 1982 but increased to 32·3% in the 2010–12 sample (table 2). Meanwhile, energy contribution from fat was 12·0% in 1982 but increased to 32·3% in the 2010–12 sample (table 2).

Sodium intake decreased by 20·0% and refined grain intake by 25·5%; consumption of marine omega-3 fatty acids, fruits, nuts, and PUFAs also increased moderately (table 2). However, during the same time period, consumption of whole grains and vegetables decreased and consumption of red meat, processed meat, and sugar-sweetened beverages increased. When examining other dietary factors included in the Chinese Dietary Guidelines, we observed relatively large increases in the consumption of eggs, fish (plus shellfish and other seafood), and vegetable oils (table 2).

The proportion of adults consuming the minimum recommended amounts of fruits and dairy products was less than 10%, with a slightly increasing trend from 1982 to 2012 (figure 1). More than 80% of the population exceeded the maximum recommended amount of refined grains and more than 90% exceeded the recommended sodium intake. From 1982 to 2012, a notable decrease was observed in the proportion of Chinese adults who met the minimum recommendations for whole grains and vegetables, and a substantial increase was observed in the proportion exceeding the maximum recommendations for meat and saturated fat (figure 1).

High sodium intake was the leading dietary risk factor for cardiometabolic mortality and was associated with a PAF of 27·0% in 1982, compared with 17·3% in 2010–12 (figure 2). In 2010–12, low intakes of fruits (PAF 11·5%), marine omega-3 fatty acids (9·7%), vegetables (7·3%), whole grains (8·1%), and nuts (8·2%) were also important risk factors for cardiometabolic mortality in China. High intakes of red meat, processed meat, refined grains, and sugar-sweetened beverages, and low intakes of low-fat dairy products were also associated with cardiometabolic mortality in 2010–12 (figure 2). Suboptimal levels of all 12 dietary factors combined were associated with 1·07 million cardiometabolic deaths in 1982, 0·93 million cardiometabolic deaths in 1992, 1·18 million cardiometabolic deaths in 2002, and 1·51 million cardiometabolic deaths in 2010–12 (figure 3). These deaths accounted for 62·2% of all cardiometabolic deaths (which accounted for 21·6% of total deaths) in China in 1982; 57·9% of all cardiometabolic deaths...
(which accounted for 16·6% of total deaths) in China in 1992; 56·2% of all cardiometabolic deaths (which accounted for 17·6% of total deaths) in China in 2002; and 51·0% of all cardiometabolic deaths (which accounted for 20·8% of total deaths) in China in 2012.

The mean BMI in China was 21·1 kg/m² in 1982, 22·0 kg/m² in 1992, 23·1 kg/m² in 2002, and 23·9 kg/m² in 2010–12, with an average increase rate of around one BMI unit per decade of the study period and an increasing prevalence of overweight across all age groups between 1982 and 2012 (figure 4A). Average systolic blood pressure increased from 115 mmHg in 1982, to 119 mmHg in 1992, to 120 mmHg in 2002, and to 123 mmHg in 2010–12, with an increasing prevalence among all age groups older than 40 years (figure 4B). These shifts resulted in substantial increases in the number of Chinese adults with overweight (figure 4A) and the number of adults with hypertension (figure 4B) from 1982 to 2012. In 1982, 0·07 million cardiometabolic deaths were attributable to high BMI and 0·77 million were attributable to high systolic blood pressure. By 2012, the number of cardiometabolic deaths attributable to high BMI had increased to 0·33 million and those attributable to high systolic blood pressure had increased to 1·11 million (figure 4E, F).

**Discussion**

By use of a comparative risk assessment model and nationally representative dietary data, we comprehensively estimated the number of cardiometabolic deaths related to suboptimal dietary habits among Chinese adults from 1982 to 2012, taking into account population growth and ageing. According to the CNNS data, some aspects of Chinese dietary patterns improved from 1982 to 2012. A relatively large improvement was observed in the PAF of a combination of 12 dietary factors associated with cardiometabolic mortality, which decreased from 62·2% in 1982 to 51·0% in 2010–12. Although this improvement in diet might have slowed the rapid increase in cardiometabolic deaths occurring in China, the absolute number of cardiometabolic deaths still increased substantially from 1982 to 2012. During the same time period, the population-level BMI distribution and systolic blood pressure distribution both shifted towards the right, with mean population BMI increasing by 2·8 kg/m² and mean systolic blood pressure by 8 mmHg. In 2010–12, an estimated 0·33 million cardiometabolic deaths were attributable to high BMI and 1·11 million were attributable to elevated systolic blood pressure.

Despite the observed dietary improvements in China, results of our study indicate that suboptimal dietary factors were associated with 51·0% of all cardiometabolic deaths in 2010–12 (and that these cardiometabolic deaths accounted for 20·8% of total deaths), which is greater than that estimated in the USA, where 45·4% of cardiometabolic deaths were attributable to suboptimal diet in 2012. In 2016, suboptimal diet was the second-leading risk factor for DALYs and deaths worldwide, accounting for 9·6% of all DALYs and 18·8% of all deaths related to suboptimal dietary habits among Chinese adults from 1982 to 2012, taking into account population growth and ageing. According to the CNNS data, some aspects of Chinese dietary patterns improved from 1982 to 2012. A relatively large improvement was observed in the PAF of a combination of 12 dietary factors associated with cardiometabolic mortality, which decreased from 62·2% in 1982 to 51·0% in 2010–12. Although this improvement in diet might have slowed the rapid increase in cardiometabolic deaths occurring in China, the absolute number of cardiometabolic deaths still increased substantially from 1982 to 2012. During the same time period, the population-level BMI distribution and systolic blood pressure distribution both shifted towards the right, with mean population BMI increasing by 2·8 kg/m² and mean systolic blood pressure by 8 mmHg. In 2010–12, an estimated 0·33 million cardiometabolic deaths were attributable to high BMI and 1·11 million were attributable to elevated systolic blood pressure.

Despite the observed dietary improvements in China, results of our study indicate that suboptimal dietary factors were associated with 51·0% of all cardiometabolic deaths in 2010–12 (and that these cardiometabolic deaths accounted for 20·8% of total deaths), which is greater than that estimated in the USA, where 45·4% of cardiometabolic deaths were attributable to suboptimal diet in 2012. In 2016, suboptimal diet was the second-leading risk factor for DALYs and deaths worldwide, accounting for 9·6% of all DALYs and 18·8% of all
deaths.13 In the USA, suboptimal diets are associated with more all-cause deaths than any other risk factors.14 In China, dietary factors are also the leading risk factor for morbidity and mortality, accounting for 16·3% of DALYs and 30·6% of all-cause deaths in 2010.2 Our estimate of the proportion of all-cause deaths due to dietary factors (20·8%) was lower than that estimated in the Global Burden of Disease Study (GBD) 2010 for China (30·6%),2 because we only estimated cardiometabolic deaths whereas the GBD 2010 analysis for China also included other causes of death, such as cancer. Additionally, in our combined group of dietary factors, we chose not to include some foods and nutrients that were included in the GBD 2010 study on China, such as fibre, to avoid potential overlap with other dietary risk factors such as whole grains.

We observed notable improvements in intake of several dietary factors, including increases in marine omega-3 fatty acids, fruit, nuts, and PUFAs, and decreases in sodium and refined grains. Total energy intake decreased substantially from 1982 to 2012, largely reflecting a substantial decrease in levels of physical activity accompanied by rapid urbanisation. Despite some dietary improvements, we observed a westernisation of dietary patterns, which included decreased intakes of vegetables and whole grains, and increased intakes of red meat.

Figure 4: Prevalence of overweight and obesity and hypertension, and the associated cardiometabolic mortality burden in the Chinese population, 1982–2012
(A) Prevalence of overweight and obesity (BMI ≥ 25 kg/m²) in adults aged 20 years and older in 1982 and 2012. (B) Prevalence of hypertension (systolic blood pressure >130 mmHg or diastolic blood pressure >80 mmHg, or both) in adults aged 20 years and older in 1982 and 2012. (C) Number of men and women with overweight and obesity in urban and rural areas. (D) Number of men and women living with hypertension in urban and rural areas. (E) Cardiometabolic deaths attributable to high BMI, 1982–2012. (F) Cardiometabolic deaths attributable to high systolic blood pressure, 1982–2012.
processed meat, sugar-sweetened beverages, saturated fat, and alcohol. These dietary changes led to a substantial change in the macronutrient composition of Chinese diets, from a very high carbohydrate diet to a relatively high fat diet. Previous studies have reported similar trends in the Chinese population, showing increased consumption of animal-based diets and transitioning to dietary patterns similar to western patterns. The westernisation of dietary patterns in China, together with sedentary lifestyles and other obesogenic factors, probably offset the protective effects from dietary improvements and contributed to the increase in the prevalence of obesity and hypertension in China.

Concerted efforts are needed to improve dietary quality in light of the increasing trends in BMI and blood pressure and the high burden of cardiometabolic disease in China. Improvements in diet quality and reduction of unhealthy dietary behaviours should be promoted at local and national levels and be supported by public policies in China. Intervention programmes and policies that have been successful in other countries can be adapted to the unique characteristics of the food system and culture in China. Greater adherence to the Chinese Dietary Guidelines, along with their visual representation (the Chinese Food Pagoda), has been associated with a lower mortality risk, especially for cardiometabolic mortality, in Chinese men and women. Adherence to a healthier dietary pattern has also been associated with a lower mortality risk in South Korean, Japanese, and Singapore Chinese populations. Compared with Japan and South Korea, the average consumption levels that we observed in China were much lower for fish, marine omega-3 fatty acids, and fruit, and were higher for vegetables and PUFAs. We also found that the Chinese population had lower intakes of sugar-sweetened beverages and processed meat than Japanese or South Korean populations. China (4.9 g per day), Japan (4.9 g per day), and South Korea (5.3 g per day) all had higher levels of sodium intake than the overall world average (4.0 g per day).

Our study has various strengths. By use of the most recent nationally representative data available, it provides an up-to-date description of dietary patterns of adults in China. To our knowledge, this study is the first population-level analysis of the association between cardiometabolic mortality and overall dietary patterns in China, based on the comparative risk assessment method. It is also the first to incorporate population ageing and growth in a time-trend analysis of the cardiometabolic mortality burden. Previous disease burden estimations included events at only one timepoint, which reflected changes in PAFs but ignored population ageing and growth. In our study, we accounted for population ageing and growth by estimating cardiometabolic mortality events using the cardiometabolic rate combined with Chinese population census data for 1980, 1990, 2000, and 2010. We also accounted for demographic data including age, sex, and urban or rural living area. Additionally, our findings are generalisable to the Chinese adult population as a whole because we used nationally representative cardiometabolic mortality and dietary intake data.

Several limitations should be considered when interpreting our results. First, the aetiological effects of risk factors on cardiometabolic mortality were mainly derived from meta-analyses of studies done in western populations, although when possible we did prioritise meta-analyses done in Asian populations. However, the observational studies included in these meta-analyses adjusted for potential confounding variables, so the associations are likely to represent underlying physiological mechanisms connecting diet and cardiometabolic diseases, which are generally similar across different populations. Future estimations are warranted when additional meta-analyses from Asian, specifically Chinese, populations become available. Second, we cannot draw conclusions about causality from our study, because our estimation of the cardiometabolic mortality burden is based on the theoretical ideal level of each individual risk factor, in combination with the effect size for each factor estimated from meta-analyses of observational cohort studies. Our estimation based on the comparative risk assessment model cannot prove that changes in these dietary factors would reduce cardiometabolic mortality risk in the way that we estimated. Third, our estimation of dietary intake was mainly based on 3-day 24-h dietary recalls, and thus measurement error is inevitable. To reduce measurement errors and selection bias from different age groups or urban and rural areas, we took the average of three 24-h dietary recalls and used the stratum-specific mean intakes, adjusted for total energy intake. Fourth, as death certificates were a major source of cause-of-death ascertainment, when interpreting our results it is important to consider that the way physicians complete death certificates or assign causes of death is based on available information and might be subject to potential bias, especially for deaths occurring outside of the hospital, which might result in bias in estimation of the total number of cardiometabolic deaths. Finally, we were not able to stratify according to geographical locations, which warrants further studies as various geographical locations in China have substantial differences in dietary patterns and disease patterns.

In conclusion, using four nationally representative dietary surveys in China done between 1982 and 2012, we observed several improvements in dietary intakes, including decreased sodium intake and increased intake of fruits, nuts, marine omega-3 fatty acids, and PUFAs; however, current consumption patterns for these dietary factors remain suboptimal. We also observed a rapid westernisation of the Chinese diet, including increases in consumption of red meat, processed meat, and sugar-sweetened beverages. A combination of 12 dietary risk factors was associated with 62.2% of all cardiometabolic...
deaths in 1982. This PAF improved to 51% in 2010–12 (accounting for 20–8% of total deaths in China). Despite this improvement, the cardiometabolic disease burden associated with dietary factors remains alarmingly high, which underscores the need for public health nutrition strategies to improve diet quality in China.

Contributors
All authors participated in study design, generation of hypotheses, interpretation of data, and critical review of the report. YH, XL, and GD were responsible for data collection and data analysis of the exposures. YL, DDW, and FBH are responsible for data analysis and interpretation of results on disease burden. YH and YL wrote the first draft of the paper.

Declaration of interests
FBH reports receiving research support from the California Walnut Commission and honoraria for lectures from Metagenics and Standard Process and honoraria from Diet Quality Photo Navigation, outside the submitted work. YL reports receiving research support from the California Walnut Commission. All other authors declare no competing interests.

Acknowledgments
We thank all the team members and participants involved in the China National Nutrition Surveys. For this study, we also used data freely available online from the China Public Health Statistical Yearbook and the National Population Census Datasets. We give special thanks to Goodarz Danaei from Harvard T. H. Chan School of Public Health who provided help with the statistical methods and data analysis. The 1982 CNNS was supported by the Major Program of National Medical and Health Research of China’s Ministry of Health. The Ministry of Health in China provided special funding support to the 1992 CNNS, which was organised by the Ministry of Health, Ministry of Agriculture, Ministry of Public Security, and National Bureau of Statistics. The 2002 CNNS was supported by the Ministry of Health and the Ministry of Science and Technology in China (2001-DEA30035, 2003-DIA6N008), UNICEF, WHO, Unilever China, and Danone Nutrition Institute China. The 2010–12 CNNS was supported by the Special Fund for Health-Scientific Research in the Public Interest (No. 20120212) from the Ministry of Health and Family Planning Commission of the People’s Republic of China. DDW was supported by a postdoctoral fellowship granted by the American Heart Association (16POST3100031). We give special thanks to Goodarz Danaei from Harvard T. H. Chan School of Public Health who provided help with the statistical methods and data analysis. The 1982 CNNS was supported by the Major Program of National Medical and Health Research of China’s Ministry of Health. The Ministry of Health in China provided special funding support to the 1992 CNNS, which was organised by the Ministry of Health, Ministry of Agriculture, Ministry of Public Security, and National Bureau of Statistics. The 2002 CNNS was supported by the Ministry of Health and the Ministry of Science and Technology in China (2001-DEA30035, 2003-DIA6N008), UNICEF, WHO, Unilever China, and Danone Nutrition Institute China. The 2010–12 CNNS was supported by the Special Fund for Health-Scientific Research in the Public Interest (No. 20120212) from the Ministry of Health and Family Planning Commission of the People’s Republic of China. DDW was supported by a postdoctoral fellowship granted by the American Heart Association (16POST3100031).

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