Socioeconomic inequalities in dementia burden related to high body mass index, 2005–2018: findings from 1.25 million Chinese adults

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Summary

Background Dementia has become a major public health concern worldwide, but comprehensive assessments of dementia burden attributable to high body mass index (BMI) in China have not been done.

Methods We used a temporal-spatial Bayesian hierarchical model to estimated BMI levels based on 1.25 million Chinese. We estimated dementia burden attributable to high BMI by age, sex, year, and socioeconomic development in terms of deaths and years of life lost (YLLs) and assessed the effect of population ageing.

Findings The average age-standardised BMI was 24.58 kg/m^2 and 24.15 kg/m^2 for men and women in 2018, respectively. 12,901 (95% UI, 10,617–15,420) dementia deaths were attributable to high BMI in China in 2018, with 5417 deaths from man and 7421 deaths from woman. The attributable age-standardised YLL rates for dementia increased 27% from 2005 to 2018. The attributable age-standardised mortality rates increased with human development index. People aged 80 years and older had the highest attributable mortality rate, and the rate decreased with decreasing age. Population ageing was an important component of the increase in dementia death.

Interpretation The rapid increase and large inequality highlighted the urgent need for evidence-based policies and interventions. We therefore call for establishing stronger anti-dementia strategies to promote the healthy ageing.

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Keywords: Disease burden; Obesity; Dementia; Year of life lost; Mortality

Introduction

Dementia is a global health concern that is associated with significant memory loss and impaired functioning in everyday life, causing immense costs and burdens to individuals, their families, and health care systems. In 2019, 51.6 million cases, 25.3 million disability-adjusted life-years, and 1.6 million deaths for dementia were estimated globally, with 2.60-fold, 2.62-fold, and 2.89-fold increase from 1990, respectively.[1] A multicentre survey conducted between 2015 and 2018 in China

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Research in context

Evidence before this study

We searched PubMed, Embase, and Web of Science for articles published using search terms ("body mass index" OR "obesity" OR "overweight") AND ("dementia" OR "Alzheimer's disease" OR "neurological disorders") AND ("death" OR "mortality" OR "disease burden" OR "YLL") AND ("China" OR "Chinese"), with no language restriction, until March 12, 2023.

Previous studies have reported a global or national dementia burden attributable to high body mass index (BMI) levels; however, with a large population and vast territory in China, systematically examining spatiotemporal variation and economic development levels in China and its different regions is imperative. Moreover, further assessment of the effect of population ageing on the dementia burden will be especially valuable for assessing the importance of healthy ageing.

Added value of this study

We found the age-standardised year of life lost (YLL) rate for dementia attributable to high BMI increased 27% from 2005 to 2018, and the changes in dementia death attributable to high BMI from 2005 to 2018 increased with population growth and population ageing. The age-standardised mortality rate for dementia attributable to high BMI generally increased with human development index, and the difference in attributable crude mortality rates between regions with very low HDI and regions with very high HDI became wider.

Implications of all the available evidence

Dementia is a global health concern. This study identified the spatiotemporal trends and variations in dementia mortality burden attributable to high BMI across age, sex, and socioeconomic status, which could help to identify priority groups and regions for improving dementia and obesity management and making policies for promoting physical health in China, as well as in other countries or regions with similar condition. The rapid increase and large inequality in dementia burden attributable to high BMI highlighted the urgent need for evidence-based policies and interventions, we therefore call for authorities to establish stronger anti-dementia strategies.

showed prevalence rates for dementia (6.0%) and Alzheimer's disease (3.9%) in older people, which suggested 15.07 million and 9.83 million people aged 60 years or older in China had dementia and Alzheimer's disease, respectively.[2] In the coming decades, as a consequence of progressively ageing population, the burden of dementia will continue to rise in China.

At present, there are no known cures for dementia, making it particular important to investigate risk factors that could be targeted by intervention.[2] Health factors, including body mass index (BMI), are thought to play a role in the development of dementia. High BMI in midlife has been established as a modifiable risk factor for dementia.[3] The link between obesity and dementia may be, in part, due to inflammation, insulin resistance, oxidative stress, and metabolic and vascular dysregulation.[4,5] Since high BMI is also considered an urgent health issue, increasing from 22.7 kg/m^2 in 2004 to 24.4 kg/m^2 in 2018 in China,[6] curbing the rapid increase in BMI will also help to control dementia burden. In 2003, China expanded health insurance to all, and in 2009 the government launched a major health reform with the goal of providing all citizens with equal access to basic health care of reasonable quality.[7] The 2009 reform goals were further expanded by the Healthy China 2030 Strategy, which established the importance of improving population health in advancing the country's long-term economic and social development goals.[8] Although these policies not only targeted dementia and obesity groups, they did have an important impact directly or indirectly. In this context, it's required to accurately estimating the dementia burden attributable to high BMI according to age, sex, and region over a long period of time in China.

Previous studies have reported the dementia burden related to high BMI in China at the national level.[9,10] However, given that China has vastly diversity in socioeconomic development levels, further systematical assessments of the dementia burden attributable to high BMI by socioeconomic status, sex, and age group in China will be necessary. Therefore, this study aimed to estimate deaths and years of life lost (YLLs) for dementia attributable to high BMI by socioeconomic status, sex, year, and age group in China, and calculated the changes in the key indicators between 2005 and 2018. We further explored the effect of population growth and population ageing on the dementia mortality attributable to high BMI. The findings of this study will be especially valuable for targeted improvements in dementia prevention and management and shedding light on assess the healthy ageing in the future in China, as well as in other countries or regions with similar condition.

Methods

Study design and data sources

The comparative risk assessment method was applied to estimate the dementia mortality burden attributable to high BMI from 2005 to 2018, which has been reported in detail elsewhere.[11] In summary, we estimated the attributable deaths, mortality rates, YLLs, and YLL rates for dementia attributable to high BMI by age, sex, regions, and year, and discussed the impact of socioeconomic development, population growth, and population ageing on it. All data used in this study were aggregated and did not contain any individually identifiable information; therefore, no ethics approval or consent to participate was required.

BMI data of this study were obtained from three large-scale nationally representative studies, including the China Chronic Disease and Risk Factor Surveillance,[6] the China Nation Nutrition Survey,[12] and the China Hypertension Survey.[13] The study designs of the three studies are in the Supplementary Materials. After data consolidation, 1.25 million participants aged ≥20 years were included in the current analysis, covering 31 provinces, autonomous regions, and municipalities over 9 years. Relative risks (RRs) were extracted from the Global Burden of Disease (GBD) 2019 study. Age-sex-cause-specific mortality data from 2005 to 2018 were mainly derived from surveillance systems (the Disease Surveillance Point system and Maternal and Child Surveillance System), as well as the China Cancer Registry, and the Chinese Centre for Disease Control and Prevention cause-of-death reporting system.[9,14,15] The standard life expectancy was derived from the lowest age-specific mortality rates by location and sex across all years of interest. Data on the population size, and census data were from public databases.[16]

Identification of dementia deaths

Based on the World Cancer Research Fund criteria and the GBD 2019 study,[11,17] we included Alzheimer's disease (ICD-10: G30–G31.9) and other dementia (ICD-10: F01–F01.9, F03). We classified them into 11 age groups, applying 5-year age bands for age 20 up to 80 years, with the final age group encompassing those aged 81 years and older. Although there were evidences from GBD studies to support the association between high BMI and dementia in people aged 20–39 years, no deaths from dementia had been detected in people aged 20–39 years in China. Therefore, we calculated attributive burden results for 11 age groups, but in the results, we only showed attributable burden for seven age groups (40 years and older).

Classification of socioeconomic status

We assigned socioeconomic development using the human development index (HDI). HDI was proposed by United Nations Development Program and was a composite measure of socioeconomic development including life expectancy, education, and gross income per capita index, which had been linked to the incidence of childhood and adolescent cancer in previous studies.[18] In our study, we divided the 31 provinces into six regions: very low HDI regions (≤10th percentile), low HDI regions (>10th–25th percentile), lower-middle HDI regions (>25th–50th percentile), upper-middle HDI regions (>50th–75th percentile), high HDI regions (>75th–90th percentile), and very high HDI regions (>90th percentile) to discuss the differences in mortality burden of dementia between different socioeconomic developments. The HDI value and its components by provinces were in the Supplementary Table S2.

Statistical analysis

Based on 1.25 million participants, we estimated the comprehensive age-, sex-, region-, and year-specific average BMI levels using a temporal–spatial hierarchical Bayesian model,[19] taking advantage of information on regions and age over time for missing data. Cross-validation was used to examine the predictive performance of the model by comparing the estimated BMI levels with their observed counterparts. The details of distribution of high BMI estimation are in the Supplementary Materials.

Age-sex-specific RRs measuring the effects of BMI level on the outcome were synthesized from published meta-analysis, and where available, pooled analyses of prospective observational studies, which were consistence with GBD 2019 study. More information on RR estimation had been previously provided by the Global Health Data Exchange via a web tool.[11] The details of assessment of risk-outcome pairs and their RRs were in the methods of Supplementary Materials, and RRs used in this study were showed in Supplementary Table S1. The theoretical minimum risk exposure level was established with the most recent pooled analysis of prospective observational studies,[20] defined as a uniform distribution for BMI between 20 and 25 kg/m^2. We estimated the population attributable fraction (PAF) for cause-specific deaths attributable to high BMI using the following equation:

$$PAF_{\text{oaspt}} = \frac{\int_{l}^{m} RR_{oas}(x)P_{aspt}(x)dx - RR_{oas}(TMREL)}{\int_{l}^{m} RR_{oas}(x)P_{aspt}(x)dx}$$

where $RR_{oas}(x)$ is the RR as a function of BMI at x, for cause o, age group a, and sex s, with the lowest level of observed BMI as l and the highest as m. $P_{aspt}(x)$ is the distribution of BMI at x for age group a, sex s, province p, and year t.

YLLs were obtained by multiplying the number of deaths by the standard life expectancy at each age. Deaths and YLLs attributable to high BMI were calculated by multiplying the deaths and YLLs by age-, sex-, region-, and cause-specific PAF. Mortality rates and YLL rates were calculated by dividing the number of attributable deaths and YLLs by the corresponding population, respectively. We applied the direct standardization to adjust for differences among the populations, with the standard population of the sixth national population census in 2010 (Supplementary Table S3).

We analysed the decomposition of changes in mortality attributable to high BMI by socioeconomic regions during 2005–2018. Methods developed by Das Gupta were used to conduct a decomposition of changes in mortality attributable to high BMI due to population growth, population ageing, risk-deleted mortality rate (the expected mortality that would be observed if high BMI was removed), and changes in exposure to high BMI.[21] We also calculated the percentiles 2.5 and 97.5 of the 1000 Monte Carlo runs for each quantity of interest as 95% uncertainty limits (UI), which were able to propagate uncertainty in the final analyses.

The analyses were performed using R version 4.2.1 (R Foundation for Statistical Computing, Vienna, Austria) and SAS version 9.4 (SAS Institute Inc., Cary, NC, USA).

Role of the funding source

The funders of the study had no role in the study design, data collection, data analysis, or data interpretation.

Results

With temporal-spatial Bayesian hierarchical model, we estimated the mean age-standardised BMI was 24.58 kg/m^2 (95% UI, 22.84–26.33) for man in 2018, which was 8% higher than that in 2005 (22.67 kg/m^2, 95% UI, 19.52–25.83), and 24.15 kg/m^2 (95% UI, 22.47–25.82) for woman in 2018, which was 5% higher than that in 2005 (23.00 kg/m^2, 95% UI, 21.03–24.96) (Supplementary Figure S1).

We also estimated approximately 12,901 (95% UI, 10,617–15,420) dementia deaths were attributable to high BMI in China in 2018, with 5417 (95% UI, 4314–6722) deaths from man and 7421 (95% UI, 5591–9609) deaths from woman. There were 5210 (95% UI, 4359–6173) deaths from Alzheimer's disease and 7688 (95% UI, 6219–9280) deaths from other dementias in 2018. The age-standardised mortality rates for dementia attributable to high BMI increased by 24.96% in China between 2005 (7.05 [5.70–8.85] per million people) and 2018 (8.81 [7.29–10.49] per million people), whereas death number increased by 128.18%. Moreover, 178.23 thousand (95% UI, 150.08–208.21) dementia YLLs attributable to high BMI were estimated in China in 2018, with 76.18 thousand (95% UI, 65.98–88.06) YLLs from Alzheimer's disease, and 101.77 thousand (95% UI, 83.59–121.14) YLLs from other dementias. The age-standardised dementia YLL rates attributable to high BMI increased 27.11% from 97.77 (95% UI, 81.01–118.80) per million people in 2005 to 124.28 (95% UI, 105.51–144.31) per million people in 2018 (Table 1). As for Alzheimer's disease, the age-standardised YLL rates attributable to high BMI increased 89.17% from 28.72 (95% UI, 24.93–33.20) per million people in 2005 to 54.33 (95% UI, 47.44–62.35) per million people in 2018 (Supplementary Table S4).

Fig. 1 showed the mortality rates of dementia attributable to high BMI in China by HDI from 2005 to 2018. The mortality rates for dementia attributable to high BMI increased with HDI. We observed upward trends in the crude mortality rates for dementia attributable to high BMI in all HDI regions from 2005 to 2018. On the other hand, the attributable age-standardised mortality rates in regions with high HDI decreased 9.06% from 10.49 per million people (95% UI, 6.41–16.74) in 2005 to 9.54 per million people (95% UI, 6.27–14.32) in 2018. Furthermore, from 2005 to 2018, the regions with very low HDI continuously had the lowest crude mortality rates for dementia attributable to high BMI, and the difference in attributable crude mortality rates between regions with very low HDI and regions with very high HDI became wider. The trends of attributable YLL rates were similar to attributable mortality rates (Supplementary Figure S2). Additionally, the age-standardised PAF of dementia attributable to high BMI was highest in very high HDI regions, followed by lower-middle HDI regions, upper-middle HDI region, and high HDI regions in 2018 (Supplementary Figure S3).

Table 2 and Fig. 2 showed dementia mortality rates and YLLs attributable to high BMI by HDI, sex, and age group from 2005 to 2018. For men in 2018, the high BMI-related dementia mortality rates increased from 0.17 per million people (95% UI, 0.12–0.24) aged 40–44 years to 311.62 per million people (95% UI, 231.05–410.47) aged ≥80 years. For women in 2018, the high BMI-related dementia mortality rates increased from 0.14 per million people (95% UI, 0.10–0.19) aged 40–44 years to 368.79 per million people (95% UI, 261.56–496.51) aged ≥80 years (Table 2). From 2005 to 2018, people aged 80 years and older had the highest attributable YLLs, and the YLLs decreased with decreasing age. The older population, particular those aged 80 years, accounted for the majority of attributable YLLs across the very low HDI, low HDI, lower-middle HDI, upper-middle HDI, high HDI, and very high HDI regions, respectively (Fig. 2). The mortality rates for man were constantly higher than that for woman before 80 years, however, woman aged 80 years and older had substantially higher mortality rates than that for man, resulting in higher all-age mortality rates for woman than that for man. In addition, man showed larger variation than woman in different socioeconomic regions in 2018 (Table 2). The Alzheimer's disease mortality rates attributable to high BMI by HDI, sex, and age group in 2018 were showed in Supplementary Table S5.

Concerning the changes in dementia mortality attributable to high BMI from 2005 to 2018, the attributable deaths increased with population growth and population ageing. There was lower amounts of population growth in regions with low HDI and regions with very low HDI, whereas higher amounts of

	Deaths number (95% UI)		Age standardised deaths per million people (95% UI)		YLL number in thousand (95% UI)		Age standardised YLL per million people (95% UI)	
	2005	2018	2005	2018	2005	2018	2005	2018
All participants	5654 (4580–7040)	12,901 (10,617–15,420)	7.05 (5.70–8.85)	8.81 (7.29–10.49)	79.17 (65.83–95.72)	178.23 (150.08–208.21)	97.77 (81.01–118.80)	124.28 (105.51–144.31)
Very low HDI	158 (87–279)	310 (179–519)	3.50 (1.87–6.30)	4.18 (2.42–6.99)	2.41 (1.50–3.90)	4.66 (2.98–7.18)	51.41 (30.70–86.12)	63.49 (40.91–97.52)
Low HDI	634 (378–982)	1878 (1110–2908)	4.32 (2.54–6.76)	7.83 (4.70–12.06)	9.07 (5.92–13.30)	25.67 (16.37–38.45)	61.22 (39.24–90.46)	109.38 (72.02–162.09)
Lower-middle HDI	1171 (781–1737)	2810 (2036–3833)	6.89 (4.51–10.32)	9.28 (6.75–12.63)	16.51 (11.67–23.45)	39.59 (30.05–52.07)	95.27 (66.03–137.42)	131.99 (100.77–172.68)
Upper-middle HDI	1399 (917–2053)	3454 (2441–4833)	6.10 (3.96–9.04)	8.13 (5.78–11.32)	19.99 (13.85–28.05)	48.00 (35.56–65.24)	85.76 (58.52–121.48)	115.38 (86.57–155.47)
High HDI	1850 (1131–2954)	3271 (2100–5002)	10.49 (6.41–16.74)	9.54 (6.27–14.32)	25.43 (16.59–38.86)	44.40 (29.86–65.24)	144.44 (94.43–220.51)	134.04 (93.17–192.96)
Very high HDI	316 (193–489)	969 (626–1407)	9.20 (5.62–14.26)	12.18 (8.04–17.47)	4.32 (2.79–6.42)	13.02 (8.79–18.41)	125.92 (81.67–187.47)	168.59 (117.57–234.03)
Man participants	1567 (1190–2038)	5417 (4314–6722)	4.62 (3.42–6.13)	8.47 (6.75–10.51)	24.19 (19.45–29.92)	78.88 (65.01–95.06)	68.02 (53.18–86.31)	124.16 (102.49–149.44)
Very low HDI	37 (17–77)	130 (66–233)	1.83 (0.74–4.11)	3.89 (1.93–7.05)	0.64 (0.33–1.14)	2.10 (1.20–3.39)	28.91 (13.73–56.96)	61.76 (35.36–101.49)
Low HDI	165 (87–294)	715 (377–1266)	2.66 (1.30–4.90)	6.77 (3.57–12.02)	2.59 (1.51–4.18)	10.39 (6.12–1.71)	39.42 (21.92–68.08)	99.52 (59.21–163.46)
Lower-middle HDI	337 (210–559)	1248 (829–1766)	4.57 (2.69–8.01)	9.31 (6.13–13.34)	5.18 (3.47–7.84)	18.66 (13.18–24.97)	66.49 (42.66–107.38)	138.47 (96.82–186.36)
Upper-middle HDI	398 (253–611)	1420 (951–2105)	3.96 (2.38–6.32)	7.62 (5.07–11.32)	6.62 (4.62–9.22)	21.12 (15.23–29.43)	61.77 (41.21–89.77)	113.81 (82.14–159.26)
High HDI	462 (239–840)	1335 (744–2252)	6.49 (3.25–12.05)	9.05 (5.13–15.11)	6.90 (4.11–11.56)	18.92 (11.68–29.99)	93.90 (52.98–161.77)	131.23 (83.16–204.14)
Very high HDI	120 (62–228)	466 (264–795)	8.47 (4.30–16.42)	13.63 (7.81–22.93)	1.73 (1.00–3.09)	6.36 (3.84–10.31)	120.28 (67.25–219.73)	189.37 (117.52–300.93)
Woman participants	4053 (3104–5370)	7421 (5591–9609)	8.61 (6.61–11.40)	8.92 (6.79–11.47)	54.59 (42.77–70.72)	98.64 (76.18–125.55)	116.79 (91.85–150.75)	121.66 (95.33–152.99)
Very low HDI	117 (53–236)	173 (80–374)	4.56 (2.00–9.22)	4.20 (2.02–9.00)	1.75 (0.92–3.18)	2.47 (1.33–4.95)	67.38 (35.50–124.05)	61.39 (34.18–120.48)
Low HDI	467 (233–787)	1103 (512–2112)	5.45 (2.75–9.14)	8.19 (3.98–15.37)	6.44 (3.57–10.35)	14.68 (7.52–26.88)	76.04 (42.40–121.02)	111.61 (59.89–199.66)
Lower-middle HDI	829 (464–1358)	1550 (936–2473)	8.36 (4.68–13.72)	9.05 (5.55–14.30)	11.31 (6.75–17.80)	20.88 (13.33–32.13)	113.93 (67.95–179.68)	123.96 (80.84–188.09)
Upper-middle HDI	990 (562–1630)	1996 (1160–3253)	7.43 (4.22–12.23)	8.27 (4.90–13.29)	13.28 (8.05–21.13)	26.53 (16.35–41.77)	99.86 (60.60–158.80)	112.79 (71.85–174.60)
High HDI	1365 (719–2459)	1888 (946–3493)	12.81 (6.86–22.83)	9.63 (5.10–17.31)	18.09 (9.97–31.34)	24.97 (13.52–44.51)	173.08 (97.55–294.27)	131.13 (75.76–224.65)
Very high HDI	191 (98–344)	483 (263–816)	9.32 (4.80–16.73)	10.62 (6.02–17.59)	24.97 (1.37–4.40)	6.39 (3.69–10.52)	122.82 (68.40–215.49)	147.95 (90.21–234.58)

UI, uncertainty interval; YLL, year of life lost; HDI, human development index.

Table 1: **Dementia mortality rate and YLL rate due to high body mass index by region and sex, in 2005 and 2018.**

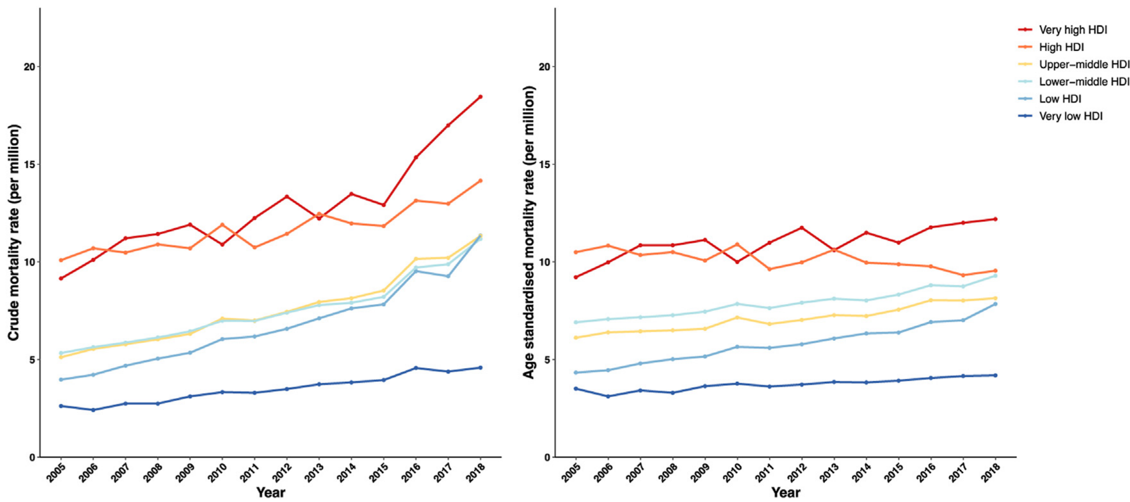

Fig. 1: Mortality rates of dementia attributable to high body mass index in China by HDI from 2005 to 2018.

population growth in regions with very high HDI. In regions with high HDI, with substantial negative risk deleted deaths, there was a relative slight increase (Fig. 3). As shown in Supplementary Figure S5, man had higher high BMI exposure in the changes between 2005 and 2018.

Discussion

With 1.25 million adults, we estimated the deaths, mortality rates, YLLs, and YLL rates for dementia attributable to high BMI and presented the differences in the key outcome indicators among different socio-economic regions between 2005 and 2018. This analysis also allowed comparisons of dementia mortality burden related to high BMI over time across age groups and sexes. In this study, we found deaths and YLLs for dementia attributable to high BMI increased sharply in China from 2005 to 2018, regardless of sex, age, and regions. There were minor disparities in the mortality and YLL rates for high BMI-related dementia between man and woman. People at higher HDI regions were at generally heavier mortality burden.

Similar with the results of previous studies,[9,11] a 2.3-fold increase in the death number for dementia attributable to high BMI was identified in China from 2005 to 2018 in this study. This rapid increase in China could be partly explained by the Chinese population growth and population ageing. In our study, the burden for dementia attributable to high BMI was substantially greater at ages over 80 years, and the decomposition analysis also suggested an important role in population growth and population ageing. With the world's largest number of people and a rapid increase in the proportion of older people,[22] China seems to have an enormous increase in the prevalence of dementia related mortality attributable to high BMI in the next decades. In 2022, the Chinese Government actively responded to population ageing by integrating the concept of healthy ageing into the economic and social development processes.[23] Therefore, continuous attention to the high BMI-related dementia burden of the older population can help provide information for the path to healthy ageing in China.[22] Another possible reason for the rapid increase is the conflict between irreversible cognitive function of dementia and the treatment-oriented medical status in China. Dementia is a chronic disease, which causes almost irreversible cognitive decline, affects day-to-day decision making, and takes up a lot of health care resources. For this, prevention is more important. Although China has tried to shift the focus of the health-care principle from treatment first to prevention first,[24] due to poorly functioning primary health care system, the health-care delivery system continues to be hospital-centric and treatment-based,[7] which couldn't curb the increase prevalence of dementia. What's more, the rapid increase in BMI level in China also contributed a lot. Previous studies have suggested an increase in total calorie intake[25] and physical inactivity[26] in the Chinese population throughout the study period. As people were exposed to increasing total calorie intake and physical inactivity, they were at increased risk of being obesity, offering potential reasons for the heavier high BMI-related mortality burden in Chinese adults. Furthermore, due to widespread poverty in China decades ago, the traditional perception of obesity as prosperity and health still exists. The low self-awareness of obesity-related serious potential consequences creates a blame culture that lends to therapeutic inertia, which could further hinder implementation of obesity prevention in a timely and effective manner.[27]

	China	Very low HDI	Low HDI	Lower-middle HDI	Upper-middle HDI	High HDI	Very high HDI
All							
40–44	0.16 (0.12–0.20)	0.10 (0.05–0.19)	0.18 (0.09–0.32)	0.16 (0.10–0.24)	0.16 (0.09–0.24)	0.16 (0.09–0.26)	0.02 (0.00–0.05)
45–49	0.27 (0.19–0.38)	0.16 (0.06–0.32)	0.03 (0.01–0.07)	0.06 (0.03–0.09)	0.57 (0.33–0.88)	0.28 (0.14–0.48)	0.44 (0.16–0.85)
50–54	0.47 (0.39–0.58)	0.47 (0.19–0.95)	0.48 (0.22–0.88)	0.36 (0.25–0.50)	0.40 (0.27–0.53)	0.62 (0.38–0.96)	0.70 (0.41–1.12)
55–59	0.71 (0.57–0.85)	0.77 (0.39–1.26)	0.88 (0.49–1.47)	0.80 (0.55–1.13)	0.71 (0.47–0.99)	0.27 (0.11–0.52)	1.21 (0.65–1.93)
60–64	2.90 (2.35–3.57)	1.69 (0.85–3.07)	2.75 (1.66–4.11)	3.08 (2.10–4.41)	2.72 (1.73–4.22)	3.23 (1.95–4.99)	2.73 (1.64–3.95)
65–69	5.10 (4.15–6.09)	3.75 (1.97–6.25)	3.88 (2.31–6.03)	5.95 (3.98–8.48)	4.21 (2.91–5.63)	6.19 (3.80–8.99)	7.34 (4.66–10.74)
70–74	15.61 (13.04–18.46)	11.47 (5.38–20.40)	11.44 (6.64–17.77)	20.22 (13.81–27.51)	14.09 (10.01–19.08)	16.43 (10.13–23.67)	18.08 (11.32–27.12)
75–79	36.78 (29.86–43.67)	22.17 (10.59–39.41)	30.66 (18.45–47.28)	45.63 (31.80–62.89)	32.40 (22.38–44.82)	38.67 (22.18–58.44)	43.56 (26.96–63.76)
≥80	346.59 (272.88–430.63)	144.43 (60.02–281.19)	314.93 (158.05–522.20)	349.22 (228.75–512.32)	321.38 (205.58–477.45)	374.40 (215.15–620.64)	494.15 (291.33–761.84)
All ages	12.03 (9.90–14.37)	4.59 (2.65–7.69)	11.35 (6.71–17.57)	11.18 (8.10–15.25)	11.33 (8.01–15.85)	14.16 (9.09–21.65)	18.46 (11.92–26.80)
Man							
40–44	0.17 (0.12–0.24)	0.16 (0.06–0.30)	0.25 (0.10–0.51)	0.14 (0.05–0.26)	0.10 (0.04–0.21)	0.26 (0.12–0.45)	0.00 (0.00–0.00)
45–49	0.42 (0.27–0.62)	0.29 (0.10–0.60)	0.06 (0.01–0.14)	0.07 (0.03–0.12)	0.91 (0.44–1.54)	0.48 (0.21–0.85)	0.06 (0.02–0.13)
50–54	0.67 (0.53–0.88)	0.91 (0.36–1.84)	0.75 (0.30–1.48)	0.39 (0.22–0.62)	0.46 (0.27–0.69)	0.98 (0.54–1.66)	1.21 (0.68–1.99)
55–59	1.01 (0.76–1.27)	0.71 (0.24–1.51)	1.26 (0.58–2.27)	1.20 (0.71–1.77)	0.93 (0.53–1.42)	0.51 (0.20–1.00)	1.77 (0.81–3.09)
60–64	3.47 (2.56–4.66)	1.21 (0.48–2.50)	2.93 (1.35–5.41)	4.13 (2.37–6.59)	3.69 (1.93–6.47)	3.24 (1.56–5.56)	2.16 (0.85–3.95)
65–69	6.04 (4.65–7.82)	4.33 (1.60–8.70)	3.93 (1.84–7.28)	7.72 (4.34–12.43)	5.39 (3.29–7.99)	6.51 (3.16–11.27)	8.46 (4.19–14.17)
70–74	18.28 (14.09–22.76)	11.26 (3.64–24.97)	11.47 (5.55–21.76)	26.76 (16.12–40.05)	16.02 (9.71–24.75)	17.84 (9.02–29.90)	22.45 (10.28–37.65)
75–79	42.20 (32.22–54.71)	24.32 (8.10–55.09)	31.19 (14.22–58.95)	52.94 (30.42–84.72)	39.12 (23.17–61.30)	41.13 (17.95–71.44)	53.73 (26.37–91.92)
≥80	311.62 (231.05–410.47)	121.18 (33.99–283.88)	252.33 (101.99–517.57)	326.18 (172.93–519.35)	275.74 (149.60–461.33)	341.30 (148.52–635.01)	539.75 (260.89–999.14)
All ages	10.03 (7.99–12.44)	3.77 (1.91–6.76)	8.63 (4.55–15.29)	9.98 (6.64–14.13)	9.23 (6.19–13.69)	11.41 (6.36–19.25)	0.00 (0.00–0.00)
Woman							
40–44	0.14 (0.10–0.19)	0.04 (0.01–0.10)	0.10 (0.03–0.21)	0.19 (0.10–0.29)	0.21 (0.10–0.37)	0.06 (0.02–0.11)	0.04 (0.01–0.11)
45–49	0.13 (0.08–0.18)	0.03 (0.01–0.07)	0.00 (0.00–0.00)	0.04 (0.02–0.09)	0.22 (0.11–0.36)	0.07 (0.02–0.18)	0.86 (0.24–1.73)
50–54	0.26 (0.19–0.34)	0.00 (0.00–0.00)	0.18 (0.04–0.40)	0.33 (0.20–0.48)	0.32 (0.18–0.49)	0.23 (0.09–0.44)	0.13 (0.02–0.33)
55–59	0.40 (0.28–0.53)	0.78 (0.30–1.51)	0.46 (0.16–1.01)	0.40 (0.18–0.68)	0.47 (0.28–0.74)	0.02 (0.00–0.05)	0.62 (0.25–1.11)
60–64	2.31 (1.73–2.94)	2.04 (0.79–4.50)	2.40 (1.27–4.24)	2.00 (1.20–3.05)	1.66 (0.96–2.47)	3.12 (1.31–5.70)	3.20 (1.68–5.09)
65–69	4.09 (3.14–5.28)	3.04 (1.31–5.98)	3.67 (1.55–6.81)	4.20 (2.20–6.94)	2.90 (1.78–4.44)	5.69 (2.89–9.41)	6.19 (3.17–10.26)
70–74	12.98 (10.21–16.17)	10.82 (4.02–21.91)	10.73 (4.51–19.34)	13.65 (8.82–19.98)	12.14 (7.50–17.61)	14.57 (7.38–24.54)	14.11 (7.31–23.72)
75–79	31.71 (24.27–39.92)	18.57 (6.14–38.98)	29.58 (14.72–49.91)	38.57 (22.99–59.54)	25.37 (15.05–38.89)	35.25 (17.02–61.39)	33.45 (16.76–55.31)
≥80	368.79 (261.56–496.51)	151.40 (45.20–378.42)	338.10 (124.39–702.54)	363.33 (193.47–633.38)	346.12 (179.76–604.22)	389.26 (171.87–773.31)	434.63 (204.20–775.00)
All ages	13.93 (10.50–18.04)	5.23 (2.43–11.35)	13.34 (6.20–25.55)	12.26 (7.40–19.57)	13.21 (7.68–21.53)	16.56 (8.29–30.63)	18.99 (10.36–32.12)

HDI, human development index. Although there were evidences from GBD studies to support the association between high body mass index and dementia in people aged 20–39 years, no deaths from dementia have been detected in people aged 20–39 years in China.

Table 2: **Dementia mortality rates due to high body mass index by HDI, sex, and age group in 2018, per million people.**

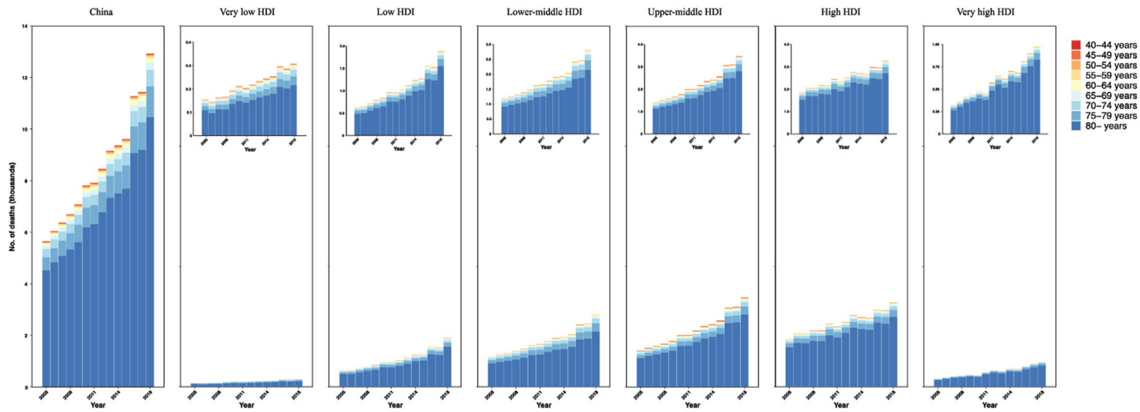

Fig. 2: YLLs of dementia attributable to high body mass index in China by HDI and age group from 2005 to 2018. HDI, human development index; YLL, year of list lost. For regions of different economic development, the upper and lower pictures are consistent, only without the vertical axis.

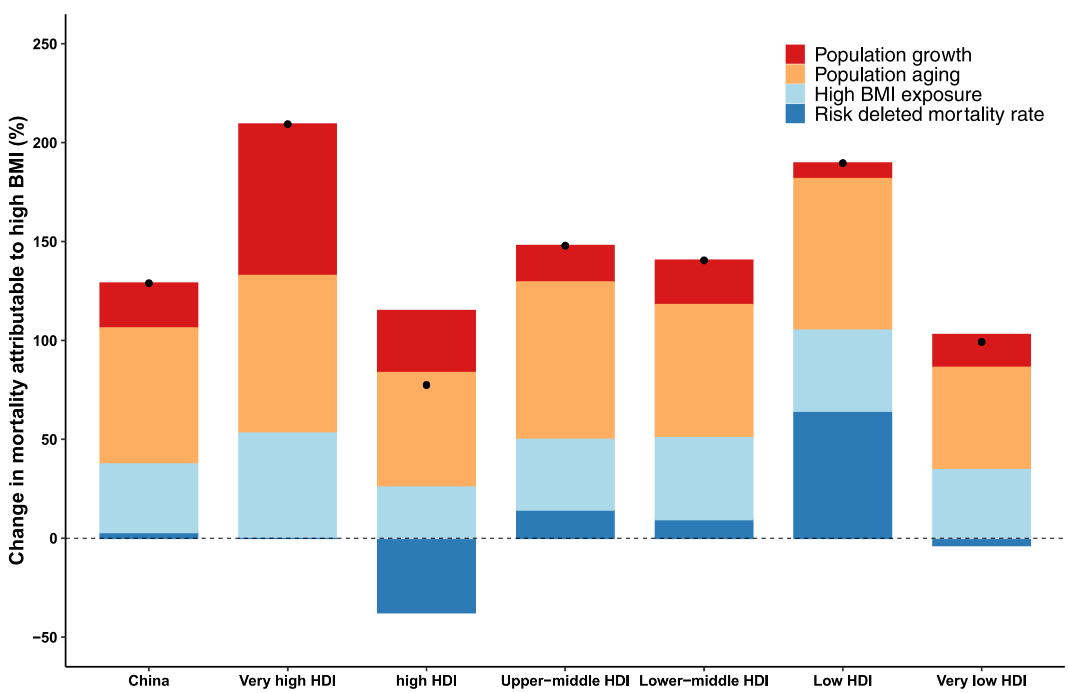

Fig. 3: Changes in dementia mortality attributable to high body mass index from 2005 to 2018 by HDI regions in China, according to the contributions of population growth, population ageing, risk-deleted mortality rate, and BMI exposure. Black dots indicate overall change in mortality.

Although there were minor disparities in the mortality and YLL rates for high BMI-related dementia between man and woman, we identified significant disparities in two domains. First, the mortality rates for man were constantly higher than that for woman before 80 years, however, people aged 80 years and older had substantially higher mortality rates for woman than that for man. Second, man showed larger variation than woman in different HDI regions. These imply the sex-equitable implementation of programmes for the prevention of dementia should still be encouraged. Furthermore, dementia mortality has become a common health issue for all older people. Older people, at higher risk of dementia, tend to use long-term care, which adds to private and public financial and instrumental care burdens.[22] The absence of coordinated investments in care for the older people in China suggests that the economic and social challenges associated with population ageing could be greater for China than other countries.[22] In this situation, the prospect of healthy ageing provides supports to reducing mortality and improving the health of older people, and evaluating dementia burden and trends attributable to high BMI, which can shed light on assess the healthy ageing in the future.

People at higher HDI regions were at generally heavier mortality burden for dementia attributable to high BMI, and the disparities between regions with very high HDI and regions with very low HDI were getting wider. It could partly because that life expectancy in less developed regions is lower, so that dementia mortality, which usually occurs at later life stages, is not as prevalent in low socioeconomic development regions due to higher early-old age mortality. In our decomposition analysis, we noticed regions with very high HDI had the highest population growth of any other regions; however, with the second highest population growth, regions with high HDI showed a decline in the age standardised mortality rates and age standardised YLL rates from 2005 to 2018. One possible explanation for this is that regions with high HDI provide sufficient health care for their growing population. Previous study showed people could get high universal health coverage (ranging from 74% to 84%) in high HDI region in 2018, compared with relative low universal health coverage (ranging from 43% to 63%) in 2003.[28] Underpinning such progress was their strong commitment to long-term strategies and efforts to ensure equitable coverage with financial protection for all, which can be learned by other regions. What's more, we noticed that severe underdiagnosis was more common in low- and middle-income countries, suggesting there were more underdiagnosis in low HDI regions than in high HDI regions in China, which further supported large socioeconomic disparities in the attributable dementia burden.[29] Given the importance of government financial engagement in dementia prevention and the fiscal capacity of subnational government, national-level policies are needed to support the lower-income region to better prevent and care dementia among older people, such as establishing a national public health infrastructure.

Although we didn't assess the effect of other risk factors on dementia, there was an evidence that people with more education had a lower prevalence of mild cognitive impairment and Alzheimer's disease, with the highest prevalence in illiterate individuals, followed by those educated to a primary school level (20.1%), and those with high school education (8.0%).[2] Apart from that, unmarried people and rural residents also showed a higher incidence of dementia.[2,30] It illustrated with respect to reducing the attributable dementia burden of China's future older population, increases in educational attainment and more attention in vulnerable people may contribute to improvements in incidence and mortality of dementia.

To the best of our knowledge, this is the first comprehensive study to systematically report the dementia mortality burden attributable to high BMI by age, sex, and region from 2005 to 2018 in China, and discuss the impact of socioeconomic status, population growth, and population ageing on it. We identified the most vulnerable groups using 1.25 million Chinese adults, for which additional targeted interventions were required. The results could be valuable for improving dementia management and shed light on assess the healthy ageing in the future in China, as well as in other countries or regions with similar condition.

This study also has a few limitations. First, we did not classify other risk factors and specific dementia except Alzheimer's disease due to limited data. Second, previous study showed that 71.4% of dementia was underdiagnosed in China, which suggested heavier dementia burden than what we estimated.[2] Third, we assigned socioeconomic development only using the HDI which might affect the assessment of socioeconomic inequalities. Fourth, this study extracted RRs from the GBD 2019 study, which are assumed to be constant across age groups, regions, and years; however, RRs are expected to vary in different subgroups. Fifth, the assumptions underlying PAF estimation, including no unmeasured confounding and other risk factors unaffected by exposure removal, are difficult to assess in reality. Sixth, the reported UI only takes into account the RRs and the theoretical minimum risk exposure level, which affect the accuracy. Seventh, a relatively small number of remote and economically deprived areas covered by data collection from the Disease Surveillance Point system resulted in unstable cause-specific mortality estimates in some provinces, which may have negatively affected the estimation accuracy.

The rapid increase and large inequality in dementia burden attributable to high BMI highlighted the urgent need for evidence-based policies and interventions in China. We therefore call for establishing stronger anti-dementia strategies, which should include national-level policies to support the lower-income region to better prevent and care dementia among older people, controlling prevalence of obesity and other risk factors to attenuate dementia onset, improving management of patients with dementia, optimising a dementia nursing system, and increasing public awareness of dementia.

Contributors
ZW and MZhou contributed to the conception and design of the study. YT conducted the data analysis and prepared the first draft. YT and ZW directly accessed and verified the underlying data reported in the manuscript. ZZ, YK, LW, PY, YS, XW, CZ, ZW, and MZhou were involved in data preparation. YT, XC, and YK evaluated the exposure levels of BMI. YT, ZZ, XC, YK, and ZW performed the statistical analysis and data interpretation. ZZ, YF, MZhang, YH, ZH, JC, RG, XP, XY, MZhou, and ZW participated in data interpretation and provided important comments on the manuscript. WZ and MZhou helped to

improve this manuscript. All authors confirmed that they had full access to all the data in the study and accept responsibility to submit for publication.

Data sharing statement
The data used for the analyses are available with publication by email request to the corresponding author.

Declaration of interests
We declare no competing interests.

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Appendix A. Supplementary data
Supplementary data related to this article can be found at https://doi.org/10.1016/j.lanwpc.2023.100862.

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