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RESEARCH ARTICLE

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The burden of diseases attributable to high body mass index in Asia from 1990 - 2019: results from the global burden of disease study 2019

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ABSTRACT

Aim: Our study aimed to report the burden of diseases attributable to high body mass index (BMI) in Asia from 1990 to 2019.

Methods: Utilizing data from the Global Burden of Disease (GBD) Study 2019, we calculated disability-adjusted life years (DALYs) and deaths, with trends quantified by the estimated annual percentage change (EAPC). We also made projections for selected countries and estimated the relationship between the Sociodemographic Index (SDI) and high BMI-related disease burden.

Result: From 1990 to 2019, high BMI-related diseases observed significant increases in the absolute number of deaths and DALYs, with EAPCs of 4.62 and 4.69, respectively, while the age-standardized rates of both deaths and DALYs also showed upward trends, with EAPCs of 1.39 and 1.80. Cardiovascular diseases, diabetes and kidney diseases, and neoplasms were the major contributors to the high BMI-related burden. The burden of high BMI-related diseases generally tended to be greater among males and older age groups. Predictions for selected countries indicated a continued rise in the number of deaths and DALYs for high BMI-related diseases, with a stabilization in the age-standardized rate. There was no significant association between SDI levels and the burden of high BMI-related diseases in Asia (coefficient=0.13, $p = 0.39$).

Conclusion: The burden of high BMI-related diseases, a major public health issue, was increasing in Asia. To address this problem, coordinated action by governments, civil society and other key stakeholders should be taken to enhance awareness of the risks associated with high BMI and effectively reduce its impact.

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The global burden of diseases (GBD 2019); high body mass index; disability adjusted life year; mortality; Asia

Introduction

High body mass index (BMI), as a risk factor for a range of chronic diseases, including cardiovascular disease, diabetes and kidney diseases, various neoplasms and so on, was increasing worldwide, becoming one of the largest increases in risk exposure during the past 3 decades [1–4]. The burden of these diseases not only encompassed the direct impact on individual health and quality of life but also carried significant socioeconomic implications due to increased healthcare costs and lost productivity. However, despite being a critical issue requiring immediate attention and a modifiable behavioral factor, there was no effective management of high BMI within current health system. In Asia, the prevalence of high BMI has been on an upward trajectory, paralleling the region's rapid economic development, urbanization, and lifestyle transitions.

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The adoption of Western diets and sedentary behaviors, fueled by globalization and urbanization, significantly contributing to the obesity epidemic in Asia [5]. This epidemiological shift warrants a comprehensive assessment to inform public health strategies and resource allocation.

As a comprehensive international effort, the Global Burden of Disease (GBD) Study 2019 provides an extensive database, which includes disability-adjusted life years (DALYs) and mortality data for diseases attributable to high BMI across age, sex, and geography over the past 30 years. Several studies have reported the global burden of a series of high BMI-related diseases or focused on specific diseases attributed to high BMI [1–3,6]. For instance, Yuhan's study utilized the GBD 2019 dataset to estimate the global burden of diseases attributable to high BMI, identifying the highest age-standardized DALY and mortality rates in the Central Asia region [6]. Xing's research examined the global burden of cancer linked to high BMI, revealing that East Asia suffered the greatest burden of cancer attributable to high BMI [3]. However, a detailed and collective study on the entire burden of high BMI-related diseases in Asia remains lacking. To fill the gap, we aimed to estimate the burden of high BMI-related diseases at age, sex, year, and country level in Asia from 1990 to 2019. We also made a prediction in 3 selected countries and analysis the association between high BMI-related diseases burden and the Sociodemographic Index (SDI).

Methods

Data sources

The data source in this study was extracted from the Global Health Data Exchange query tool (VizHub - GBD Results (healthdata.org)), with data downloaded at the sex, age, year, and country levels. GBD 2019 synthesizes an extensive and expanding array of data input sources, encompassing censuses, surveys, civil registration, vital statistics, disease registries, health service use, and diverse health-related datasets, which are accessible through an interactive citation tool available in the GHDx (Global Health Data Exchange) at http://ghdx.healthdata.org/gbd-2019/data-input-sources. GBD 2019 estimated health loss, covering 369 diseases and injuries, along with 87 risk factors across 204 countries and territories globally, with a description of the foundational methods provided on the official website (Global Burden of Disease (GBD) | Institute for Health Metrics and Evaluation (healthdata.org)). The 95% uncertainty intervals (UI) were computed utilizing the GBD 2019 global age-standardized population, with population predictions acquired from the World Population Prospects 2017 Revision.

Definitions

High BMI was considered as BMI >25 kg/m^2 in adults aged 20 years and older, with thresholds based on the International Obesity Task Force standards applied to individuals aged 1–19 years [2]. Disability-adjusted life years (DALYs) are calculated as the sum of years of life lost (YLLs) due to premature death and years lived with disability (YLDs), reflecting the gap between the actual health condition of the population and an optimal state of complete health, where one DALY represents the loss of one year of full health.

The Sociodemographic Index (SDI), used as a comprehensive measure of development status, was calculated from factors including educational attainment in individuals over 15 years old, the fertility rate in women under 25 years old, and lag-distributed income per capita [7].

Statistical analysis

The estimated annual percentage changes (EAPCs), used to illustrate long-term trends, were calculated by a regression model using the formula $y=\alpha+\beta x+\varepsilon$, where 'x' denotes the calendar year and 'y' represents the natural logarithm (ln) of the rate of disease; the EAPCs were then calculated using the equation EAPC $= 100\times[\exp(\beta) - 1]$, with its 95% UI established by the regression model. Specifically, an EAPC value greater than 0, accompanied by a 95% UI that also remains above 0, signals an increasing trend in disease burden. Conversely, an EAPC less than 0, with its 95% UI also below 0, indicates a decreasing trend. A log-linear age-period-cohort analysis was applied to forecast the burden of high BMI-related diseases over the next 25 years, utilizing the NORDPRED package in R based on recent trend data. The statistical analyses were performed with the R program (version 4.1.3, R core team). Results were considered statistically significant if the P value was less than 0.05.

This study employed Spearman's rank correlation analysis to investigate the relationship between SDI and ASR. To minimize the risk of false positive results due to multiple comparisons, the Benjamini-Hochberg method was applied to adjust the false discovery rate (FDR < 0.05). Additionally, locally weighted scatterplot smoothing (LOWESS) was used to model the nonlinear trend in the data, providing a deeper understanding of the complex interaction between SDI and disease burden.

Results

The burden of diseases attributable to high BMI in Asia

Between 1990 and 2019, the age-standardized rates of DALYs in high BMI-related diseases observed a significant increase, rising from 973.39 (95% UI: 381.21-1832.68) per 100,000 population in 1990 to 1606.54 (95% UI: 969.72-2339.04) in 2019, by an average of 1.8 (95% UI: −1.76-1.84). This upward trend was paralleled by an increase in the age-standardized death rates for high BMI-related diseases, escalating from 33.59 (95% UI: 12.6-64.88) per 100,000 population in 1990 to 49.51 (95% UI: 28.28-75.85) in 2019, with the EAPC being 1.39 (95% UI: 1.35-1.43) (Figure 1; Table 1; Supplementary Table 1). Among these diseases, pancreatic cancer exhibited the fastest growth DALY rates, with an EAPC of 3.68 (95% UI: 3.61-3.76). Despite the overarching trend of escalating disease burden, the age-standardized rates of DALYs for liver cancer, subarachnoid hemorrhage, and asthma exhibited a decline (Supplementary Tables 2 and 3).

By 2019, high BMI emerged as the seventh most significant risk factor for disease DALYs in Asia, marking a significant rise from its thirteenth-place ranking in 1990 among all level 2 GBD risk factor

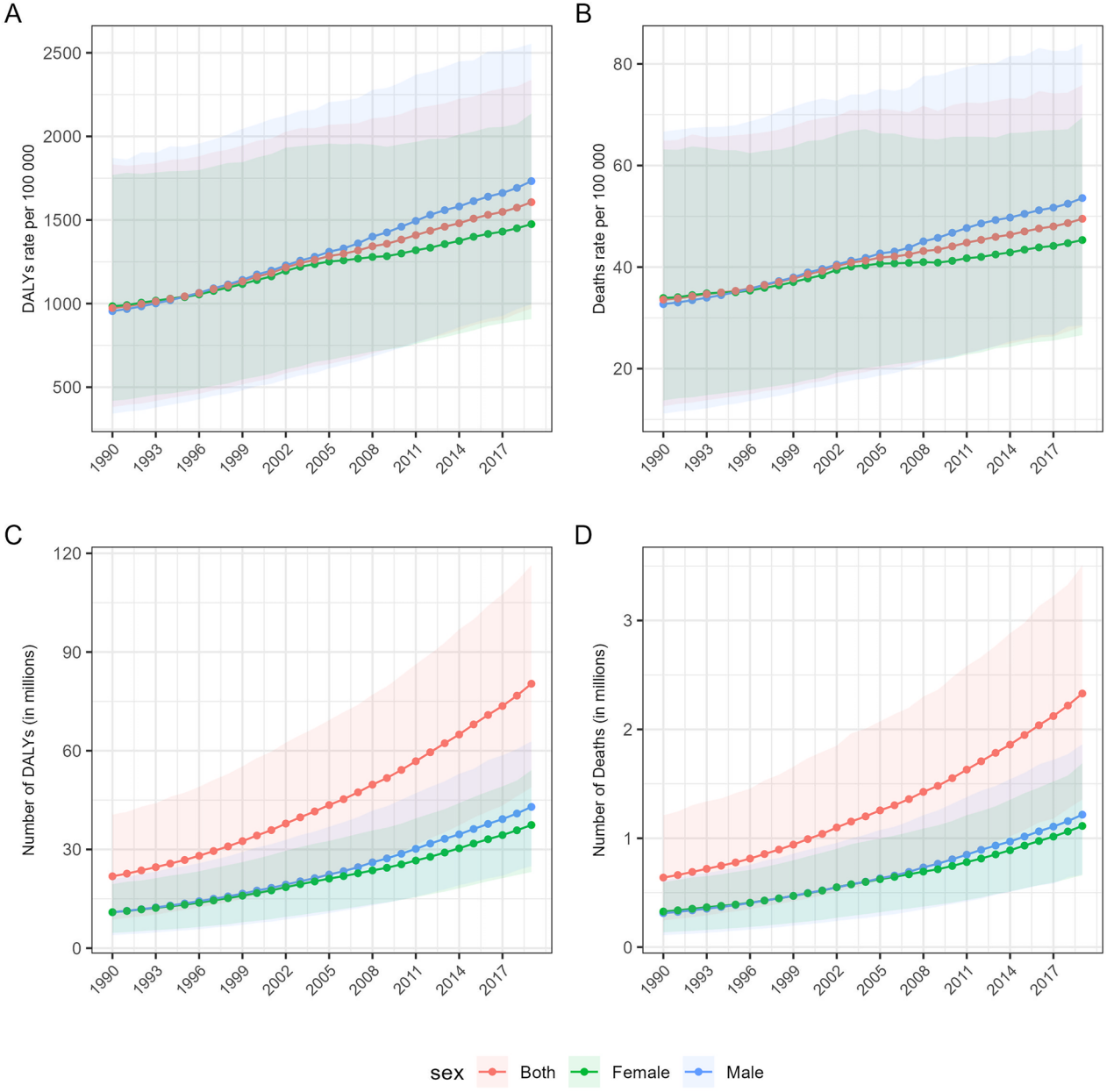

Figure 1. Age-standardized rates and numbers of DALYs and deaths due to high body mass index in Asia for females, males and both sexes combined. DALYs, disability-adjusted life years.

Table 1. Numbers and age-standardized rates of disability-adjusted life-years due to high body mass index in Asia from 1990 to 2019, with EAPC from 1990 to 2019.

	Age-standardized rates of DALYs per 100 000 people (95% UI)			Numbers of DALYs (95% UI)		
	1990	2019	EAPC	1990	2019	EAPC
Overall						
Both	973.39 (381.21–1832.68)	1606.54 (969.72–2339.04)	1.8 (1.76–1.84)	21836993.33 (8644567.59–40589801.76)	80359966.96 (48859112.28–116400548.66)	4.69 (4.65–4.72)
Female	984.41 (419.01–1769.29)	1475.33 (907.46–2136.86)	1.43 (1.37–1.49)	10932536.52 (4673454.33–19451266.89)	37430372.97 (23133110.41–54089891.17)	4.39 (4.34–4.44)
Male	955.1 (341.55–1871.41)	1732.67 (996.2–2554.3)	2.16 (2.13–2.19)	10904456.81 (3967199.24–21079606.93)	42929593.99 (24979475.15–62829257.79)	4.96 (4.91–5)
Cardiovascular diseases						
Both	624.45 (240.14–1183.57)	915.06 (538.02–1343.69)	1.41 (1.37–1.45)	14098840.25 (5505735.96–26438728.55)	45838602.24 (27225796.05–66751858.56)	4.27 (4.22–4.32)
Female	608.34 (251.33–1097.81)	771.07 (467.22–1145.32)	0.83 (0.77–0.89)	6777770.77 (2822677.39–12128705.98)	19537947.31 (11892103.67–28968865.95)	3.75 (3.69–3.8)
Male	635.21 (225.54–1246.05)	1056.41 (593.52–1584.17)	1.92 (1.87–1.98)	7321069.48 (2648076.6–14164710.52)	26300654.93 (14935129.8–38901709.79)	4.7 (4.63–4.77)
Diabetes and kidney diseases						
Both	182.36 (80.62–322.64)	442.58 (286.4–615.29)	3.16 (3.08–3.25)	4134426.8 (1839423.01–7318869.51)	22373170.18 (14537184.34–30978212.56)	6.09 (6.01–6.17)
Female	197.8 (93.38–336.42)	444.02 (298–609.11)	2.9 (2.79–3.01)	2227759.25 (1060193.98–3796588.56)	11360140.77 (7644766.01–15537257.03)	5.89 (5.79–5.98)
Male	166.95 (66.27–311.55)	440.57 (271.01–628.46)	3.45 (3.38–3.51)	1906667.56 (775823.9–3534793.73)	11013029.41 (6820361.25–15720278)	6.31 (6.25–6.37)
Neoplasms						
Both	68.64 (21.57–148.7)	102.88 (50.79–173.33)	1.14 (1.02–1.26)	1530694.8 (480902.86–3324100.53)	5162960.99 (2559181.76–8662507.25)	4.02 (3.92–4.12)
Female	60.52 (20.89–130.47)	88.2 (44.89–147.04)	1.2 (1.07–1.32)	660376.64 (227448.93–1430622.02)	2263764.71 (1156245.6–3777212.95)	4.26 (4.17–4.35)
Male	76.35 (19.89–174.62)	118 (51.15–217.26)	1.13 (0.98–1.28)	870318.15 (226354.67–2010841.78)	2899196.28 (1267311.54–5310620.95)	3.85 (3.7–3.99)
Musculoskeletal disorders						
Both	32.43 (10.36–69.41)	59.79 (27.25–108.03)	2.37 (2.29–2.46)	763689.73 (242195.09–1634745.18)	3013942.84 (1374757.11–5448771.06)	5.14 (5.04–5.24)
Female	40.25 (13.17–84.78)	70.33 (32.55–129.31)	2.19 (2.11–2.27)	468385.66 (152639.12–981931.58)	1793824.79 (829167.63–3305007.4)	5.05 (4.95–5.15)
Male	24.5 (7.43–54.91)	48.82 (21.8–90.09)	2.64 (2.55–2.73)	295304.07 (89890.61–652619.28)	1220118.05 (545701.07–2236053.68)	5.29 (5.19–5.39)
Chronic respiratory diseases						
Both	34.79 (12.62–71.16)	36.44 (19.27–59.92)	−0.03 (−0.11–0.06)	779061.39 (293377.88–1565681.08)	1770523.07 (932105.18–2918433.25)	2.72 (2.64–2.8)
Female	37.45 (13.87–78.3)	38.87 (19.89–65.97)	−0.05 (−0.13–0.03)	424095.21 (162969.42–864457.63)	964387.98 (491634.51–1647517.82)	2.73 (2.65–2.8)
Male	32.22 (10.73–73.94)	33.87 (16.79–59.14)	−0.03 (−0.13–0.08)	354966.18 (125168.04–790255.85)	806135.09 (400839.14–1408610.08)	2.71 (2.61–2.81)
Neurological disorders						
Both	15.04 (2.59–47.42)	27.52 (6.05–75.87)	2.2 (2.15–2.25)	192161.07 (33347.35–598275.98)	1112157.58 (247805.49–3113829.44)	6.36 (6.31–6.41)
Female	17.76 (2.69–59.29)	31.33 (5.61–93.08)	2.05 (2–2.09)	128277.27 (19012.39–426270.06)	718323.9 (128009.59–2140779.43)	6.23 (6.19–6.27)
Male	11.08 (1.23–35.47)	22.32 (3.26–65.31)	2.6 (2.54–2.66)	63883.8 (7159.02–213141.37)	393833.68 (60027.82–1166485.45)	6.62 (6.55–6.68)
Digestive diseases						
Both	12.84 (4.3–27.72)	17.44 (8.6–31.12)	1.13 (1.01–1.24)	285963.97 (94924.74–625156.36)	860305.23 (426572.7–1538515.14)	3.98 (3.86–4.11)
Female	18.83 (6.46–39.85)	25.66 (12.85–45.63)	1.16 (1.05–1.28)	212564.41 (72068.31–456906.57)	647266.21 (326371.35–1151156.97)	4.06 (3.93–4.19)
Male	6.64 (1.76–16.06)	8.95 (3.73–17.4)	1.01 (0.9–1.13)	73399.56 (19405.35–178489.77)	213039.02 (90092.94–412849.61)	3.75 (3.62–3.89)
Sense organ diseases						
Both	2.83 (0.81–6.69)	4.84 (2.01–9.45)	2.18 (2.05–2.31)	52155.31 (15506.61–122100.23)	228304.83 (95823.72–444918.74)	5.55 (5.43–5.67)
Female	3.44 (0.94–8.32)	5.84 (2.02–12)	2.19 (2.03–2.34)	33307.3 (9093.55–79592.69)	144717.3 (50283.06–297492.61)	5.56 (5.42–5.71)
Male	2.14 (0.52–5.46)	3.73 (1.37–7.72)	2.19 (2.09–2.28)	18848.01 (4733.24–47533.81)	83587.53 (30677.26–172924.24)	5.53 (5.45–5.62)

(Supplementary Figure 1). As major contributors to high BMI-related DALYs, cardiovascular diseases (56.96%), diabetes and kidney diseases (27.55%), and neoplasms (6.40%), remained the top three health concerns from 1990 to 2019 among level 2 GBD diseases associated with high BMI. Within level 3 GBD diseases related to high BMI, stroke (25.59%), ischemic heart disease (25.22%), and diabetes mellitus (20.87%)

were ranked as the leading conditions contributing to disease DALYs, with ischemic heart disease (30.67%) being the major component of high BMI-associated deaths (Figure 2; Supplementary Figures 2 and 3).

The burden of diseases attributable to high BMI by sex and age

As shown in Figure 3, the burden of diseases increased with age, peaked at the 55–59 age range in terms of DALYs and the 65–69 age group for deaths, before both metrics exhibited a subsequent decline. With high BMI correlated exclusively with DALYs attributable to asthma for children under 20 years of age, cardiovascular diseases accounted for the largest proportion of the burden in both DALYs and deaths across nearly all age groups, followed by diabetes and kidney diseases. Notably, While cardiovascular diseases began to manifest among young adolescents, neurological disorders showed a higher burden among the older age groups, especially for 80-89 age groups.

In 2019, the age-standardize rates of DALYs [1732.67 per 100,000 population (95% UI: 996.2-2554.3) in males vs 1475.33 per 100,000 population (95% UI: 907.46-2136.86) in females]and deaths [53.59 per 100,000 population (95% UI: 28.57-83.97) in males vs 45.33 per 100,000 population (95% UI: 26.6-69.46) in females] were higher in males than in females. This trend could be attributed to the more pronounced escalation in males compared to females, both in the number and age-standardized rates of DALYs and deaths (Figure 1; Table 1; Supplementary Table 1). Within the top three major contributors to high BMI-related burden, cardiovascular diseases and neoplasms are more prevalent in males, while digestive diseases and neurological disorders are more pronounced in females. Specifically, the number of DALYs due to high BMI-related digestive diseases in females was almost triple that in males (Figure 4; Table 1, Supplementary Table 1).

The percentage contribution of high BMI-related diseases across age groups and gender disparities was shown in Figure 5. Males under the age of 50-54 years exhibited a higher DALY percentage attributable to high BMI-related diseases compared with females. Beyond this age, the trend reversed, with females surpassing males and maintaining a higher percentage of DALYs impact as age advances. The trend shift is mirrored in mortality, with females exceeding males in high BMI-related deaths starting at the 40-44 age group. Both genders showed increasing trends in younger to middle age, with a subsequent decline in the oldest cohorts.

The burden of diseases attributable to high BMI by countries

In 2019, the highest age-standardized rates of DALYs attributed to high BMI-associated diseases were observed

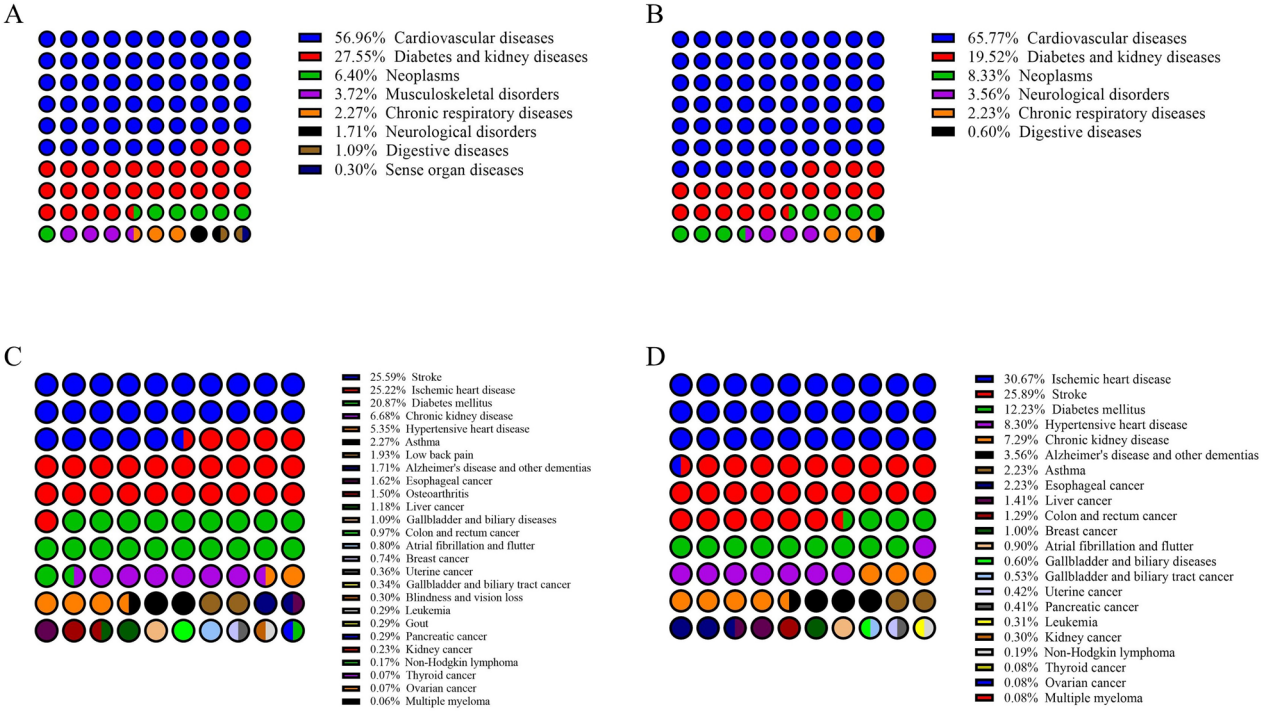

Figure 2. Distribution of DALYs (A) and deaths (B) due to high BMI-related diseases in Asia in 2019 among level 2 GBD diseases; and distribution of DALYs (C) and deaths (D) due to high BMI-related diseases in Asia in 2019 among level 3 GBD diseases. DALYs, disability-adjusted life years; GBD, the global burden of diseases study.

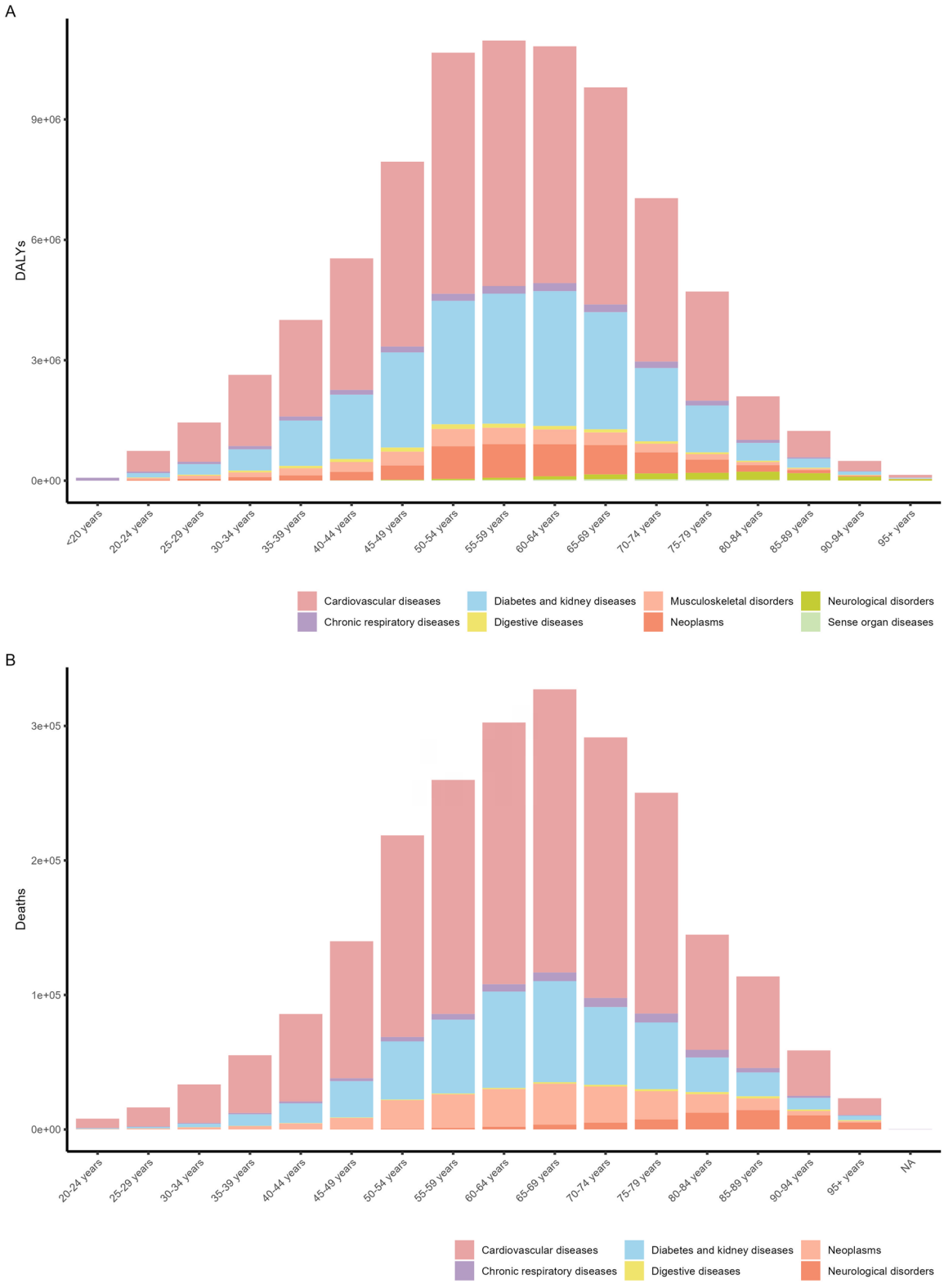

Figure 3. Numbers of DALYs (A) and deaths (B) due to high body mass index in Asia for both sexes combined. DALYs, disability-adjusted life years.

in United Arab Emirates [5732.92 (95% UI: 4111.71-7383.33) per 100,000 population], Uzbekistan [5593.13 (95% UI: 3626.74-7731) per 100,000 population], Turkmenistan [5136.48 (95% UI:3387.52-6982.54) per 100,000 population], with the lowest found in Japan, followed by Republic of Korea and Democratic People's Republic of Korea. Regarding mortality, Uzbekistan, Qatar, and the United Arab Emirates exhibited the highest

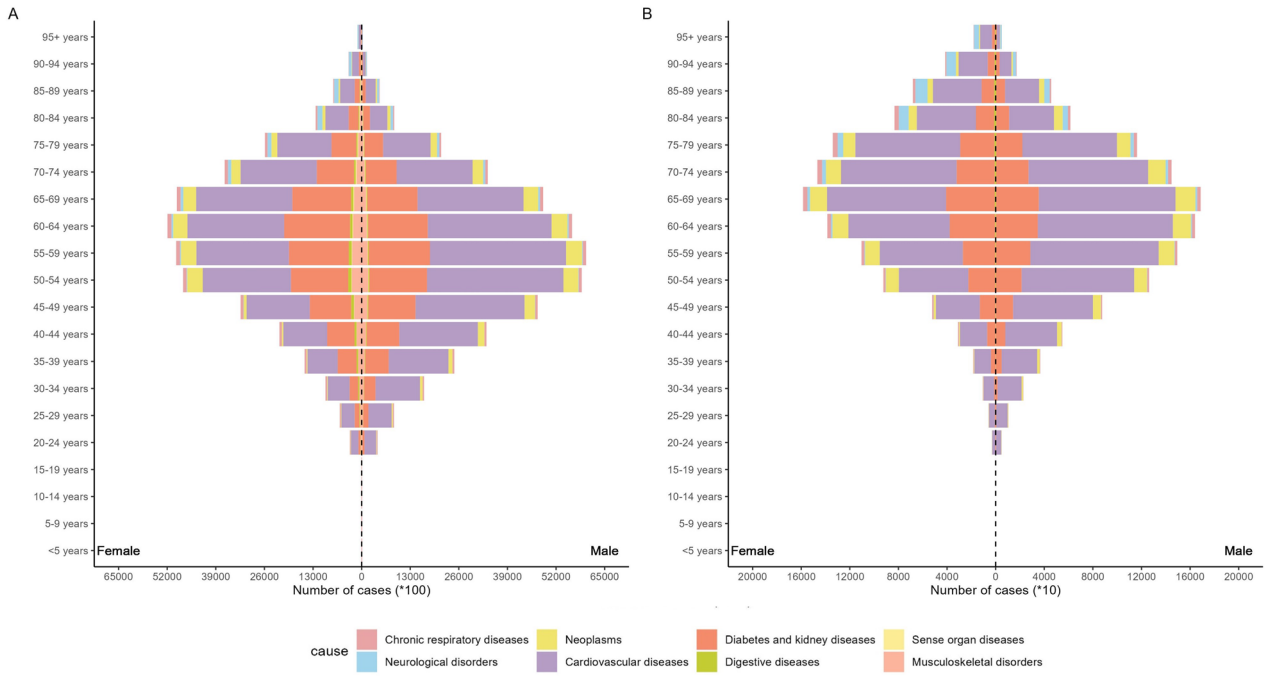

Figure 4. Numbers of DALYs (A) and deaths (B) due to high body mass index in Asia for females and males. DALYs, disability-adjusted life years.

age-standardized death rates due to high BMI-associated diseases (Figure 6; Supplementary Tables 4 and 5). In almost all Asian countries, cardiovascular and diabetes and kidney diseases were ranked as the top two leading causes of high BMI-related burden, with Mongolia being the exception; sense organ diseases ranked lowest, with Oman and Pakistan as exceptions (Figure 7). In Uzbekistan, Yemen, and Afghanistan, cardiovascular diseases along with diabetes and kidney diseases accounted for nearly 90% of the total high BMI-related disease DALYs burden. In Kyrgyzstan and Turkmenistan, cardiovascular diseases approached roughly three-quarters of the high BMI-related disease DALYs burden, while in Qatar and Sri Lanka, diabetes and kidney diseases dominate, comprising nearly half of the high BMI-related disease DALYs burden (Figure 8).

As shown in Figure 9, during the observation period, no significant correlation was observed between the burden estimates of high BMI-related diseases and SDI levels across Asian countries, with a p-value of 0.39 and a correlation coefficient of 0.13. However, as SDI increases, ASR initially decreases significantly, then rises, and subsequently stabilizes. The lowest ASR is observed when SDI is approximately 0.5.

Prediction of high BMI-related diseases burden

A troubling rise in the numbers of high BMI-related DALYs and Deaths was predicted in selected countries, where the United Arab Emirates, Uzbekistan, and Turkmenistan led in DALYs, and Uzbekistan, Qatar, and the United Arab Emirates ranked highest for mortality. Despite the overall growth in the absolute number of cases, a possible slowing down of the increase was predicted in the age-standardized rates of DALYs for high BMI-related diseases in the selected countries (Figure 10).

Discussion

Our study revealed a significant increase in the burden of diseases attributable to high BMI across Asia from 1990 to 2019. Over the past 3 decades, the rank of high BMI as a risk factor advanced from 13th to 7th among the level 2 GBD risk factors. This escalation trend could partially be attributed to the growth and aging of the population. In terms of sex, males generally observed a higher burden. But in specific conditions such as digestive diseases and within older age groups, the burden shifted to be higher in females. Furthermore, high BMI disproportionately impacted older adults, reflecting a higher susceptibility and potential cumulative effects of high BMI over a lifetime leading to disease in these older cohorts. Conversely, the least impact was seen in the age group below 20 years, indicating the potential for early intervention and prevention strategies in these younger populations.

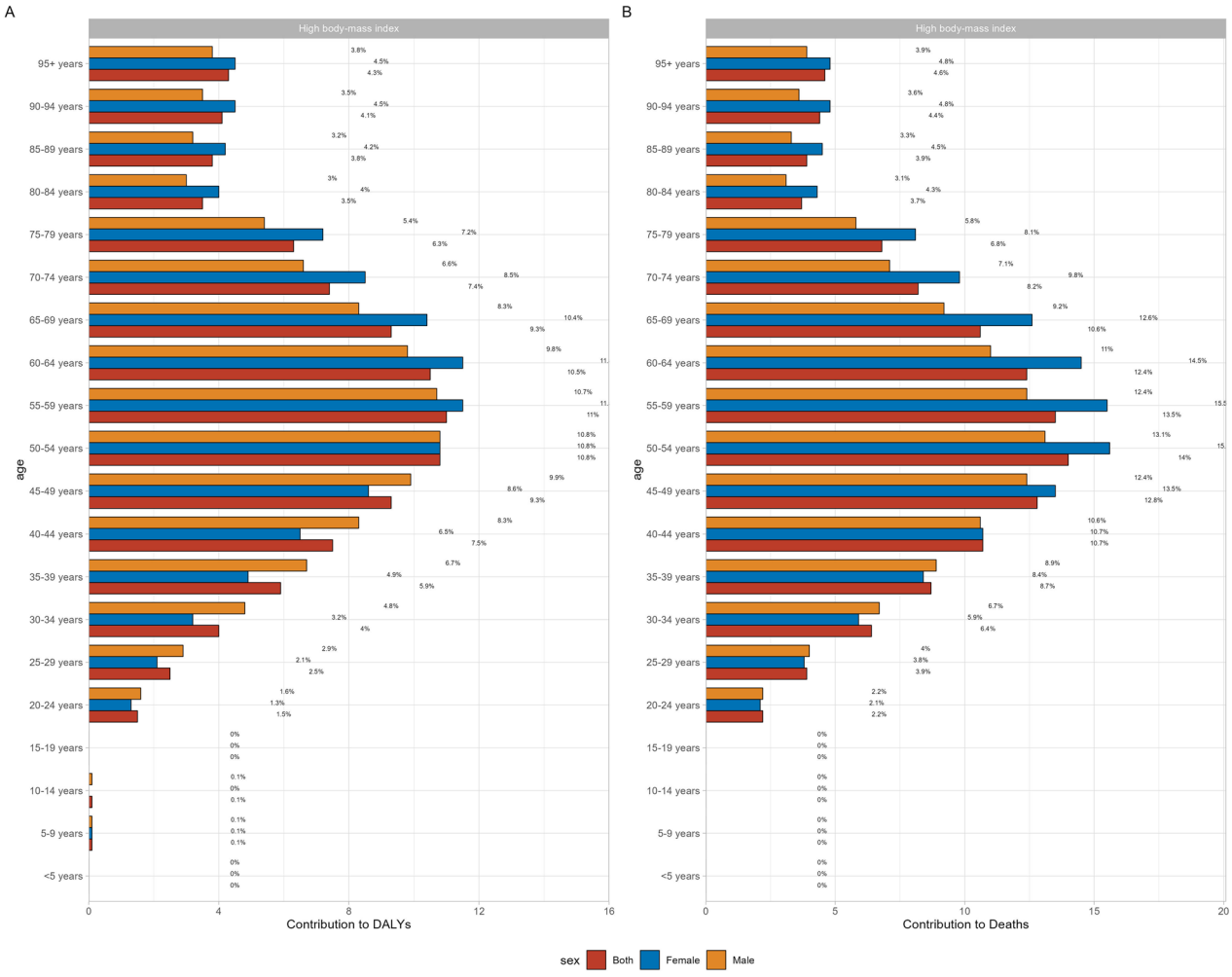

Figure 5. Percentage contribution of high body mass index to all-age DALYs (A) and deaths (B) in 2019 in Asian for females, males and both sexes combined. DALYs, disability-adjusted life years.

Despite observing the lowest burden of high BMI-related diseases in children and young adults, there has been a significant rise in the prevalence of obesity among children and young adolescents, which has become a global public health crisis. Between 1975 and 2016, the global prevalence of obesity among children and adolescents rose from 0.7% to 5.6% in boys and from 0.9% to 7.8% in girls, while the increasing trajectory of mean BMI in this demographic has plateaued in many high-income countries since approximately 2000, albeit remaining at elevated levels, yet has shown an accelerated rise in East, South, and Southeast Asia [8]. Obesity not only affecting their immediate health but also setting a trajectory for chronic conditions later in life [9,10]. On the one hand, children suffering from overweight face heightened metabolic and cardiovascular risks, such as high blood pressure and type 2 diabetes [9]. And since obesity in youth often tracks into adulthood, that would increase the likelihood of developing cardiovascular diseases, diabetes, and certain cancers later in life, potentially impacting both life expectancy and quality of life [9]. On the other hand, childhood obesity is often accompanied by psychological effects, contributing to a cycle of poor health that can impact educational outcomes and social interactions [11]. For example, bodyweight frequently emerged as a significant factor for teasing and bullying among children and adolescents [11]. Besides that, obesity among children and young adolescents could also impose significant socio-economic burdens due to increased healthcare costs and potential loss of productivity in the future [9].

The strong persistence of overweight status, coupled with the preventability of obesity and its related diseases, makes early-stage prevention a high priority [12]. Effective management of childhood and adolescent obesity necessitates a comprehensive approach involving healthcare professionals, parents, educators, and policymakers to foster environments conducive to healthy lifestyles. Interventions aimed at enhancing diet,

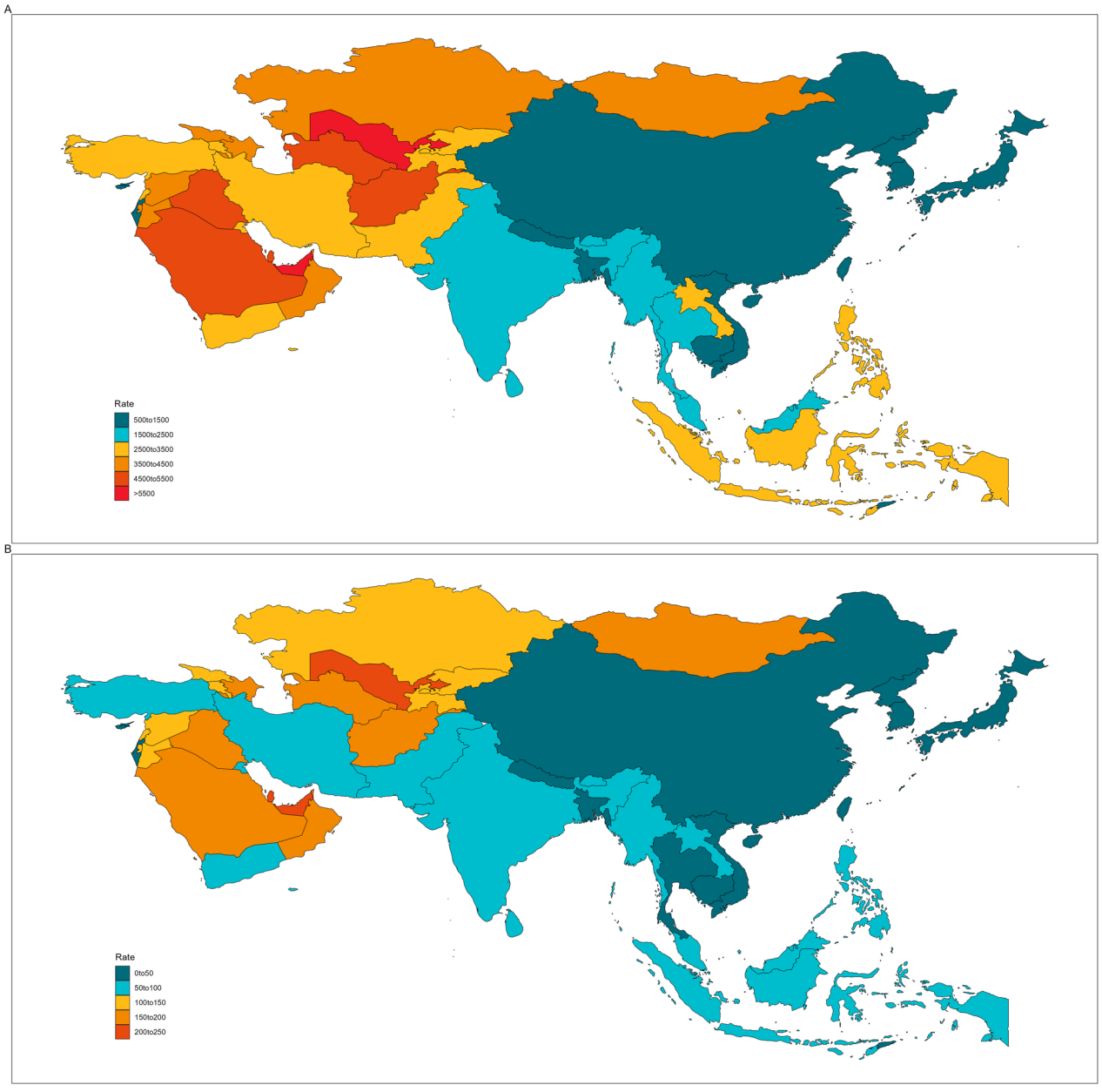

Figure 6. Age-standardized DALY(A) and death (B) rates of high BMI-related diseases in Asian countries or territories in 2019. DALYs, disability-adjusted life years.

physical activity, sleep quality, and reducing sedentary behaviors should be grounded in the family setting, which could be further supported by integrating educational programs in schools and community [13]. Addressing the psychological impact and stigma associated with obesity is also crucial for enhancing adherence to treatment programs and overall well-being. This multidisciplinary strategy not only manages obesity but also prevents its long-term complications.

As for adults, a significant gender disparity was observed in the burden of high BMI-related diseases with males generally bearing a higher burden. Sattar's study revealed that men typically become more insulin resistant with weight gain, accumulating harmful 'ectopic fat' in areas such as the liver and muscles, which exacerbates insulin resistance in turn and leads to a higher incidence of diabetes [14]. However, males seldom proactively seek out weight loss interventions, and current weight loss programs, largely developed and tested on women, highlight the need for targeted interventions and the identification of barriers to their participation [14]. Despite the earlier onset of ischemic heart disease in males, women with diabetes face a disproportionately increased risk of cardiovascular diseases, revealing the intricate interplay between these conditions [15]. Additionally, overweight and even

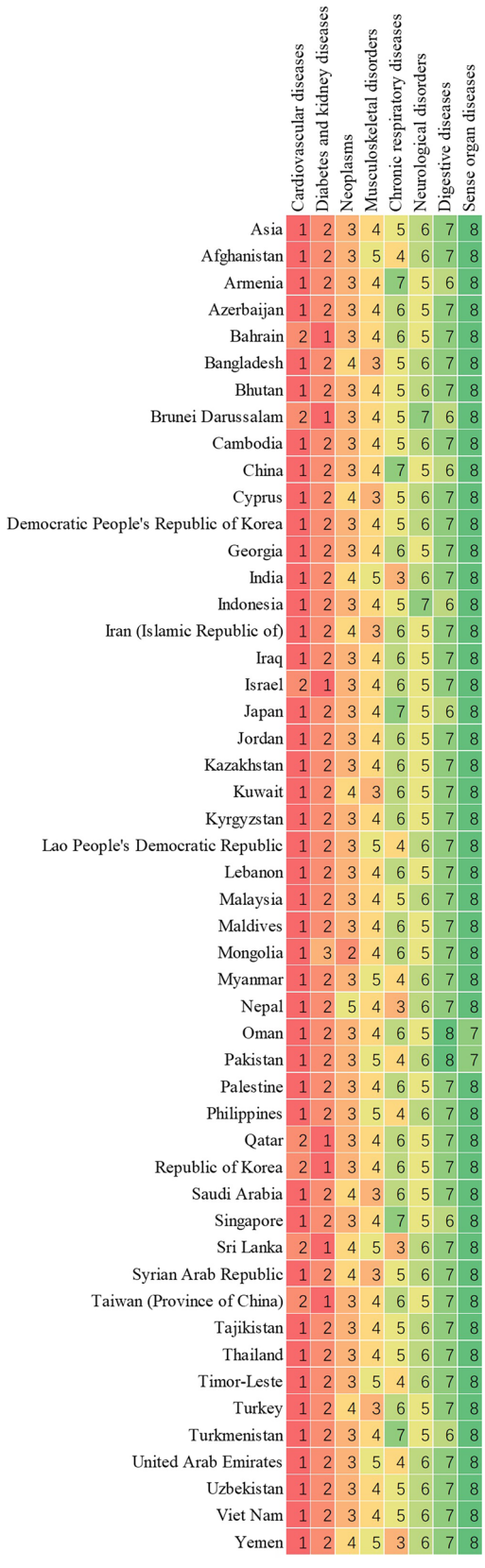

Figure 7. Ranking of age-standardized DALY rates for high BMI-related diseases by Asian countries or territories, 2019. DALYs, disability-adjusted life years.

obesity are regarded as an indication of wealth and health in certain countries, where cultural norms and values play a significant role in shaping perceptions of body size [16]. In this cultural context, the societal preference for larger body mass, particularly among men, may lead to an under-recognition of the health risks associated with obesity, further complicating efforts to address its impact on public health [17,18].

Driven by societal gender role stereotypes that emphasize attractiveness and the pervasive association of thinness with femininity and beauty, women are more likely to adopt unhealthy weight-control practices[19]. Meanwhile, there is also research indicating that women, particularly those who are overweight, may have a low perception of the health threats associated with obesity [20]. Both excessive weight-control behaviors and the underestimation of obesity-related risks underscore the need for a more balanced approach to body weight management—one that prioritizes overall health, highlighting that coordinated efforts across all sectors of society are essential to promote positive health messaging and shift cultural narratives toward valuing health over unrealistic aesthetic standards.

For both gender, older and middle-age adults faced a greater burden of diseases related to high BMI. This could attribute to their increased susceptibility to the harmful effects of high BMI, such as hormonal changes and insulin resistance, which raise the risk of chronic diseases [6]. Additionally, the stable energy intake and reduced physical activity with advanced age also contribute to this heightened risk [21].

Since 1980, the global prevalence of excessive weight gain has doubled, with nearly one-third of the world's population classified as overweight or obese [22]. Obesity, once considered predominantly a high-income country issue, is now increasingly prevalent in low- and middle-income countries, particularly in urban areas [22]. According to the Asian Development Bank, urbanization has rapidly progressed in Asia over the past 2 decades [23]. This urbanization, along with rising incomes, is shifting diets toward more animal-source foods, sugars, fats, oils, refined grains, and processed foods, leading to a "nutrition transition" that is contributing to increases in obesity and related diseases such as diabetes and heart disease [24]. While the accessibility of processed, high-calorie foods has increased, physical activity levels have decreased due to urban living. Regular physical activity could potentially lead to specific physiological changes such as increased insulin sensitivity, improved lipid profiles, and enhanced

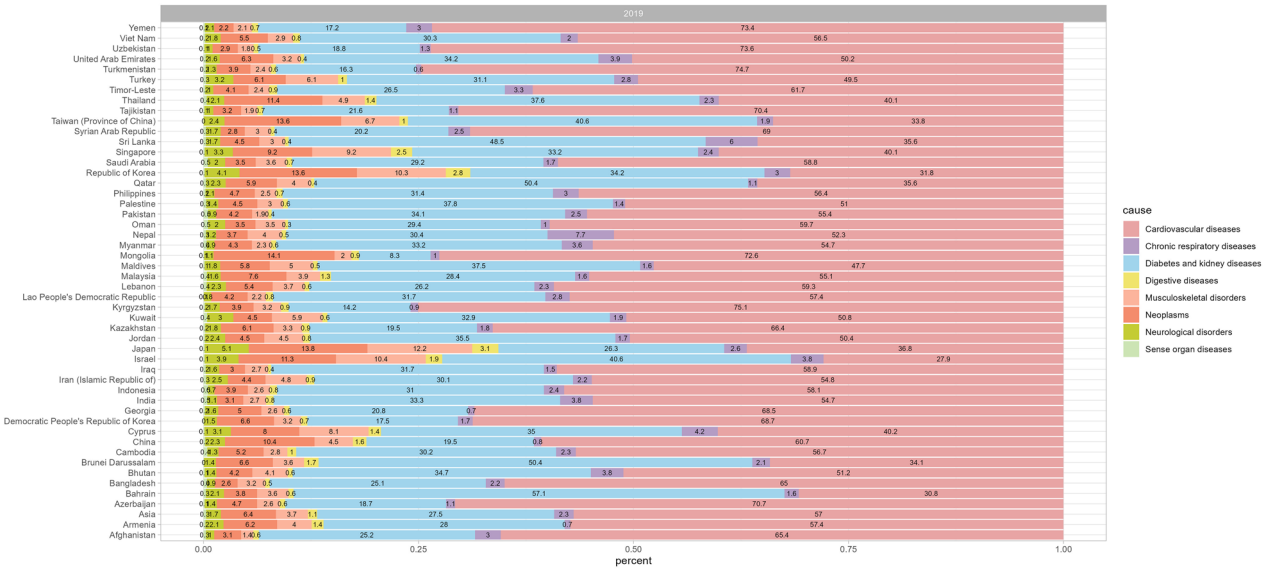

Figure 8. Distribution of age-standardized DALY rates in 2019 of high BMI-related diseases by Asian countries or territories. DALYs, disability-adjusted life years.

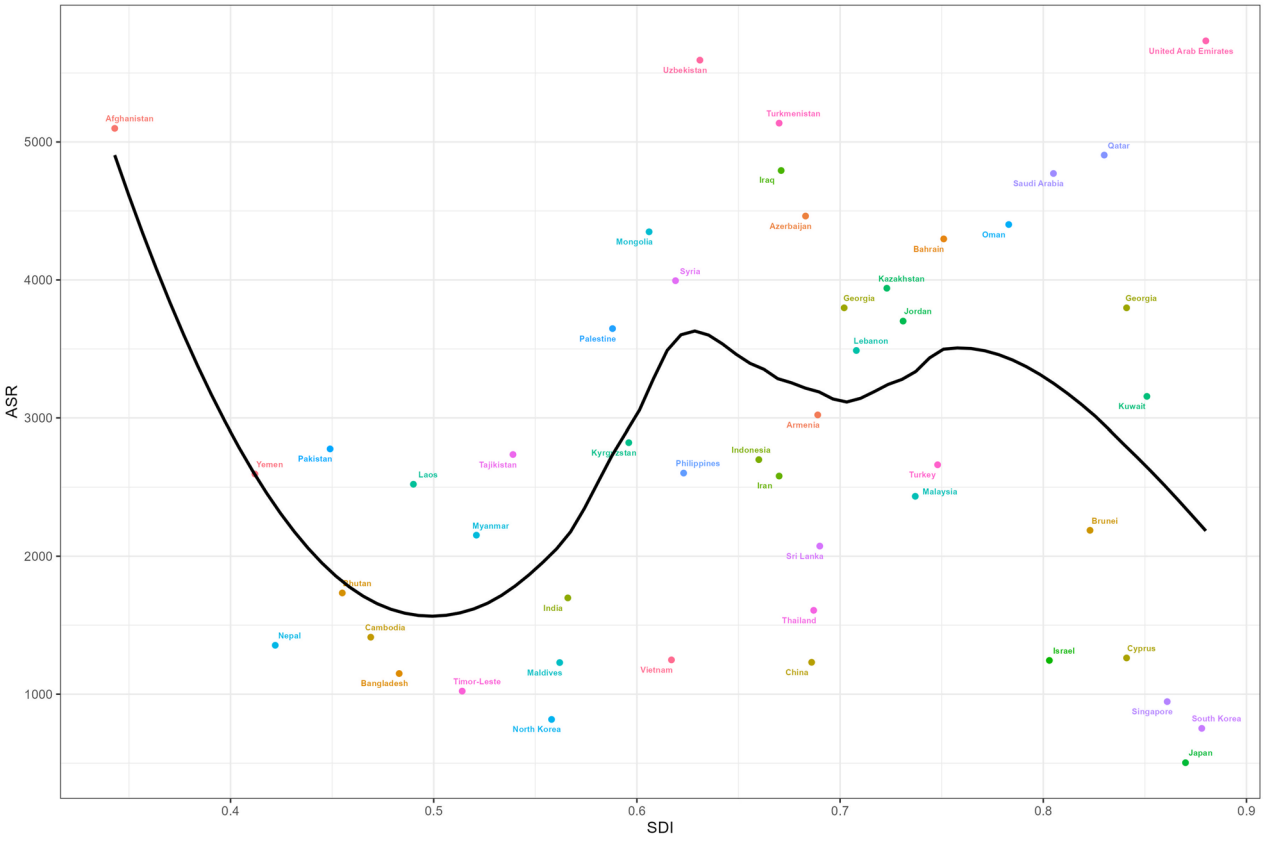

Figure 9. Age-standardized rates of DALYs due to high BMI-related diseases for Asia countries and territories by socio-demographic index, 1990–2019.

cardiovascular efficiency, reducing the risk of obesity-related chronic diseases like type 2 diabetes and heart disease, while also promoting mental and emotional well-being through better sleep, reducing symptoms of depression and anxiety, enhancing mood, and boosting overall quality of life [25–27]. Public health policies should therefore not only focus on promoting physical activity and healthier dietary choices through

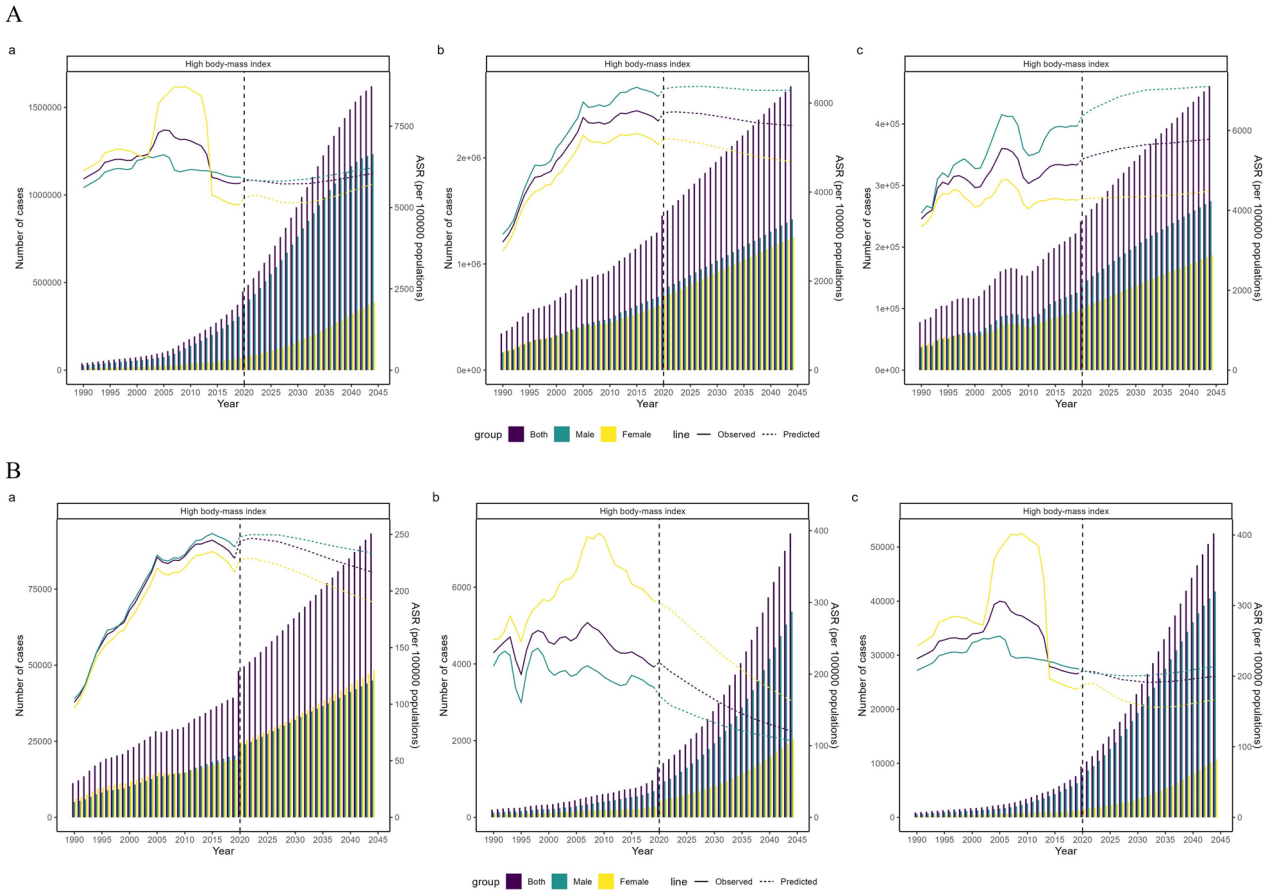

Figure 10. Observed and predicted age-standardized rates and numbers of DALYs (A) due to high BMI-related diseases in the United Arab Emirates (a), Uzbekistan (b), Turkmenistan (c), and deaths (B) due to high BMI-related diseases in Uzbekistan (a), Qatar (b), United Arab Emirates (c) for females, males and both sexes combined. DALYs, disability-adjusted life years.

public campaigns but also through structural changes such as improving urban planning to encourage physical activity and regulating food environments to limit the availability of unhealthy food options.

These interventions require a collaborative effort that encompasses government agencies, physicians, and researchers. In 2019, the lowest burdens of high BMI-associated diseases DALYs were observed in Japan, Republic of Korea and Democratic People's Republic of Korea. Among them, the Republic of Korea has implemented the Seoul Metabolic Syndrome Management (SMESY) program since 2011 as a community-wide lifestyle modification intervention; a recent retrospective study has shown it to be associated with reductions in metabolic disorders [28]. Singapore, which also experienced lower burdens in 2019, shared strategies to prevent and manage obesity that include implementing health-promoting public policies, mobilizing a social movement, fostering healthier lifestyle choices, and clinically managing high BMI [29]. As one of the most populous countries in Asia, the Chinese central government launched the 'Healthy China 2030' program, focusing on lifestyle changes to reduce chronic diseases like obesity and type 2 diabetes [30]. Given the global recognition of the necessity to combat obesity and related chronic diseases, similar efforts could potentially pave the way for further success in obesity intervention efforts worldwide.

This study offered a comprehensive estimation for the burden of high BMI-related diseases in Asia, providing policymakers with valuable references for developing effective public health strategies. However, there were also several limitations in this research. Firstly, despite the GBD 2019 employing various methods to enhance data quality and comparability, some bias is unavoidable, potentially compromising the accuracy and integrity of the data we analyzed. Secondly, we used only BMI as our measure of obesity. Although it is a popular metric, it fails to directly reflect body composition like visceral fat, which may pose a separate health risk [31]. Even among individuals with the same BMI, the patterns of obesity and the percentage of body fat vary due to differences in age, sex, and ethnicity. For example, individuals of Asian descent may possess greater body fat and face a higher risk of metabolic diseases compared to those of European

descent, even when their BMI is identical [3,5,31]. Thirdly, while this study concentrated on the effects of individual causes, it did not consider the combined impact of multiple factors.

Conclusion

The burden of high BMI-related diseases, a major public health issue, was increasing in Asia. To address this problem, coordinated action by governments, civil society and other key stakeholders should be taken to enhance awareness of the risks associated with high BMI and effectively reduce its impact. Additionally, significant sex- and age-related disparities in the high BMI-related disease burden, with men and older populations bearing a disproportionately heavy burden, underscore the importance of targeted healthcare interventions tailored to these demographic groups.

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Ethics approval and consent to participate

The institutional review board of the Affiliated Hospital of Southwest Medical University in Sichuan Province, China, determined that the study did not need approval because it used publicly available data.

Author contributions

CRediT: **Qi Chen**: Conceptualization, Methodology, Visualization, Writing – original draft, Writing – review & editing; **Shu Huang**: Methodology, Writing – original draft, Writing – review & editing; **Xiaohong Wang**: Visualization, Writing – original draft, Writing – review & editing; **Jieyu Peng**: Conceptualization, Data curation, Writing – original draft; **Ping Wang**: Data curation, Methodology, Visualization; **Rui Luo**: Conceptualization, Data curation, Writing – original draft; **Xiaomin Shi**: Data curation, Software, Visualization; **Huan Xu**: Methodology, Writing – original draft; **Wei Zhang**: Data curation, Methodology, Software; **Lei Shi**: Conceptualization, Methodology, Writing – original draft; **Yan Peng**: Writing – original draft, Writing – review & editing; **Nanjun Wang**: Conceptualization, Methodology, Writing – original draft, Writing – review & editing; **Xiaowei Tang**: Conceptualization, Methodology, Writing – original draft, Writing – review & editing.

Consent for publication

The manuscript is approved by all authors for publication.

Disclosure statement

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Availability of data and materials

The data supporting the findings of this study are available upon reasonable request from the corresponding author.

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