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Global burden and inequality of autism spectrum disorders: Based on data from the 2019 Global Burden of Disease study

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ABSTRACT

It is unclear whether the health equity of autism spectrum disorders (ASDs) has changed in different years, regions, and gender. The aims of this study were to provide a comprehensive description of the ASDs burden and provide evidence for improvement in health policies regarding ASDs inequality. This study is a population-based cross-sectional study based on the Global Burden of Disease datasets 1990–2019. We collected detailed information on ASDs between 1990 and 2019 in 204 countries worldwide, derived from the Global Burden of Disease study in 2019. Burden was calculated in terms of the incidence, prevalence and years lived with disability (YLDs). Concentration curves and concentration indices were used to summarize the degree of income-related inequality in the burden of ASDs. The overall age-standardized incidence rate (ASIR), age-standardized prevalence rate (ASPR) and age-standardized YLDs rate (ASYR) of ASDs was 9.3 (95 %UI 7.7–11.1), 369.4 (95 %UI 305.9–441.2), 56.3 (95 %UI 36.8–81.5) per 100,000 people, respectively. The ASIR, ASPR and ASYR of ASDs affected three times as many males as females. The changing trends of age-standardized rates of ASDs showed that the ASIR of ASDs a slow growing trend globally. However, the ASPR and ASYR of ASDs showed a slow decreasing trend globally. All the concentration curves were below the line of equality and statistically significant. There was no significant difference in the age-standardized rate for different years in socio-demographic index-related inequality happened over 29 years ($p > 0.05$). The global burden of ASDs has remained higher in males and pro-rich, the income-related inequality tended not to change between 1990 and 2019.

1. Introduction

According to 2019 Global Burden of Disease (GBD) Mental Disorder Collaborators, mental disorders remain one of the top ten major causes of burden worldwide, with years lived with disability (YLDs) being the cause of the majority of the burden on mental disorders, with 125.3 million YLDs (95% uncertainty interval, UI 93.0–163.2), and the proportion of global YLDs attributed to mental disorders was 14.6% [12.2–16.8] in 2019 (Collaborators“ GMD, 2022). In the mental disorders, it should be noted that autism spectrum disorders (ASDs) are persistent disabling neurodevelopmental disorders characterized by neuropsychological and behavioral deficits clinically evident from early childhood (Baxter et al., 2015). ASDs was first described in 1943 and since then, a large increase in the incidence of ASDs worldwide (Baj et al., 2021). ASDs is one of the fastest growing disabilities, accounting for substantial health loss across the lifespan (Bhat et al., 2014). Epidemiological data reveal that there were an estimated 52 million cases of ASDs, equating to a prevalence of 7.6 per 1000 or one in 132 persons in 2010 (Baxter et al., 2015). For 2016, across all 11 sites, ASDs prevalence was 18.5 per 1,000 (one in 54) children aged 8 years in the United States, the prevalence of ASDs was higher than previous estimates over the years (Maenner et al., 2020). In 3/4 patients with ASDs, the disorder is accompanied by mental retardation. In addition, it is boys who are four times more likely to suffer from ASDs than girls. To date, the etiology of the disease has not been explained, although it is believed that it is most likely the result of gene and environmental factors

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interactions (Baj et al., 2021). Understanding the burden of ASDs is essential for effective policy making. Previous research has shown that age, gender, and country of study were associated with heterogeneity in estimated prevalence of ASDs (Lai et al., 2019). Because of the great personal and sociological cost of ASDs (estimated to be $2 million/patient/year (Buescher et al., 2014)), the epidemiological description of ASDs is needed to inform public health policy and to plan for education, housing, and financial support services. In addition, improved incidence, prevalence, and YLDs estimates and identification of moderators are needed to enhance recognition and care, and to guide future research.

Though some recent studies of ASDs have carried out (Li et al., 2022; Solmi et al., 2022; Kang et al., 2023; Li et al., 2022), they only focused on the global epidemiology of ASDs. However, it is unclear whether the health equity of ASD has changed in different years, regions, and gender. In our study, we aimed to evaluate the global burden of ASDs, focusing on the incidence prevalence, and YLDs of ASDs in different years, regions, and gender. The concentration index was calculated to assess the equities in global burden of ASDs. Our findings will provide a comprehensive description of the ASDs burden and provide evidence for improvement in health policies regarding ASDs inequality.

2. Methods

2.1. Study design

This study is a population-based cross-sectional study based on the Global Burden of Disease datasets 1990–2019.

2.2. Study data

The data come from the 2019 Global Burden of Disease (GBD) study (https://vizhub.healthdata.org/gbd-results/). The official GBD website provides a detailed instruction on the general methods applied for GBD 2019 (https://www.healthdata.org/gbd/2019). According to specific research objectives, various indices such as “cause”, “location”, and “year” can be selected in data source query tool (Global Health Data Exchange, GBDx). In this study, we obtained the annual case number of ASDs in all age groups and their corresponding age-standardized rates (ASRs), including incidence, prevalence, and YLDs and the 95% uncertainty interval from 1990 to 2019. GBD world population age standard was used as age-standardized population (Global burden of 369 diseases and injuries in 204 countries and territories, 2019). A Bayesian meta-regression modelling tool, DisMod-MR 2.1, was used to ensure consistency between incidence, prevalence for most causes. Prevalence estimates were multiplied by disability weights for mutually exclusive sequelae of diseases and injuries to calculate YLDs. For administrative and data analysis purposes, the world has been divided into 21 GBD regions based on epidemiological similarity and geographic proximity. The socio-demographic index (SDI) is a composite indicator of income per capita in the 2019 GBD study, the calculation of SDI combined three main indicators: the average education level of individuals aged 15 and older, fertility rate in females under 25 years old, and the lag-distributed income per capita (Global burden of 369 diseases and injuries in 204 countries and territories, 2019; Wang et al., 2022). The SDI levels range from 0 (low SDI) to 100 (high SDI): the quintile is used to describe SDI levels, including low, medium low, medium, high, and high SDI (Global burden of 369 diseases and injuries in 204 countries and territories, 2019), the SDI levels measures the socio-demographic development of a region, with higher values indicating better socio-economic conditions. In our study, the SDI levels were used as a proxy measure for concentration curves, which can be used to show the distribution of ASD burden of disease across regions with different economic development status. Our analysis was done in accordance with the GBD protocol. All data from GBDx can be shared and modified by non commercial users through an open data sharing attribution license.

2.3. Statistical analysis

The general methods for the GBD 2019 and the methods for estimations of disease burden have been detailed in previous studies (Collaborators“ GMD, 2022; Baxter et al., 2015). Briefly, we downloaded dataset including the incidence, prevalence and YLDs of ASDs. These data are open source and available for download from the GBD Results Tool. Detailed descriptions of the methods and approach used for the GBD estimation have been previously described (Global burden of 369 diseases and injuries in 204 countries and territories, 2019). The age-standardized incidence rate (ASIR), the age-standardized prevalence rate (ASPR), the age-standardized YLDs rate (ASYR) (per 100,000 population) and estimated annual percentage change (EAPC) was calculated as previously described (Liu et al., 2019). ASIR, ASPR and ASYR were calculated by summing up the products of the age-specific rate (α_i, where i is the i^{th} age group) and the number of persons (w_i) in the same age subgroup i of the selected reference standard population, *i.e.*, $ASR = \frac{\sum_{i=1}^{A} \alpha_i w_i}{\sum_{i=1}^{A} w_i} \times 100{,}000$, $y = \alpha + \beta x + \varepsilon$, where x is year, $y = \text{In(ASR)}$, $EAPC = 100 \times (\exp(\beta) - 1)$ and its 95% confidence interval (CI) can also be obtained from the linear regression model. The ASR was in an increasing trend if the lower boundary of EAPC’s 95% CI was greater than 0, or, conversely, the ASR was in a decreasing trend if the upper boundary of EAPC’s 95% CI was less than 0. In other cases, the ASR was stable over time. Additionally, the influential factors and the change trend for ASIR, ASPR and ASYR explored by using scatter plot and line graph. Concentration curves and concentration indices (Liu et al., 2012) were used to summarize the degree of income-related inequality in the burden of ASDs. A concentration curve plots the cumulative percentage of the outcome variable (age-standardized rate in incidence, prevalence and YLDs in this study) on the y-axis against the cumulative percentage of countries or regions ranked by socioeconomic status based on the SDI levels (from the lowest SDI levels to highest SDI levels) on the x-axis.

If the concentration curve is above the line of equality (the 45-degree line), it indicates that the ASDs-induced disease burden is higher among low-SDI countries; otherwise, the disease burden is higher among high-SDI countries. We computed the concentration index based on the concentration curve.

The covariance method was used to calculate the concentration index (Peng et al., 2023).

$$C = \frac{2}{\mu} cov(h_i, r_i)$$

In the above calculation formula, C represents the concentration index, cov means the covariance, r indicates the ranking of region i in the socio-economic distribution (from poorest to wealthiest), and h represents the health outcomes, μ considered as an average health outcome (Peng et al., 2023).

Concentration index = 0 indicates that the health outcomes have a complete equal distribution, and the concentration curve is consistent with the equal distribution line. The concentration index < 0 means that the adverse health outcomes (disease burden) are concentrated in poor (low SDI levels) countries, with the concentration curve above the equality line, and vice versa.

A positive value indicates that the age-standardized rate is higher for the richer people. All statistics were performed using the STATA (Version Stata/MP 14.0), R program (Version 4.1.3) and RStudio 2022.02.1 Build 461. A p value of less than 0.05 was considered statistically significant.

2.4. Ethics statement

Our study was based on publicly available anonymized databases, and thus exempt from ethical compliance.

3. Results

3.1. The global burden and changing trends of ASDs

From 1990 to 2019, the global incident cases of ASDs rose from 6.03 $\times 10^5$ to 6.04 $\times 10^5$, increasing by 1.5‰, the ASIR of ASDs was ranged from 9.2 per 100,000 persons in 1990 to 9.3 per 100,000 persons in 2019. The results revealed that, overall, a growing trend of ASIR was observed from 1990 to 2019 (EAPC = 0.06; 95% CI 0.04 to 0.07). In 2019, the global incident cases of ASDs were 459,492.9 (95% UI 384,472.4 to 544,405.9) in males, which was 3.2-folds more than those in females (144,297.0; 95% UI 115,510.3 to 174,371.1). Moreover, a high ASIR of ASDs was recorded in under 5 years subgroup, in high SDI subgroup and in High-income North America subgroup, respectively. (Table 1 and Fig. 1).

As shown in STable 1, from 1990 to 2019, the global number of prevalent ASDs rose from 2.03 $\times 10^7$ to 2.83 $\times 10^7$, increasing by 39.3%. However, the ASPR of ASDs decreased from 372.8 per 100,000 persons to 369.4 per 100,000 persons over 29 years. The results revealed that, overall, a downtrend of ASPR was observed between 1990 and 2019 (EAPC = -0.02; 95% CI −0.03 to −0.01). In 2019, the global number of prevalent ASDs were 21,633,775.9 (95% UI 17,978,516.1 to 25,761,347.6) in males, which was 3.2-folds more than those in females (6,691,162.7; 95% UI 5,436,261.6 to 8,153,529.4). Moreover, a high ASPR of ASDs was recorded in under 5 years subgroup, in high SDI subgroup and in High-income North America subgroup, respectively (STable 1 and SFig 1).

As shown in STable 2, the years lived with ASDs were 4,306,615.4 (95% UI 2,821,511.9 to 6,232,360.5) in 2019, which was 1.39-folds higher than those in 1990 (3,105,909.1; 95% UI 2,025,303.0 to 4,514,467.3). However, the ASYR of ASDs decreased from 56.7 per 100,000 persons to 56.3 per 100,000 persons over 29 years. The results revealed that, overall, a downtrend of ASYR was observed between 1990 and 2019 (EAPC = -0.02; 95% CI −0.03 to −0.01). In 2019, the years lived with ASDs were 3,294,467.6 (95% UI: 2,152,733.3 to 4,769,102.9) in males, which was 3.3-folds more than those in females (1,012,147.8, 95% UI: 663,237–1,477,449.8). Moreover, a a high ASYR of ASDs was recorded in under 5 years subgroup, in high SDI subgroup and in High-income Asia Pacific subgroup, respectively (STable 2 and SFig 2).

3.2. The influential factors for the burden of ASDs

The Scatter plot showed that the countries in which the SDI was approximately 0.6 had the lowest ASIR, ASPR and ASYR of ASDs, while those with SDI near 1.0 presented a high ASIR, ASPR and ASYR (Fig. 2). In males, an obvious growing trend of ASIR, ASPR and ASYP was observed between 1990 and 2019 in high SDI subgroup, but in other SDI subgroups, the ASIR, ASPR and ASYR of ASDs remained stable over 29 years. However, in females, the ASIR, ASPR and ASYR of ASDs remained stable over 29 years in all SDI subgroups (Fig. 3).

Table 1
The incidence of autism spectrum disorders, and its changing trends from 1990 to 2019.

Characteristics	1990		2019		1990–2019
	Incident cases No. $\times 10^3$ (95% UI)	ASIR per 100,000 No. (95% UI)	Incident cases No. $\times 10^3$ (95% UI)	ASIR per 100,000 No. (95% UI)	EAPC in ASIR No. (95 %CI)
Overall	602.9 (501.4–718.3)	9.2 (7.6–10.9)	603.8 (501.7–720.1)	9.3 (7.7–11.1)	0.06 (0.04–0.07)
Sex					
Male	461.6 (386.4–548.2)	13.6 (11.4–16.1)	459.5 (384.5–544.4)	13.7 (11.5–16.3)	0.04 (0.02–0.06)
Female	141.2 (113.4–170.9)	4.4 (3.6–5.4)	144.3 (115.5–174.4)	4.6 (3.7–5.6)	0.12 (0.11–0.13)
Age					
<5 years	602.9 (501.4–718.3)	95.4 (79.3–113.6)	603.8 (501.7–720.1)	91.1 (75.7–108.6)	−0.09 (-0.12–0.06)
5–9 years	0 (0–0)	0 (0–0)	0 (0–0)	0 (0–0)	0 (0–0)
10–14 years	0 (0–0)	0 (0–0)	0 (0–0)	0 (0–0)	0 (0–0)
15–19 years	0 (0–0)	0 (0–0)	0 (0–0)	0 (0–0)	0 (0–0)
20+ years	0 (0–0)	0 (0–0)	0 (0–0)	0 (0–0)	0 (0–0)
Socio-demographic index					
Low	0 (0–0)	9.2 (7.6–10.9)	0 (0–0)	9.2 (7.6–11)	0.04 (0.03–0.04)
Low-middle	0 (0–0)	8.2 (6.7–9.8)	0 (0–0)	8.4 (6.9–10)	0.07 (0.06–0.08)
Middle	0 (0–0)	8.4 (6.9–10.1)	0 (0–0)	8.4 (6.9–10.1)	−0.04 (-0.06–0.02)
High-middle	0 (0–0)	10.2 (8.4–12.1)	0 (0–0)	10.3 (8.6–12.3)	0.03 (0–0.06)
High	75.7 (63.9–89.1)	13.3 (11.3–15.7)	72.2 (60.8–85.0)	14.5 (12.3–17.1)	0.36 (0.31–0.41)
Region					
High-income Asia Pacific	14.6 (12.2–17.3)	15.4 (12.9–18.3)	10.4 (8.7–12.3)	15.7 (13.1–18.6)	0.11 (0.09–0.14)
Central Asia	9.2 (7.6–11.0)	9.9 (8.1–11.8)	8.9 (7.3–10.6)	9.9 (8.1–11.8)	0 (-0.02–0.01)
East Asia	111.6 (91.7–133.8)	9.3 (7.6–11.1)	71.1 (58.3–84.9)	9.6 (7.9–11.5)	0.03 (-0.04–0.09)
South Asia	129.8 (106.7–155.4)	7.6 (6.2–9)	121.9 (100.1—145.6)	7.6 (6.2–9.1)	0.01 (0–0.01)
Southeast Asia	49.2 (40.3–58.8)	8.2 (6.7–9.7)	42.8 (35.0–51.3)	8.2 (6.7–9.8)	0.02 (0.01–0.02)
Australasia	1.7 (1.4–2.0)	11 (9.2–13.1)	2.0 (1.6–2.3)	11.1 (9.3–13.2)	0.07 (0.05–0.08)
Caribbean	3.9 (3.2–4.7)	9 (7.4–10.8)	3.5 (2.9–4.2)	9 (7.4–10.7)	−0.01 (-0.02–0.01)
Central Europe	7.5 (6.2–8.9)	9.4 (7.8–11.1)	4.8 (4.0–5.8)	9.4 (7.8–11.2)	−0.01 (-0.02–0)
Eastern Europe	14.2 (11.8–17.0)	10.2 (8.4–12.1)	11.2 (9.2–13.3)	10.3 (8.5–12.3)	0.05 (0.03–0.06)
Western Europe	31.7 (26.9–37.3)	14.2 (12.1–16.7)	29.3 (24.9–34.5)	14.2 (12–16.7)	−0.02 (-0.03–0.01)
Andean Latin America	5.2 (4.3–6.3)	9.1 (7.5–10.9)	5.6 (4.7–6.8)	9 (7.4–10.8)	−0.05 (-0.08–0.02)
Central Latin America	21.9 (18.0–26.1)	9.2 (7.6–11)	19.3 (16.0–23.1)	9.2 (7.6–10.9)	−0.02 (-0.02–0.01)
Southern Latin America	6.1 (5.1–7.3)	12.1 (10.2–14.5)	5.8 (4.8–6.9)	12.5 (10.4–14.9)	0.1 (0.08–0.13)
Tropical Latin America	15.8 (13.0–18.8)	9.2 (7.6–11)	14.4 (11.9–17.1)	9.3 (7.7–11.1)	0.06 (0.03–0.08)
North Africa and Middle East	44.28 (36.2–53.1)	7.9 (6.5–9.5)	45.0 (36.8—53.9)	7.7 (6.3–9.3)	−0.06 (-0.08–0.05)
High-income North America	29.88 (25.1–35.1)	13.6 (11.4–16)	33.1 (27.8–38.8)	16.4 (13.8–19.3)	0.8 (0.67–0.93)
Oceania	0.8 (0.7–1.0)	7.6 (6.2–9.2)	1.5 (1.3–1.8)	7.6 (6.2–9.3)	0.03 (0.01–0.04)
Central Sub-Saharan Africa	12.6 (10.3–15.0)	9.9 (8.1–11.8)	20.8 (17.1–24.9)	9.8 (8–11.7)	−0.03 (-0.04–0.03)
Eastern Sub-Saharan Africa	42.9 (35.4–51.3)	10.1 (8.3–12.1)	67.4 (55.6–80.5)	10 (8.2–11.9)	−0.03 (-0.04–0.02)
Southern Sub-Saharan Africa	7.2 (6.0–8.6)	9.8 (8.1–11.7)	7.8 (6.5–9.3)	9.8 (8.1–11.7)	0 (-0.01–0.02)
Western Sub-Saharan Africa	42.8 (35.5–51.3)	10 (8.3–12)	77.1 (64.0–92.4)	9.8 (8.2–11.8)	−0.07 (-0.08–0.06)

ASIR, age-standardized incidence rate; EAPC, estimated annual percentage change; UI, uncertainty interval; CI, confidence interval.

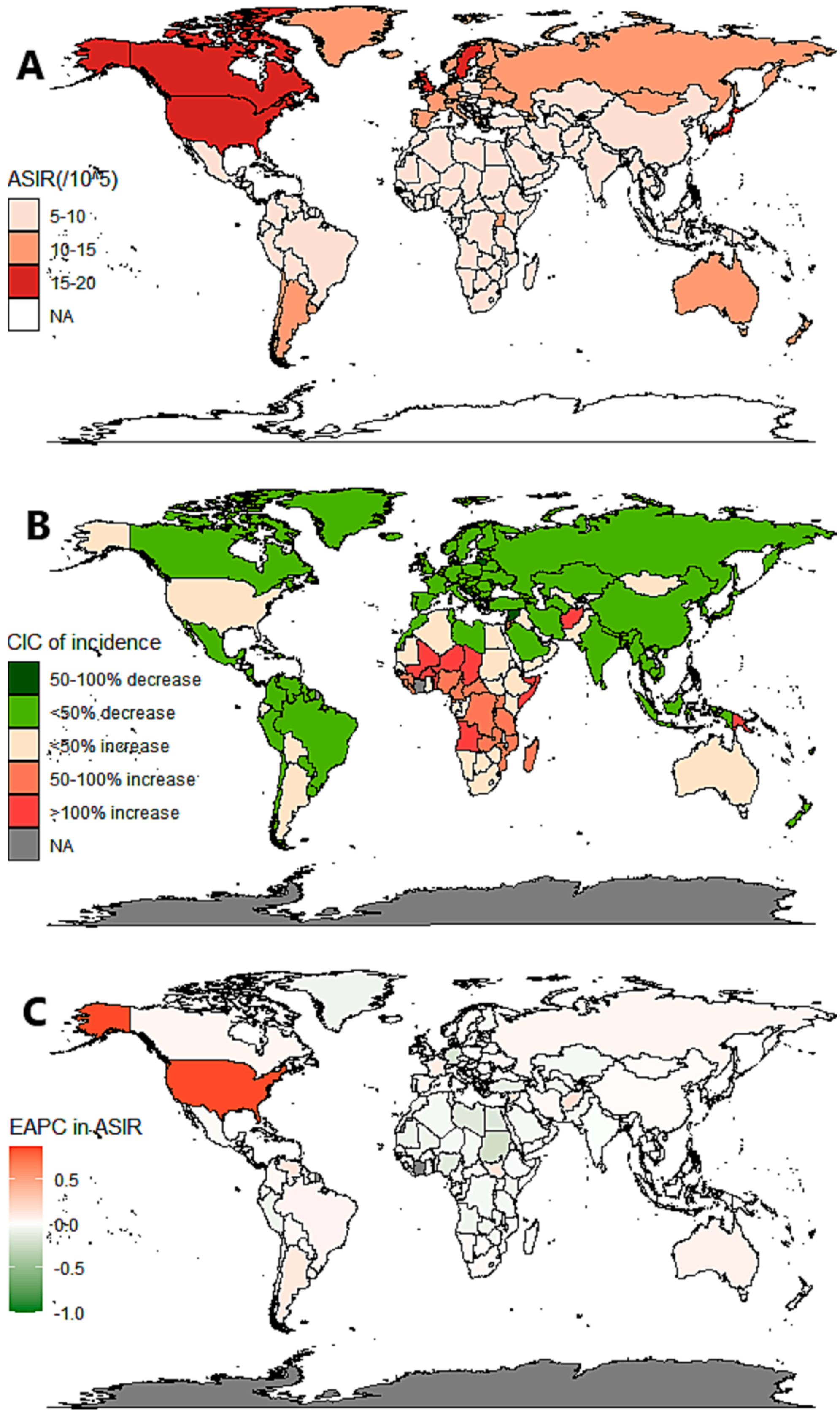

Fig. 1. The global incidence burden and changing trends of ASDs between 1990 and 2019 in 204 countries and territories. (A) The ASIR of autistic spectrum disorders in 2019. (B) The relative change in incident cases of autistic spectrum disorders between 1990 and 2019. (C) The EAPC in ASIR of autistic spectrum disorders from 1990 to 2019. ASIR, age-standardized incidence rate; CIC, change in cases; EAPC, estimated annual percentage change.

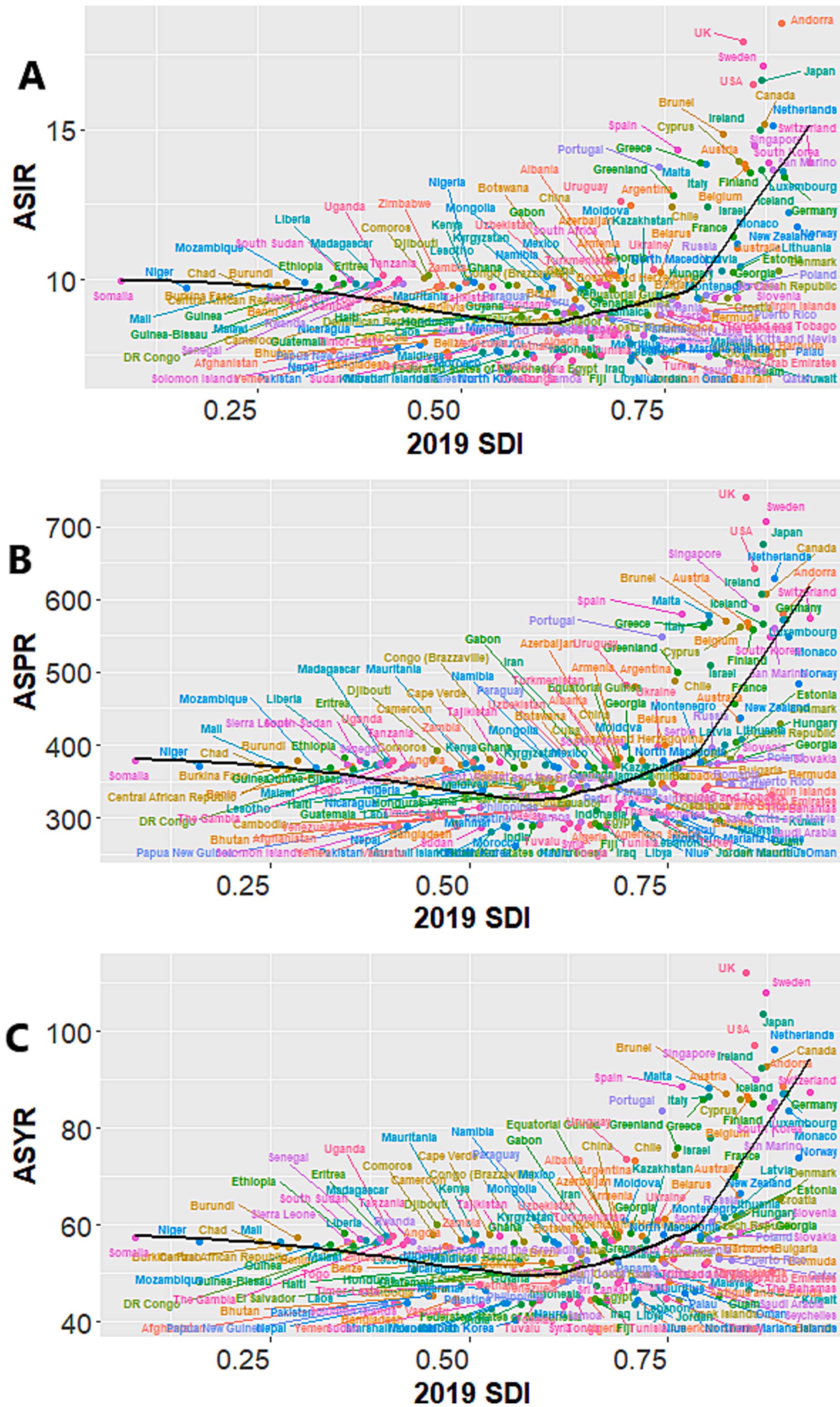

Fig. 2. The association between age standardized rate of autistic spectrum disorders and SDI between 1990 and 2019 in 204 countries and territories. (A) ASIR and SDI. (B) ASPR and SDI. (C) ASYR and SDI. ASIR, age-standardized incidence rate; ASPR, age-standardized prevalence rate; ASYR, age-standardized YLDs rate; YLDs, years lived with disability; SDI, socio-demographic index.

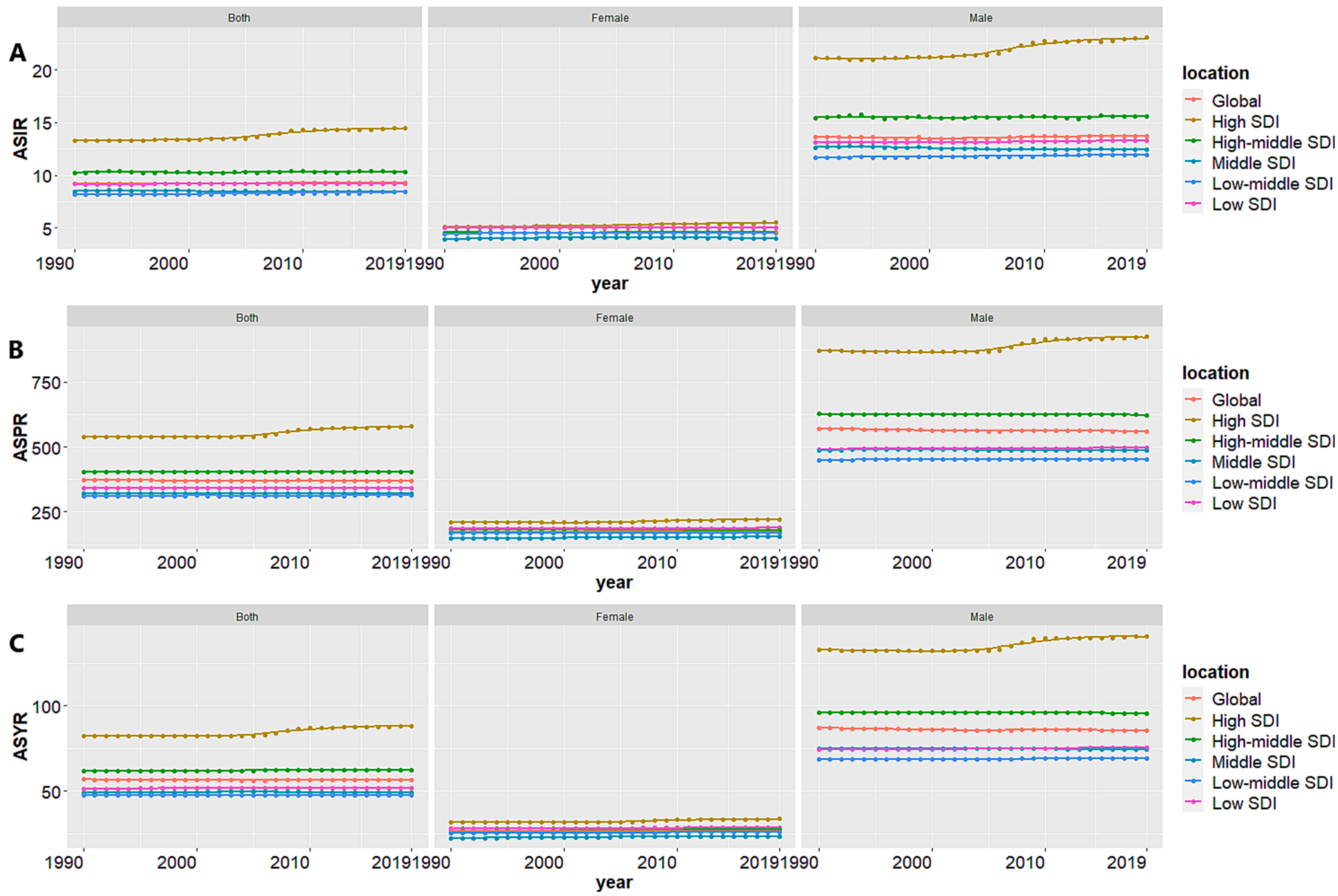

Fig. 3. The change trends of age-standardized rate of autistic spectrum disorders among SDI groups and gender from 1990 to 2019 (A) ASIR. (B) ASPR. (C) ASYR. ASIR, age-standardized incidence rate; ASPR, age-standardized prevalence rate; ASYR, age-standardized YLDs rate; YLDs, years lived with disability; SDI, socio-demographic index.

3.3. *Health equity of ASDs between 1990 and 2019*

The concentration curves and concentration indices for age-standardized rate of ASDs from 1990 to 2019 presented in Fig. 4 and Table 2. All the curves were below the line of equality and statistically significant, suggesting that the ASIR, ASPR and ASYP of ASDs were more concentrated among the higher SDI between 1990 and 2019. There was no significant difference in the age-standardized rate for different years meant there was no significant changes in SDI-related inequality happened over 29 years ($p > 0.05$).

The regression equation between concentration indices for age-standardized rate of ASDs and its influence factors is educed (Table 3). The regression analysis showed that influencing factors SDI levels (Low SDI, Low-middle SDI, Middle SDI, High-middle SDI, High SDI) and sex (male, female) statistically correlated with ASIR, ASPR and ASYR of ASDs, respectively ($P < 0.05$). Analysis of contribution rate on effect factors of concentration indices, the results showed sex contributed 91.81%, 88.83%, and 88.57% to concentration indices of ASIR, ASPR and ASYR of ASDs, respectively.

4. Discussion

Having sufficient information on factors affecting the burden of ASDs and its inequalities could help to prevent and decrease the risk of ASDs. This study examined the global burden of ASDs and socioeconomic-related inequality. In our study, the overall ASIR, ASPR and ASYR of ASDs was 9.3 (95 %UI 7.7–11.1), 369.4 (95 %UI 305.9–441.2), 56.3 (95 %UI 36.8–81.5) per 100,000 people, respectively. It was different between males and females, and ASIR, ASPR and ASYR of ASDs among males were about three times higher than those in females. The results were consistent with previous studies (Lai and Baron-Cohen, 2015; Constantino et al., 2010; Kim et al., 2011; Zwaigenbaum et al., 2012). However, it is worth noting that the risk of undiagnosed ASD in women is much higher than in men (Bargiela et al., 2016). This gender bias has a serious impact on the health of girls and women with ASD, and it has been identified by the ASD academic circles as a key issue that needs to be studied and solved by research (Pellicano et al., 2014). The changing trends of age-standardized rates of ASDs showed that the ASIR of ASDs a slow growing trend globally. However, the ASPR and ASYR of ASDs showed a slow decreasing trend globally. Furthermore, when SDI was greater than 0.6, the ASIR, ASPR and ASYR of ASDs were increasing with SDI growth. The increase global burden of ASDs was attributed to a varies of efforts. First, heightened awareness and enhanced diagnostic methods have contributed to identifying more cases (Kim et al., 2011). Second, environmental factors are increasingly recognized as contributing to the rising incidence of ASDs (Modabbernia et al., 2017). Lastly, societal and demographic changes, more parents are choosing to have children at an older age, and the older age of the parents also influences the increased prevalence of ASDs (Wu et al., 2017). The global burden of ASDs has remained pro-rich, the income-related inequality tended not to change between 1990 and 2019. This may be due to the fact that high SDI countries have better access to health care facilities, and the higher ASIR, ASPR, and ASYR reported in these countries may reflect the better level of diagnosis rather than higher ASIR, ASPR, and ASYR of ASDs. On the other hand, some low SDI countries have limited health care resources and may not have enough epidemiological data on ASDs,

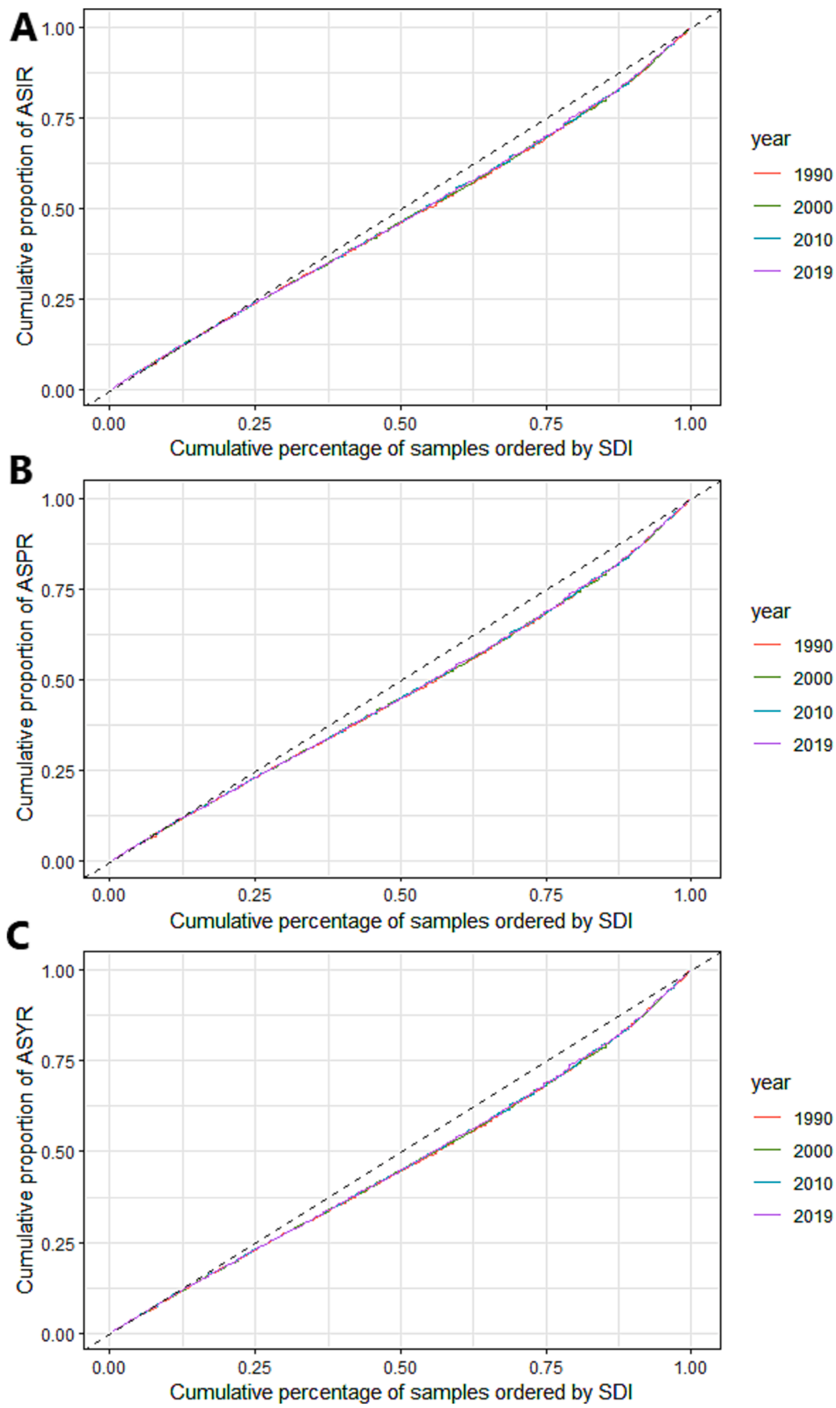

Fig. 4. Concentration curves for age standardized rate of autistic spectrum disorders between 1990 and 2019 (A) ASIR. (B) ASPR. (C) ASYR. ASIR, age-standardized incidence rate; ASPR, age-standardized prevalence rate; ASYR, age-standardized YLDs rate; YLDs, years lived with disability; SDI, socio-demographic index.

leading to inaccuracies (Samms-Vaughan, 2014). These results will improve the latest incidence, prevalence, and YLDs estimates and identify of the important contributing factors of burden and changing trends of ASDs. These findings will enhance recognition and care of ASDs, and to guide future research.

Previous research has shown that there was limited clinical or epidemiological evidence in ASDs (Baxter et al., 2015). Immense challenges remained and progress was uneven in estimating the incidence, prevalence, and YLDs of ASDs. ASDs were difficult to screen and diagnose in very young (non-verbal) children (Baxter et al., 2015). Our results revealed that the ASDs burden in the incident cases, prevalent cases, and YLDs increased worldwide. The overall number of the incident cases, prevalent cases, and YLDs increased by 1.5‰, 39.3% and 38.6%, respectively. This growth is expected to continue due to population growth and the ability of clinicians to understand and deal with ASDs increased accordingly (Collaborators" GMD, 2022). However, the age-standardized rates of prevalence and YLDs for ASDs showed a slow decreasing trend globally. The most likely explanation is that the effective intervention programs for ASDs have the potential to alleviate the severity of symptoms and reduce the risk of YLDs. However, the substantial burden of ASDs in lifespan has important public health and policy implications. Thus, support and interventions for patients with

Table 2
Concentration indices for age-standardized rate of autism spectrum disorders from 1990 to 2019.

	Concentration indices		p-value *	p-value #
	Mean	Standard Error		
ASIR				
Year of 1990	0.061	0.008	0.0000	
Year of 2000	0.059	0.008	0.0000	0.9854
Year of 2010	0.057	0.009	0.0000	
Year of 2019	0.056	0.009	0.0000	
ASPR				
Year of 1990	0.076	0.008	0.0000	
Year of 2000	0.074	0.009	0.0000	0.9883
Year of 2010	0.073	0.009	0.0000	
Year of 2019	0.072	0.009	0.0000	
ASYR				
Year of 1990	0.079	0.008	0.0000	
Year of 2000	0.077	0.008	0.0000	0.9777
Year of 2010	0.075	0.009	0.0000	
Year of 2019	0.074	0.009	0.0000	

The concentration index for age-standardized rate in incidence, prevalence and YLDs ranked by SDI. ASIR, age-standardized incidence rate; ASPR, the age-standardized prevalence rate; ASYR, the age-standardized YLDs rate.
* This method checks up the value of the age-standardized rate is zero by hypothesis testing. p-value < 0.05 means the age-standardized rate is not equal to 0, otherwise, the age-standardized rate is equal to 0.
# Check of variance was used among different year groups. p-value < 0.05 means there is significant difference in the age-standardized rate for different years, otherwise, no significant difference.

ASDs and their families need to extend beyond pediatric health and early education to primary health care providers at the community level, additional skills training and vocational support (Baxter et al., 2015).

However, overall, a high ASIR, ASPR and ASYR of ASDs was recorded in high SDI subgroup. A big surprise in our study is that the countries in which the SDI was approximately 0.6 had the lowest ASIR, ASPR and ASYR of ASDs. When SDI was greater than 0.6, the association between age-standardized rates of ASDs and SDI in 2019 are shown that the ASIR, ASPR and ASYR of ASDs were increasing with SDI growth. Additionally, the patients of ASDs were more in males than in females worldwide. Further study showed that the changing trend of ASIR, ASPR and ASYP showed a significant growing trend in males in high SDI subgroup from 1990 to 2019, but in other SDI subgroups, the ASIR, ASPR and ASYR of ASDs remained stable in males at the same time. However, in females, the ASIR, ASPR and ASYR of ASDs remained stable over 29 years in all SDI subgroups. These results highlight some managerial implications for further research into the effect of differential exposures to possible risk factors.

Several strengths and limitations in our study should be considered. The strengths of our study include the using of concentration curves and concentration indices to measure health inequality, which is sensitive to changes in population distribution among different socio-economic groups and can reflect the socio-economic dimensions of health inequality (Wagstaff et al., 1991). Additionally, our in-depth data mining and analysis of GBD data could fill the gap where the actual data on ASDs burden are sparse or unavailable. These results can effectively guide medical policy decision-making. At the same time, the present study has some limitations. First, the data coming from the GBD study uses the WHO world standard population. Although this ensures consistent comparisons between studies, it may not accurately capture the unique age distribution of specific regions or countries, which may lead to bias in age specific calculations. Second, when evaluating the severity of health losses caused by diseases, the GBD uses disability weights. These weights are derived from comprehensive surveys and research. However, they may not always be consistent with the different cultural and social beliefs of the studied disease (Salomon et al., 2015). Third, our research is conducted at the global and national levels. In order to provide evidence within a specific country, it is necessary to conduct research within that country. Fourth, the GBD uses modeling techniques such as cross-walking to address data gaps. However, these methods come with fundamental assumptions that may affect the final estimate (Haagsma et al., 2013). Especially, there might be more uncertainty in the estimated value in some low SDI countries. The absence of data from developing countries, the limited information for adults and the lack of studies reporting population-representative estimates for incidence, prevalence, and YLDs meant that generalized hypothesis had to be made to build a comprehensive model for the distribution of ASDs. To move from estimations and assumptions toward certainties, future studies should set up special databases. In particular, the data of the ASDs routine surveillance and sentinel surveillance and special survey in developing countries are urgently required.

5. Conclusions

The global burden of ASDs has remained higher in males and pro-rich, the income-related inequality tended not to change between 1990 and 2019.

Table 3
The regression equation between concentration indices for age-standardized rate of ASDs and its influence factors.

Factor	Coefficient	Standard error	Contribution rate §	p-value *	p-value #	R-squared
ASIR						
SDI levels	1.09	0.09	8.16%	0.000		
sex	10.31	0.24	91.81%	0.000	0.0000	0.8661
year	0.11	0.01	0.03%	0.425		
cons	−31.66	28.47	–	0.267		
ASPR						
SDI levels	51.29	3.65	11.16%	0.000		
sex	409.37	10.32	88.83%	0.000	0.0000	0.8568
year	0.32	0.60	0.02%	0.594		
cons	−1020.58	1195.31	–	0.394		
ASYR						
SDI levels	7.94	0.55	11.41%	0.000		
sex	62.56	1.57	88.57%	0.000	0.0000	0.8589
year	0.05	0.09	0.02%	0.548		
cons	−168.20	181.37	–	0.354		

The concentration index for age-standardized rate in incidence, prevalence and YLDs ranked by SDI. ASIR, age-standardized incidence rate; ASPR, the age-standardized prevalence rate; ASYR, the age-standardized YLDs rate.
§ Contribution rate, the contribution proportion of each factor to concentration indices of age-standardized rate in R-squared for the regression equation.
* This method checks up the coefficient is zero by hypothesis testing. p-value < 0.05 means the coefficient has statistical significance, the coefficient is not equal 0, otherwise, has no statistical significance.
# p-value < 0.05 means the regression equation is of significance and applicable, otherwise, has no statistical significance.

CRediT authorship contribution statement

Lijun Yang: Data curation, Formal analysis, Methodology, Writing – original draft, Writing – review & editing. **Feng Chen:** Data curation, Project administration, Supervision, Writing – original draft, Writing – review & editing. **Xingyu He:** Writing – original draft, Writing – review & editing. **Yu Tong:** Writing – original draft, Writing – review & editing. **QingYun Li:** Writing – original draft, Writing – review & editing. **Ting Yang:** Writing – original draft, Writing – review & editing. **Rong Peng:** Funding acquisition, Project administration, Writing – review & editing. **Huiqing Wang:** Funding acquisition, Project administration, Writing – review & editing. **Zheng Shi:** Funding acquisition, Project administration, Writing – review & editing.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

Data will be made available on request.

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Patient consent statement

Not applicable.

Appendix A. Supplementary data

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