

Preplanned Studies

Shifting Burden of Neural Tube Defects from Early-Life Mortality to an Aging Population Living with Disability — China, 1990–2023

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Summary

What is already known about this topic?

The burden of neural tube defects (NTDs) has declined with folic acid supplementation and fortification, but comprehensive all-age estimates are lacking.

What is added by this report?

Using data from the Global Burden of Disease Study 2023, we assessed the all-age NTD burden in China during 1990–2023. Incidence, mortality, and disability-adjusted life year (DALY) rates declined significantly, whereas prevalence increased among adults aged ≥ 50 years and DALY rates increased among those aged ≥ 75 years, indicating a shift from early-life mortality to disability in an aging population.

What are the implications for public health practice?

Life-course care should combine primary prevention, long-term rehabilitation and multidisciplinary management for people with NTDs.

China, all three rates declined more among men than among women, and incidence and mortality rates declined most sharply among children aged < 5 years. Age-specific EAPC analyses in China showed increasing prevalence and DALY rates among adults aged ≥ 50 years. In 2023, China's SDI was within the high-SDI range; over 1990–2023, reductions in its incidence, mortality, and DALY rates exceeded those in every SDI quintile. Joinpoint-derived AAPCs further showed increasing DALY rates among adults aged ≥ 75 years in China and the high-middle-SDI quintile and among those aged ≥ 50 years in the high-SDI quintile.

Conclusion: The NTD burden in China has declined since 1990, but a shift toward older age groups highlights the need for integrated life-course care and sustained prevention.

ABSTRACT

Background: Although the perinatal burden of neural tube defects (NTDs) has declined, comprehensive all-age burden assessments in China and sociodemographic index (SDI) quintiles are lacking.

Methods: Using data from the Global Burden of Diseases, Injuries, and Risk Factors Study 2023, we analyzed NTD burden trends in China and five SDI quintiles during 1990–2023. Rate trends were assessed using estimated annual percentage changes (EAPCs) and Joinpoint-derived average annual percentage changes (AAPCs).

Results: In China, NTD incidence, mortality, and disability-adjusted life year (DALY) rates decreased significantly during 1990–2023, whereas the prevalence rate showed no significant change. Within

Neural tube defects (NTDs) are serious congenital anomalies associated with perinatal mortality and lifelong disability. Globally, birth defects burden has decreased, particularly in regions with a low sociodemographic index (SDI) (1). In China, folic acid supplementation has contributed to a decline in NTD birth prevalence from 5.3 to 0.5 per 10,000 between 2007 and 2021 (2). Meanwhile, rising years lived with disability suggest a shift toward nonfatal outcomes (3). Although, most studies have focused on perinatal burden of NTDs, improve survival, particularly among people with spina bifida, has resulted in aging population living with disability. A nationwide insurance claims–based study estimated that at least 92,551 people in the United States were living with spina bifida in 2019, with prevalence documented across all adult age groups, including those aged ≥ 65 years (4). Comprehensive all-age assessments in China and comparisons across SDI quintiles remain lacking.

Using the Global Burden of Diseases, Injuries, and Risk Factors Study 2023 (GBD 2023), we analyzed all-age NTD burden by sex and age in China during 1990–2023, with five SDI quintiles as contextual comparators.

Absolute numbers and rates of incidence, prevalence, mortality, and disability-adjusted life years (DALYs) for NTDs in China and across the five SDI quintiles were extracted from the GBD 2023 (5). Data are publicly available through the Global Health Data Exchange (GHDx) GBD Results Tool <https://vizhub.healthdata.org/gbd-results/>. The SDI is a composite index ranging from 0 to 1 and based on fertility among those younger than 25 years, education among those aged 15 years and older, and lag-distributed income per capita (5). Based on 2023 values, locations were categorized as low-SDI (0.0000–0.5316), low-middle-SDI (0.5316–0.6305), middle-SDI (0.6305–0.6767), high-middle-SDI (0.6767–0.7188), and high-SDI (0.7188–1.0000) (<https://ghdx.healthdata.org/record/gbd-2023-socio-demographic-index-sdi>). Examples are provided in [Supplementary Table S1](#) (available at <https://weekly.chinacdc.cn>). Although GBD 2023 does not explicitly assign China to a category, its 2023 SDI was estimated at 0.7275, within the high-SDI range. DALYs were calculated as years of life lost plus years lived with a disability. Rates were age-standardized to the GBD world standard population (5). Burden trends from 1990 to 2023 were analyzed by sex and age in China and compared the five SDI quintiles.

Statistical significance was defined as a two-sided α level of 0.05. Percentage changes in absolute numbers from 1990 to 2023 and 95% uncertainty intervals (UIs) were estimated using the delta method. Rate trends were assessed using estimated annual percentage changes (EAPCs) with 95% UIs from log-linear models. Joinpoint regression (version 5.4.0; National Cancer Institute, Bethesda, MD, USA) identified changes in trend slope, allowing a maximum of 4 joinpoints and using permutation tests ($\alpha=0.05$). Segment-specific annual percentage changes (APCs) and average annual percentage changes (AAPCs) for 1990–2023 were calculated. Additional analyses and graphics were generated using R, version 4.5.2 (R Foundation for Statistical Computing, Vienna, Austria). Detailed ICD definitions, formulas, and age-standardization methods are provided in the Supplementary Materials.

In China, the numbers of incident cases, prevalent

cases, deaths, and DALYs in 2023 were 3,258.36 (95% UI: 2,842.75–3,694.51), 71,879.03 (95% UI: 59,349.41–86,825.24), 411.22 (95% UI: 284.88–570.67), and 55,780.00 (95% UI: 41,672.03–71,605.38), respectively ([Table 1](#)). Compared with 1990, these numbers decreased by 88.75% (95% UI: 88.72–88.78), 33.95% (95% UI: 33.73–34.16), 97.31% (95% UI: 97.29–97.32), and 96.00% (95% UI: 95.98–96.03), respectively. Incidence, mortality, and DALY rates declined significantly, with EAPCs of -4.17 (95% UI: -4.81 to -3.52), -10.61 (95% UI: -11.48 to -9.73), and -9.96 (95% UI: -10.76 to -9.15), respectively; prevalence showed no significant change (EAPC: 0.11, 95% UI: -0.49 to 0.72). Age-standardized incidence, mortality, and DALY rates were higher in men in 1990 but higher in women by 2023, reflecting steeper declines in men ([Supplementary Table S2](#), available at <https://weekly.chinacdc.cn>). Age-specific EAPCs were heterogeneous ([Supplementary Table S3](#), available at <https://weekly.chinacdc.cn>). Incidence and mortality rates declined most sharply among children aged <5 years. Prevalence rate showed no significant trend among persons aged ≤ 49 years but increased among those aged ≥ 50 years. Mortality rate declined in all age groups aged ≤ 74 years, while DALY rates declined among those aged ≤ 49 years but increased among those aged ≥ 50 years.

[Table 1](#) presents NTD burden across the five SDI regions and China. Temporal trends are shown in [Figure 1A–D](#). In both 1990 and 2023, the age-standardized incidence rates were highest in the low-SDI regions and lowest in the high-SDI regions. All SDI quintiles recorded significant declines, greatest in the high-middle-SDI regions (EAPC: -3.10 , 95% UI: -3.34 to -2.85) and the smallest in the low-SDI regions (EAPC: -1.37 , 95% UI: -1.45 to -1.29), while China experienced a greater decline (EAPC: -4.17 , 95% UI: -4.81 to -3.52). Regarding prevalence, the steepest decline was observed in low-middle-SDI regions (EAPC: -1.23 , 95% UI: -1.32 to -1.13), whereas high-SDI regions showed a non-significant increase. China's EAPC for prevalence was not statistically significant; rates decreased during 1990–1999, rose after 2005, and remained below all SDI quintiles throughout the study period. Age-standardized mortality rates fell across all SDI quintiles, were inversely associated with SDI, and declined more steeply at higher SDI regions (EAPC: -5.15 , 95% UI: -5.44 to -4.85 in high-SDI *vs.* -1.52 ,

TABLE 1. Burden of NTDs for China and five SDI quintiles, 1990–2023.

Indicator	Group	Absolute number [†] (95% UI)			Age-standardized rates/100,000 (95% UI)		
		1990	2023	Percentage change (%)	1990	2023	EAPC
Incidence	China	28,967.67 (23,124.54, 34,854.15)	3,258.36 (284.75, 3694.51)	-88.75 (-88.78, -88.72)	2.66 (2.12, 3.20)	0.73 (0.64, 0.83)	-4.17 (-4.81, -3.52)*
	Low-SDI	76,560.79 (63,623.45, 90,374.77)	79,182.30 (68,659.65, 90,100.85)	3.42 (3.20, 3.65)	4.84 (4.02, 5.71)	3.29 (2.85, 3.74)	-1.37 (-1.45, -1.29)*
	Low-middle-SDI	36,009.72 (29,721.27, 42,536.86)	17,930.44 (15,417.32, 20,478.35)	-50.21 (-50.32, -50.09)	3.33 (2.75, 3.93)	1.72 (1.48, 1.96)	-2.27 (-2.38, -2.15)*
	Middle-SDI	19,629.15 (16,230.39, 23,289.35)	8,120.66 (6,986.24, 9,291.53)	-58.63 (-58.72, -58.53)	2.40 (1.99, 2.85)	1.05 (0.91, 1.21)	-2.73 (-2.85, -2.62)*
	High-middle-SDI	31,131.38 (25,663.69, 36,583.50)	7,831.33 (6,805.87, 8,858.02)	-74.84 (-74.90, -74.79)	2.50 (2.06, 2.94)	0.94 (0.82, 1.07)	-3.10 (-3.34, -2.85)*
Prevalence	High-SDI	25,490.93 (21,273.72, 29,478.13)	8,285.07 (7,274.61, 9,173.46)	-67.50 (-67.56, -67.43)	1.60 (1.34, 1.85)	0.80 (0.70, 0.88)	-2.08 (-2.46, -1.71)*
	China	108,818.21 (83,544.31, 139,848.11)	71,879.03 (59,349.41, 86,825.24)	-33.95 (-34.16, -33.73)	9.01 (6.91, 11.56)	6.65 (5.49, 7.98)	0.11 (-0.49, 0.72)
	Low-SDI	287,742.19 (240,018.50, 340,822.68)	468,114.72 (394,972.98, 546,796.62)	62.69 (62.30, 63.07)	27.02 (22.57, 31.91)	22.37 (18.92, 26.03)	-0.73 (-0.79, -0.66)*
	Low-middle-SDI	187,472.55 (155,545.61, 221,424.44)	184,920.54 (154,325.66, 21,313.60)	-1.36 (-1.60, -1.12)	21.50 (17.96, 25.49)	15.20 (12.72, 17.86)	-1.23 (-1.32, -1.13)*
	Middle-SDI	113,126.16 (92,390.47, 134,857.69)	107,154.03 (90,001.47, 126,420.37)	-5.28 (-5.52, -5.04)	15.64 (12.84, 18.67)	11.46 (9.60, 13.53)	-1.10 (-1.17, -1.04)*
Mortality	High-middle-SDI	185,446.24 (152,453.83, 225,297.93)	154,583.15 (130,357.10, 181,559.55)	-16.64 (-16.86, -16.43)	14.63 (12.04, 17.66)	10.74 (9.07, 12.60)	-0.87 (-0.95, -0.79)*
	High-SDI	238,132.61 (198,630.37, 284,527.19)	245,168.86 (208,170.91, 285,261.55)	2.95 (2.71, 3.20)	12.20 (10.15, 14.57)	11.62 (9.87, 13.56)	0.08 (-0.11, 0.27)
	China	15,262.52 (8,072.40, 24,418.03)	411.22 (284.88, 570.67)	-97.31 (-97.32, -97.29)	1.40 (0.74, 2.24)	0.08 (0.05, 0.11)	-10.61 (-11.48, -9.73)*
	Low-SDI	24,679.78 (12,022.23, 42,000.93)	24,914.49 (13,214.08, 43,143.28)	0.95 (0.09, 1.81)	1.64 (0.80, 2.78)	1.05 (0.56, 1.82)	-1.52 (-1.60, -1.43)*
	Low-middle-SDI	12,872.32 (6,503.18, 22,964.32)	6,610.61 (3,603.36, 12,818.25)	-48.64 (-49.13, -48.16)	1.22 (0.62, 2.19)	0.62 (0.34, 1.21)	-2.10 (-2.16, -2.05)*
DALYs	Middle-SDI	9,350.87 (5,600.80, 14,656.97)	4,875.24 (2,820.84, 8,000.74)	-47.86 (-48.24, -47.49)	1.16 (0.69, 1.81)	0.62 (0.36, 1.01)	-2.34 (-2.49, -2.19)*
	High-middle-SDI	15,496.72 (10,683.06, 21,740.86)	2,854.75 (1,945.55, 4,524.17)	-81.58 (-81.68, -81.47)	1.25 (0.86, 1.75)	0.32 (0.21, 0.50)	-4.95 (-5.22, -4.68)*
	High-SDI	13,118.72 (9,392.01, 17,175.00)	2,379.40 (2,058.16, 2,738.40)	-81.86 (-81.92, -81.80)	0.81 (0.58, 1.06)	0.20 (0.17, 0.23)	-5.15 (-5.44, -4.85)*
	China	1,395,231.49 (764,333.07, 2,213,112.98)	55,780.00 (41,672.03, 71,605.38)	-96.00 (-96.03, -95.98)	127.44 (69.40, 202.51)	8.58 (6.20, 11.57)	-9.96 (-10.76, -9.15)*
	Low-SDI	2,283,209.20 (1,158,363.55, 3,824,453.02)	2,353,059.59 (1,300,231.83, 3,979,568.38)	3.06 (2.22, 3.90)	152.82 (78.93, 253.73)	99.58 (55.23, 168.01)	-1.47 (-1.55, -1.39)*
DALYs	Low-middle-SDI	1,198,672.25 (632,670.89, 2,094,077.88)	639,258.65 (373,652.71, 1,193,086.20)	-46.67 (-47.14, -46.20)	114.52 (60.79, 199.70)	59.61 (34.53, 111.97)	-2.04 (-2.10, -1.99)*
	Middle-SDI	865,018.51 (538,477.93, 1,338,569.17)	462,595.77 (276,853.24, 741,231.94)	-46.52 (-46.89, -46.16)	107.18 (66.90, 165.42)	58.23 (34.67, 93.56)	-2.29 (-2.44, -2.15)*
	High-middle-SDI	1,431,006.70 (995,628.60, 1,980,713.32)	291,729.17 (212,474.68, 435,501.80)	-79.61 (-79.72, -79.51)	114.96 (79.96, 159.24)	30.89 (21.90, 47.53)	-4.73 (-4.99, -4.47)*
	High-SDI	1,226,489.11 (891,184.32, 1,597,333.63)	266,727.75 (228,514.79, 307,842.61)	-78.25 (-78.32, -78.18)	75.25 (54.43, 98.18)	20.47 (17.70, 23.53)	-4.76 (-5.05, -4.48)*

Abbreviation: NTDs=neural tube defect; SDI=sociodemographic index; EAPC=estimated annual percentage change; UI=uncertainty interval; DALYs=disability-adjusted life year.

* $P<0.05$.

† Absolute numbers represent incident cases, prevalent cases, deaths, and total DALYs, whereas rates represent incidence, prevalence, mortality, and DALY rates.

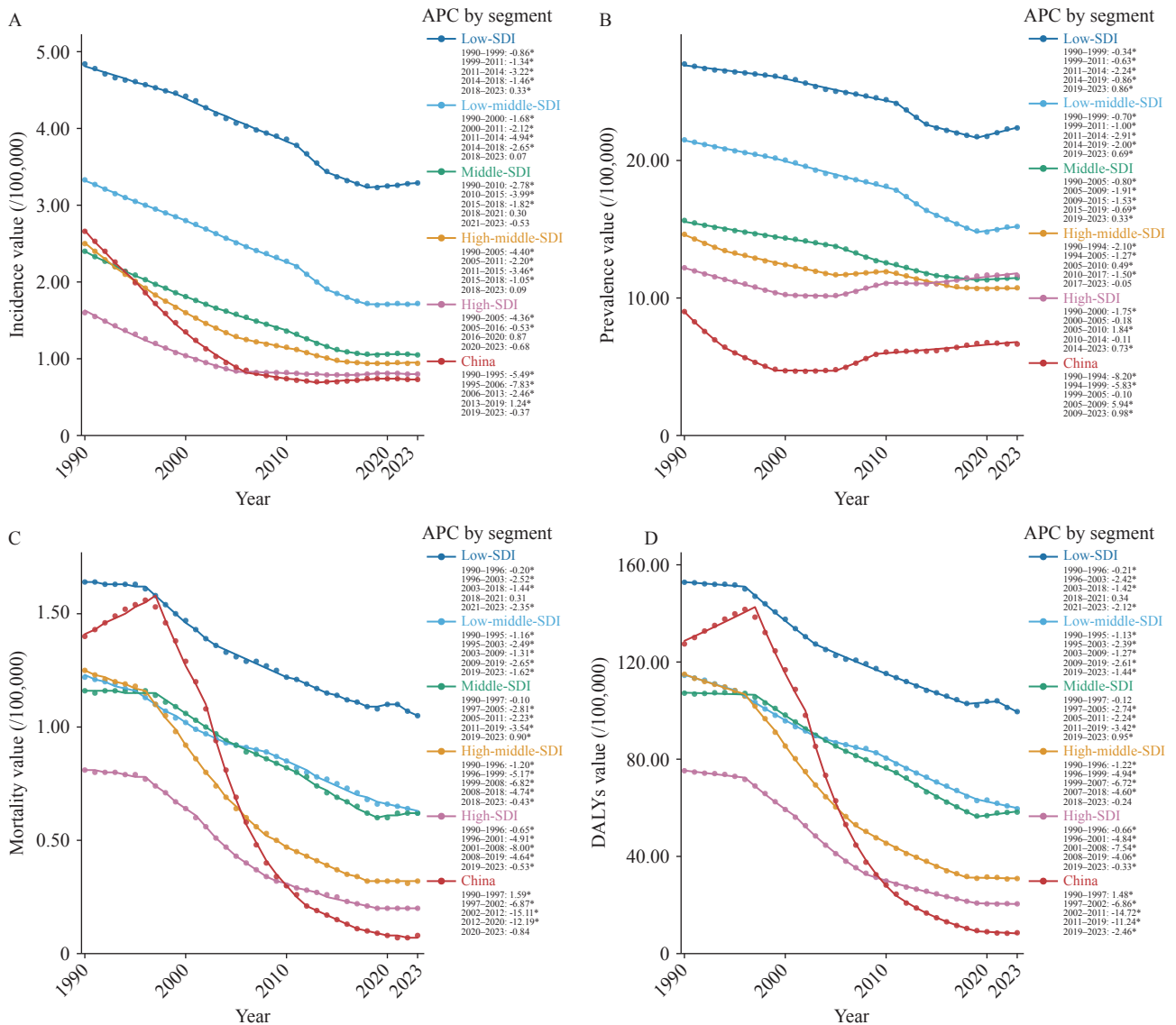


FIGURE 1. Age-standardized incidence, prevalence, mortality, DALY rates of NTDs for China and five SDI quintiles, 1990–2023. (A) Incidence; (B) Prevalence; (C) Mortality; and (D) DALYs.

Abbreviation: DALY=disability-adjusted life year; NTDs=neural tube defect; SDI=sociodemographic index; APC=annual percentage change.

* $P < 0.05$.

95% *UI*: -1.60 to -1.43 in low-SDI). DALY rates were also inversely related to SDI, with greater declines at higher SDI regions (EAPC: -4.76, 95% *UI*: -5.05 to -4.48 in high-SDI *vs.* -1.47, 95% *UI*: -1.55 to -1.39 in low-SDI). China's DALY EAPC was -9.96 (95% *UI*: -10.76 to -9.15), a steeper reduction than across all SDI quintiles.

In China, the incidence and mortality rates have decreased in all age groups (Figure 2). The prevalence rate showed a downward trend among those under 50 years of age, while it showed an upward trend among those 50 years of age and older (AAPC: 1.40, 95% *UI*:

1.36–1.45 in 50–74 years age group; and 1.87, 95% *UI*: 1.82–1.92 in 75 years and above age group). The DALY rate showed a downward trend among individuals under 75 years of age, while it showed an upward trend among those 75 years of age and older (AAPC: 2.14, 95% *UI*: 2.09–2.19), consistent with the results of the EAPC fitting model. Analyses stratified by SDI quintile and age group further revealed that the prevalence of NTDs increased among individuals aged 50 years and older in the high-middle and high-SDI regions. The DALY rate for NTDs showed an upward trend among people aged 50 years and older in high-

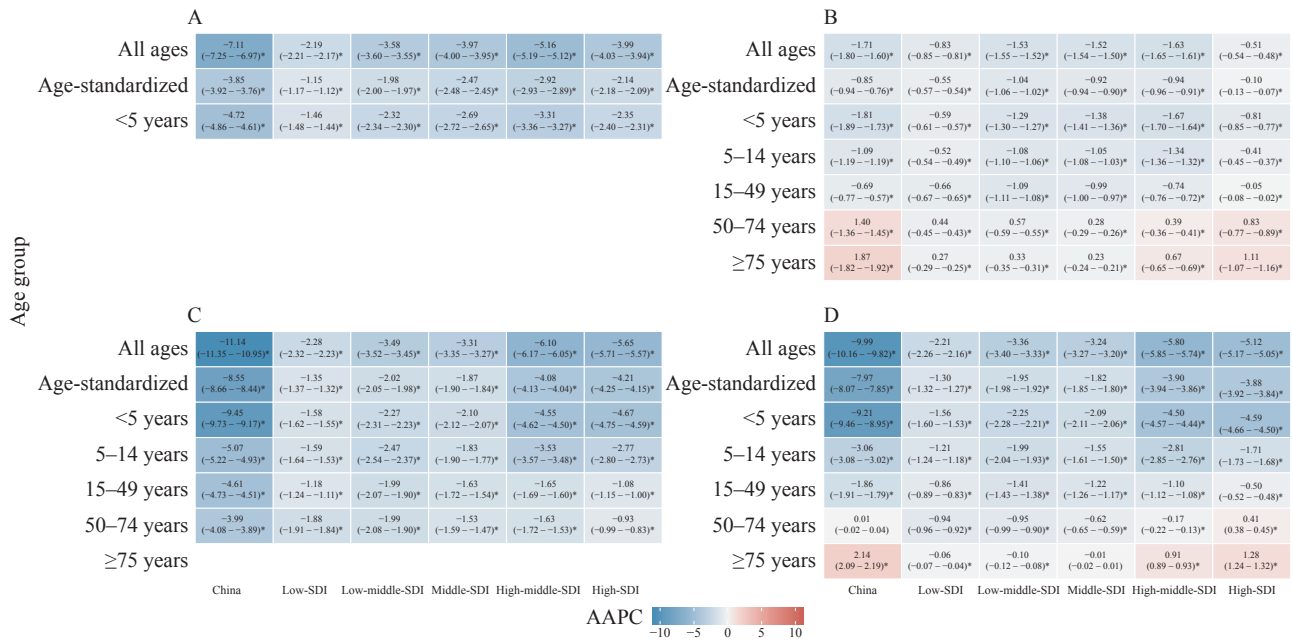


FIGURE 2. AAPCs (95% UI) in incidence, prevalence, mortality, and DALY rates of NTDs by age group for China and five SDI quintiles, 1990–2023. (A) Incidence; (B) Prevalence; (C) Mortality; and (D) DALYs.

Abbreviation: AAPCs=average annual percentage changes; UI=uncertainty interval; DALY=disability-adjusted life year; NTDs=neural tube defects; SDI=sociodemographic index.

* $P < 0.05$.

SDI regions, and among those aged 75 years and older in high-middle-SDI regions.

DISCUSSION

The burden of NTDs in China declined substantially, reflecting improved prevention and control (2). Regional surveillance data support this trend; from 1993 to 1996, folic acid use reduced spina bifida by 78% in northern China and by 51% in southern China (6). China's greater decline relative to the SDI quintiles may reflect the early and sustained implementation of nationwide folic acid interventions and advances in maternal and neonatal care. However, the age-standardized prevalence rates in China rebounded from 2005 to 2023, indicating a recent reversal of the previous decline. This rebound may reflect improved survival, expanded surveillance, and greater diagnostic capacity and healthcare access, increasing the detection of individuals with NTDs, including those with associated Chiari II malformations and hydrocephalus (1,7).

Higher SDI was associated with lower age-standardized incidence, mortality, and DALY rates and steeper declines in these measures. A companion GBD 2021 analysis of congenital birth defects similarly

found that mortality and DALY rates in children were negatively correlated with SDI and declined most rapidly in high- and high-middle-SDI regions, where high-quality perinatal care, folic acid fortification, and organized surveillance are more widespread (8). High-SDI regions also tend to report higher or rising birth prevalence than some middle-SDI regions, resulting in a U-shaped relationship between prevalence and SDI (8). The rising age-standardized prevalence in high-SDI regions and China may reflect improved case identification and longer survival rather than a reversal of gains in primary prevention.

The burden of NTDs is shifting toward older age groups, particularly in higher SDI regions. A 50-year Swedish register study documented a decline in birth prevalence from 5.2 to 1.2 per 10,000 births and an improvement in first-year survival from 75 to 94%, with stable mortality thereafter, resulting in an accumulating adult population over successive decades (9). Adult cohorts indicate that many people with spina bifida are now middle-aged or older and often have complex multisystem morbidity (10). This demographic shift underscores the need to strengthen life-course care pathways and long-term rehabilitation among older people with NTDs.

This study has some limitations. First, the study relies on modeled estimates from GBD 2023, which

are subject to inherent uncertainty, especially in low-SDI regions, where surveillance systems and vital registration data remain limited. Second, the GBD estimates do not include information on prenatal diagnosis or pregnancy termination, making it difficult to distinguish between true epidemiological changes and those resulting from changes in case ascertainment and reporting. Finally, the ecological framework of this study cannot fully explain the recent increases in age-standardized incidence and prevalence rates.

In conclusion, although the NTD burden in China has declined substantially since 1990, prevalence has recently increased and the burden has shifted toward older age groups, with a similar pattern observed in high-SDI regions. This shift highlights the need to integrate life-course care and rehabilitation with existing prevention strategies to reduce long-term disability among the growing population of older people with NTDs.

Conflicts of interest: No conflicts of interest.

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Ethics approval and consent to participate: This study was a secondary analysis of publicly available data from the Global Burden of Disease Study 2023 (GBD 2023) database. Because the data were anonymized and did not involve direct interactions with human participants, ethical approval and informed consent were not required for this study.

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SUPPLEMENTARY MATERIALS

Disease definitions

Neural tube defects (NTDs) were defined using International Classification of Diseases, Tenth Revision (ICD-10) codes Q00-Q01.9 and Q05-Q05.9 and International Classification of Diseases, Ninth Revision (ICD-9) codes 740-741.9 and 742.0.

Age standardization

Age-standardized rates were obtained from GBD 2023 and calculated using the GBD world standard population. Beginning with GBD 2017, the standard population was updated using the unweighted mean of the age-specific proportional population distributions of national locations with populations greater than 5 million in each GBD year.

SUPPLEMENTARY TABLE S1. Examples of countries or territories by SDI quintile and SDI index value in 2023.

SDI quintile	Location name	2023 SDI index value
Low-SDI	Afghanistan	0.3337
	Angola	0.4991
	Bangladesh	0.5171
	Chad	0.2393
	Democratic Republic of the Congo	0.3950
	Haiti	0.4638
	Mozambique	0.3417
	Niger	0.2030
	Uganda	0.4421
Low-middle-SDI	Yemen	0.4464
	Belize	0.6285
	Democratic People's Republic of Korea	0.5771
	Ghana	0.5737
	Guatemala	0.5538
	Morocco	0.6124
	Myanmar	0.5320
	Namibia	0.6195
	Samoa	0.6045
Middle-SDI	Syrian Arab Republic	0.5887
	Tajikistan	0.5512
	Algeria	0.6578
	Bolivia (Plurinational State of)	0.6317
	Egypt	0.6765
	Gabon	0.6309
	Maldives	0.6610
	Mongolia	0.6597
	Palestine	0.6380
	Paraguay	0.6741
	Tonga	0.6360
	Viet Nam	0.6430

Continued

SDI quintile	Location name	2023 SDI index value
High-middle-SDI	Albania	0.7068
	Armenia	0.7173
	Azerbaijan	0.7053
	Botswana	0.6776
	Colombia	0.6888
	Costa Rica	0.7154
	Cuba	0.6949
	Fiji	0.6864
	Thailand	0.6872
	Turkmenistan	0.6822
High-SDI	Argentina	0.7647
	Australia	0.8529
	Canada	0.8873
	Germany	0.8786
	Kazakhstan	0.7272
	Lebanon	0.7237
	Malaysia	0.7704
	Republic of Korea	0.8917
	Saudi Arabia	0.8284
	Switzerland	0.9461
Not assigned	Brazil	0.6839
	China *	0.7275
	Ethiopia	0.3937
	India	0.6070
	Indonesia	0.6657
	Iran (Islamic Republic of)	0.7176
	Japan	0.8759
	Nigeria	0.5119
	Russian Federation	0.8225
	United States of America	0.8765

Abbreviation: SDI=sociodemographic index.

* China's SDI index value is 0.7275 in 2023, which falls within the high-SDI range according to the official GBD 2023 quintile cut-off.

Statistical Analysis

For absolute numbers of incident cases, prevalent cases, deaths, and DALYs, the percentage change from 1990 to 2023 was calculated as: $\frac{V_{2023} - V_{1990}}{V_{1990}} \times 100\%$, where V_{1990} and V_{2023} denote the values in 1990 and 2023, respectively. The corresponding 95% uncertainty intervals (UIs) were estimated using the delta method.

For the rate of each indicator, the overall temporal trend was assessed using the estimated annual percentage change (EAPC). The following log-linear model was fitted: $\ln(R_t) = \alpha + \beta t + \varepsilon_t$, where R_t is the rate in year t , α is the intercept, β is the annual slope, and ε_t is the error term. The EAPC was calculated as: $EAPC = [\exp(\beta) - 1] \times 100$. The 95% UI for the EAPC was derived from the fitted log-linear model.

Joinpoint regression was used to identify changes in trend slope. For each identified segment (k), the annual percentage change (APC) was calculated as: $APC_k = [\exp(\beta_k) - 1] \times 100$. The where β_k is the slope coefficient for segment k. The average annual percentage change (AAPC) for 1990–2023 was calculated as the duration-weighted

SUPPLEMENTARY TABLE S2. Burden of NTDs in China by sex, 1990–2023.

Indicator	Group	Absolute number [†] (95% UI)			Age-standardized rates/100,000 (95% UI)		
		1990	2023	Percentage change (%)	1990	2023	EAPC
Incidence	Total	28,967.67 (23,124.54, 34,854.15)	3,258.36 (2,842.75, 3,694.51)	−88.75 (−88.78, −88.72)	2.66 (2.12, 3.20)	0.73 (0.64, 0.83)	−4.17 (−4.81, −3.52)*
	Male	16,144.06 (12,863.04, 19,730.37)	1,679.17 (1,463.42, 1,896.83)	−89.60 (−89.62, −89.57)	2.79 (2.22, 3.41)	0.70 (0.61, 0.80)	−4.49 (−5.13, −3.85)*
	Female	12,823.61 (10,146.78, 15,518.55)	1,579.20 (1,377.11, 17,94.04)	−87.69 (−87.72, −87.65)	2.51 (1.99, 3.04)	0.76 (0.67, 0.87)	−3.79 (−4.42, −3.14)*
	Total	108,818.21 (83,544.31, 139,848.11)	71,879.03 (59,349.41, 86,825.24)	−33.95 (−34.16, −33.73)	9.01 (6.91, 11.56)	6.65 (5.49, 7.98)	0.11 (−0.49, 0.72)
	Male	57,047.72 (43,884.85, 72,368.86)	38,752.15 (32,111.89, 46,629.93)	−32.07 (−32.28, −31.86)	9.08 (6.99, 11.54)	6.79 (5.57, 8.20)	0.06 (−0.48, 0.60)
	Female	51,770.49 (39,322.21, 66,986.88)	33,126.88 (27,072.38, 40,038.84)	−36.01 (−36.22, −35.80)	8.95 (6.80, 11.57)	6.50 (5.35, 7.77)	0.17 (−0.52, 0.87)
Mortality	Total	15,262.52 (8,072.40, 24,418.03)	411.22 (284.88, 570.67)	−97.31 (−97.32, −97.29)	1.40 (0.74, 2.24)	0.08 (0.05, 0.11)	−10.61 (−11.48, −9.73)*
	Male	8,863.77 (4,224.18, 17,072.26)	192.16 (104.76, 297.62)	−97.83 (−97.85, −97.81)	1.53 (0.73, 2.95)	0.06 (0.03, 0.10)	−11.69 (−12.64, −10.74)*
	Female	6,398.75 (3,034.62, 11,323.23)	219.06 (128.45, 350.43)	−96.58 (−96.60, −96.55)	1.25 (0.59, 2.21)	0.09 (0.05, 0.15)	−9.47 (−10.28, −8.65)*
	Total	1,395,231.49 (764,333.07, 2,213,112.98)	55,780.00 (41,672.03, 71,605.38)	−96.00 (−96.03, −95.98)	127.44 (69.40, 202.51)	8.58 (6.20, 11.57)	−9.96 (−10.76, −9.15)*
	Male	808,850.10 (393,333.73, 1,542,350.56)	27,283.96 (18,826.78, 37,223.41)	−96.63 (−96.65, −96.60)	139.37 (67.66, 266.18)	7.33 (4.73, 10.92)	−10.89 (−11.75, −10.02)*
	Female	586,381.39 (280,458.44, 1,025,532.93)	28,496.04 (19,893.00, 40,242.06)	−95.14 (−95.18, −95.10)	113.95 (54.33, 199.80)	10.03 (6.21, 15.35)	−8.94 (−9.69, −8.18)*

Abbreviation: NTDs=neural tube defects; EAPC=estimated annual percentage change; UI=uncertainty interval; DALYs=disability-adjusted life years.

* $P < 0.05$.

[†] Absolute numbers represent incident cases, prevalent cases, deaths, and total DALYs, whereas rates represent incidence, prevalence, mortality, and DALY rates.

geometric mean of the segment-specific APCs: $AAPC = \left\{ \exp \left[\frac{\sum_{k=1}^K w_k \beta_k}{\sum_{k=1}^K w_k} \right] - 1 \right\} \times 100$, where K is the total number of identified segments and w_k is the duration, in years, of segment k .

SUPPLEMENTARY TABLE S3. Burden of NTDs in China by age group, 1990–2023.

Indicator	Age group (years)	Absolute number [†] (95% UI)			Age-specific rates/100,000 (95% UI)		
		1990	2023	Percentage change (%)	1990	2023	EAPC
Incidence	<5	28,967.67 (23,124.54, 34,854.15)	3,258.36 (2,842.75, 3,694.51)	−88.75 (−88.78, −88.72)	26.13 (20.86, 31.44)	5.24 (4.57, 5.94)	−4.70 (−5.15, −4.24)*
		33,636.61 (25,902.89, 42,673.17)	10,078.06 (8,279.60, 12,053.12)	−70.04 (−70.13, −69.95)	30.35 (23.37, 38.50)	16.21 (13.32, 19.39)	−0.72 (−1.51, 0.07)
Prevalence	5–14	31,183.63 (23,648.15, 39,957.52)	19,372.22 (16,052.01, 23,345.94)	−37.88 (−38.08, −37.68)	15.06 (11.42, 19.29)	10.20 (8.45, 12.29)	−0.04 (−0.74, 0.67)
	15–49	41,291.46 (30,730.95, 54,380.37)	30,728.30 (25,245.62, 37,301.22)	−25.58 (−25.84, −25.32)	6.18 (4.60, 8.13)	4.76 (3.91, 5.78)	0.12 (−0.37, 0.61)
	50–74	2,497.05 (1,645.49, 3,568.67)	10,182.51 (7,810.44, 12,835.11)	307.78 (305.92, 309.65)	1.44 (0.95, 2.06)	2.24 (1.72, 2.82)	1.96 (1.67, 2.25)*
	≥75	209.46 (134.61, 311.92)	1,517.95 (1,149.60, 1,897.09)	624.68 (621.13, 628.23)	1.08 (0.69, 1.60)	1.96 (1.48, 2.45)	2.43 (2.14, 2.73)*
	<5	14,916.00 (7,820.86, 24,030.19)	341.41 (210.54, 496.61)	−97.71 (−97.73, −97.70)	13.46 (7.06, 21.68)	0.55 (0.34, 0.80)	−11.10 (−12.05, −10.12)*
	5–14	199.17 (116.75, 315.83)	32.80 (22.25, 49.17)	−83.53 (−83.64, −83.43)	0.10 (0.06, 0.15)	0.02 (0.01, 0.03)	−5.86 (−6.12, −5.60)*
Mortality	15–49	130.63 (75.64, 193.88)	26.38 (17.86, 39.58)	−79.80 (−79.93, −79.68)	0.020 (0.011, 0.029) [§]	0.004 (0.003, 0.006)	−5.29 (−5.68, −4.90)*
	50–74	16.72 (9.51, 26.43)	10.63 (6.80, 14.77)	−36.43 (−36.83, −36.03)	0.010 (0.005, 0.015)	0.002 (0.001, 0.003)	−4.42 (−4.67, −4.17)*
DALYs	<5	1,348,257.20 (711,574.19, 2,166,384.41)	33,430.03 (21,826.13, 47,022.07)	−97.52 (−97.54, −97.50)	1216.36 (641.96, 1954.45)	53.78 (35.11, 75.64)	−10.87 (−11.80, −9.94)*
	5–14	25,495.80 (17,369.37, 35,496.53)	8,508.12 (6,376.62, 10,960.37)	−66.63 (−66.78, −66.48)	12.31 (8.39, 17.14)	4.48 (3.36, 5.77)	−3.12 (−3.43, −2.82)*
	15–49	20,281.54 (14,292.24, 26,933.17)	10,461.86 (7,505.61, 13,864.44)	−48.42 (−48.64, −48.19)	3.03 (2.14, 4.03)	1.62 (1.16, 2.15)	−1.54 (−1.81, −1.26)*
	50–74	1,147.75 (790.06, 1,546.95)	2,989.48 (2,144.37, 4,084.64)	160.46 (159.26, 161.67)	0.66 (0.46, 0.89)	0.66 (0.47, 0.90)	0.42 (0.24, 0.60)*
	≥75	49.20 (29.57, 76.00)	390.51 (255.36, 569.68)	693.74 (688.81, 698.66)	0.25 (0.15, 0.39)	0.50 (0.33, 0.74)	2.87 (2.52, 3.22)*

Abbreviation: NTDs=neural tube defects; EAPC=estimated annual percentage change; UI=uncertainty interval; DALYs=disability-adjusted life years.

* $P < 0.05$.

[†] Absolute numbers represent incident cases, prevalent cases, deaths, and total DALYs, whereas rates represent incidence, prevalence, mortality, and DALY rates.

[§] The four small nonzero estimates shown to three decimal places are reported at this precision to avoid rounding to zero; all other values are reported to two decimal places.