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Global and regional burden of congenital birth defects, 1990–2021: persistent healthcare disparities and emerging challenges from non-fatal health burden

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ABSTRACT

Introduction Approximately 3%–6% of infants were born with congenital birth defects worldwide every year, which ranked as the third leading cause of deaths among the population under 20 years of age in 2021.

Methods By adopting the methodology from Global Burden of Disease Study 2021, we systematically analysed the burden and temporal trend of congenital birth defects at the global and regional levels. Correlations between these metrics and Healthcare Access and Quality (HAQ) Index were investigated by the Spearman correlation analyses.

Results In 2021, there were 7.2 million cases of congenital birth defects and 0.53 million associated deaths. The highest incidence rates were observed in Central Asia, Central Sub-Saharan Africa and Western Sub-Saharan Africa, while the highest mortality rates were reported in Oceania, Western Sub-Saharan Africa and the Caribbean. Congenital heart anomalies remained the leading cause of deaths and disability-adjusted life years (DALYs). The proportion of years lived with disability (YLD) in total DALY increased significantly from 1990 to 2021, indicating a shift from fatal to non-fatal burden. The global age-standardised mortality rate markedly declined from 1990 to 2021, while the YLD rate remained relatively stable. Negative correlations were observed between the incidence, mortality, years of life lost (YLL) and DALY rates of congenital birth defects and HAQ Index of 204 countries and territories, whereas positive correlations were found for prevalence and YLD.

Conclusions Although remarkable progress has been made in reducing the global burden of congenital birth defects, it remains a major health issue in low sociodemographic index regions lacking equitable access to healthcare facilities. The shift from fatal to non-fatal burden underscores specific medical conditions for the increasing number of adult patients with congenital birth defects to promote postoperative rehabilitation and prevent complications.

WHAT IS ALREADY KNOWN ON THIS TOPIC

- ⇒ Approximately 3%–6% of infants were born with congenital birth defects worldwide every year.
- ⇒ Congenital birth defects ranked as the third leading cause of disability-adjusted life years (DALYs) among the population under 20 years of age in 2021.
- ⇒ Considerable progress has been made against the fatal threat of congenital birth defects through surgical intervention.

WHAT THIS STUDY ADDS

- ⇒ The highest burden from congenital birth defects was observed in underdeveloped regions such as Oceania, Africa and the Caribbean.
- ⇒ The global mortality rate significantly declined from 1990 to 2021, while the years lived with disability (YLD) rate remained stable.
- ⇒ The proportion of YLD in the total DALY was elevated from 1990 to 2021, reflecting a persistent and even increasing non-fatal burden.
- ⇒ The fatal burden was found to be negatively correlated with the Healthcare Access and Quality Index, while moderate positive correlations were found for the non-fatal burden.

HOW THIS STUDY MIGHT AFFECT RESEARCH, PRACTICE OR POLICY

- ⇒ Birth defects were still one of the major fatal threats to children living in developing regions.
- ⇒ The shift from fatal to non-fatal burden identifies particular medical issues to support postoperative rehabilitation and avoid complications.

INTRODUCTION

Birth defects, defined as structural and functional abnormalities apparent from birth, have surgical, medical or cosmetic significance.[1] Approximately 3%–6% of infants were born with congenital birth defects worldwide every year.[2] According to the Global Burden of Disease 2021, congenital birth defects ranked as the third leading cause of disability-adjusted life years (DALYs) in individuals under 20 years of age.[3] Although global under-5 mortality has decreased by 52% since 1990, largely due to the prevention and treatment of infectious disease, the proportion of deaths attributed to congenital birth defects continued to grow.[4 5] Currently, most birth defects still lack identifiable genetic or environmental causes, making drug prevention or targeted intervention difficult to achieve.[1] For major defects such as congenital heart disease (CHD) and neural tube defects, surgical care is the most effective way to prolong patients' life span and reduce associated burdens.[4] However, even after the surgery, patients with major birth defects often require ongoing healthcare and face an increased risk of disabilities throughout their lives.[2]

There is still a lack of comprehensive understanding of the global burden caused by congenital birth defects, especially regarding the non-fatal disability in adult patients. By applying the methodology from the Global Burden of Disease (GBD) 2021, we estimated the age-standardised incidence, mortality and DALY rate of congenital birth defects and all 11 subgroup diseases in 204 countries and territories, with estimated annual percentage changes (EAPCs) from 1990 to 2021 for each metric. To reflect the non-fatal burden, we calculated the proportion of years lived with disability (YLD) and years of life lost (YLL) in DALY rate across different regions, ages and sexes. Moreover, the correlation between the burden and the Healthcare Access and Quality (HAQ) Index was evaluated using the Spearman correlation analyses. To the best of our knowledge, this study provides the latest update on both the fatal and non-fatal burden of congenital birth defects across all ages and is the first to report the correlation between such burden and the HAQ Index. This provides valuable information for developing more targeted prevention and treatment strategies in the future.

METHODS

Methodology of the GBD study

The GBD 2021 database covers 204 countries and territories from 1990 to 2021, providing a systematic assessment of the global health status. The GBD collaborators used data collected by various research organisations or secondary sources. The definitions of indicators, statistical models and public involvement in the GBD database have been detailed in previous studies.[6 7]

HAQ Index

The HAQ Index ranges from 0 (worst) to 100 (best) and represents healthcare access and quality for each location. It is calculated by the GBD HAQ Index collaborators based on mortality from 33 causes that should be avoided in the presence of high-quality healthcare conditions, also known as amendable death.[8] As part of the GBD study, the HAQ Index provides a unique assessment of healthcare quality on a global scale. It uses mortality-to-incidence rates and risk-standardised death rates to make estimates comparable across countries while removing drivers not involved in the healthcare system.[9]

Sociodemographic index (SDI)

The SDI serves as a robust metric for evaluating population development levels with significant health implications. This composite measure integrates three fundamental demographic dimensions: per capita income (adjusted for temporal lag), educational attainment among adults and youth fertility patterns. Ranging from 0 (representing minimal development) to 1 (indicating optimal development), SDI provides a standardised framework for cross-national comparisons of development-health relationships.[10] This study included the latest SDI data from the GBD 2021 study, and the SDI reference quintile values were provided in online supplemental table S1.

Statistical analysis

Age-standardised rates were directly extracted from the GBD dataset. These rates were calculated by the GBD collaboration using their standard methodology: applying the GBD world standard population structure with 22 age groups and employing direct standardisation to weight age-specific rates. This approach eliminates comparability issues arising from population age structure differences.[6] To assess temporal trends, EAPCs and their 95% CIs for each metric were calculated using a linear regression model. The relationship between the natural logarithm of age-standardised rate and time was assumed to be linear, with the regression model fitted according to the formula: $y = \alpha + \beta x + \varepsilon$, where x represents the calendar year and y represents ln (age-standardised rate). EAPCs were then computed as $100 \times (e^{\beta} - 1)$. The EAPC value and its 95% CI indicate the trend in age-standardised rates.[10] The HAQ Index exhibited a non-normal distribution (confirmed by Shapiro-Wilk tests), while Pearson's correlation required normally distributed data. Therefore, Spearman rank order correlation analyses were used to assess the correlation between age-standardised rates and the HAQ Index in 204 countries and territories, which were visualised using Locally Weighted Scatterplot Smoothing curves.[10] Spearman's correlation was widely adopted in previous GBD studies to assess the correlation between age-standardised health metrics and SDI or risk factors.[10–12] All statistical analysis and visualisations were conducted using R software (V.4.3.2).

RESULTS

Global burden of congenital birth defects

As shown in figure 1 and table 1, the global age-standardised incidence rate of congenital birth defects was 116.36 per 100 000 (95% uncertainty intervals (UI) 100.28 to 135.08) among both sexes in 2021, and the prevalence rate was 913.80 (817.72 to 1029.71). More details about the incidence and prevalence of subgroup diseases were presented in online supplemental table S2 and S3. When stratified by sex (online supplemental figure S1), the prevalence of congenital birth defects was relatively

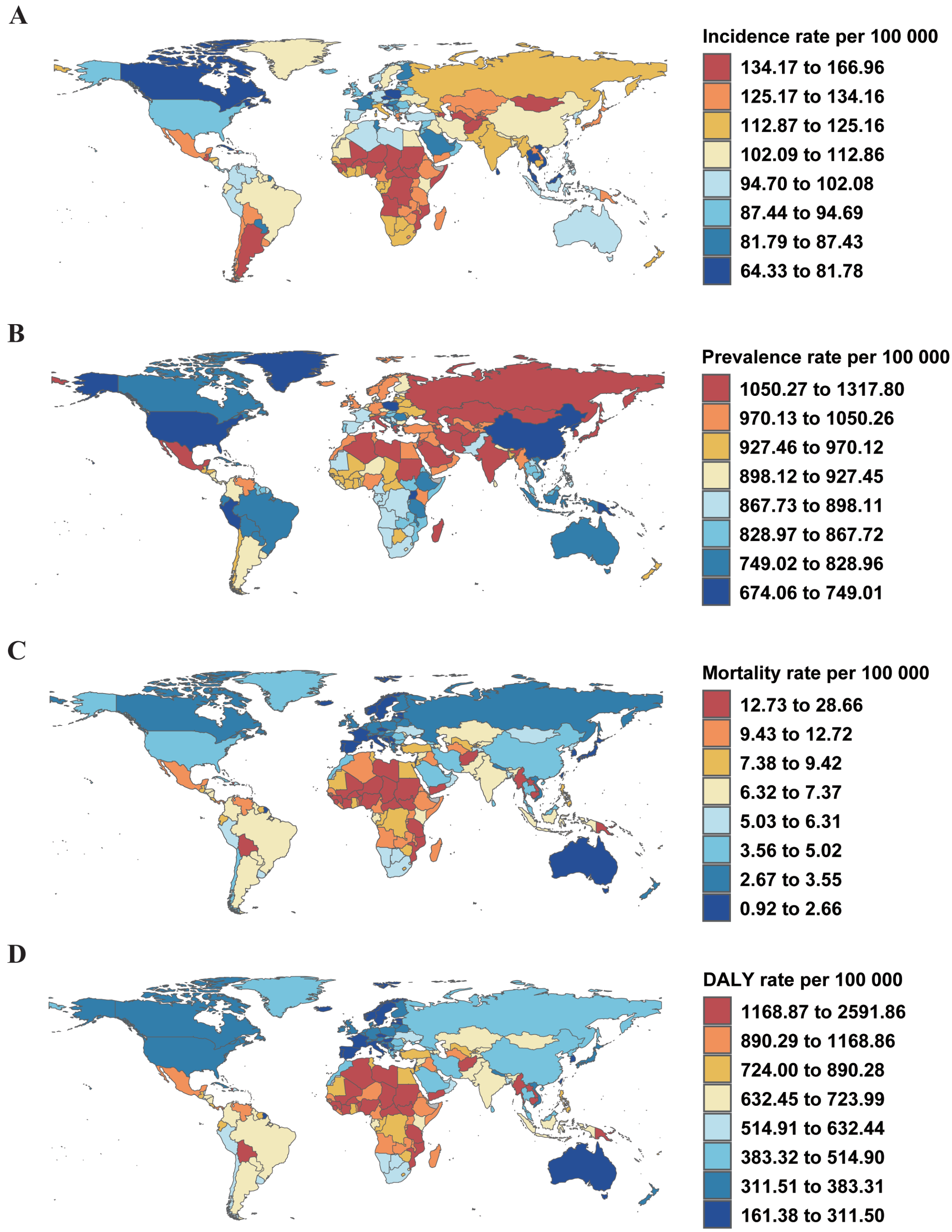

Figure 1 World maps of age-standardised incidence (A), prevalence (B), mortality (C) and disability-adjusted life year (DALY) (D) rates of congenital birth defects among both sexes in 2021.

higher among males than females in most age groups. The three countries with the highest age-standardised incidence rates were the Central African Republic (166.96 per 100 000, 95% UI 142.89 to 194.43), Brunei (163.83 per 100 000, 95% UI 138.43 to 198.77) and Tajikistan (161.02 per 100 000, 95% UI 138.33 to 186.82) (figure 1). When classified by GBD regions, the highest age-standardised incidence rates were observed in Central Asia, Central Sub-Saharan Africa and Western Sub-Saharan Africa, while lowest rates were found in Western Europe, High-income North America and Central Europe (online supplemental figure S2). For subgroup diseases, congenital musculoskeletal and limb anomalies and congenital heart anomalies had the highest incidence rates in each region. The global age-standardised mortality rate of congenital birth defects was 8.21 per 100 000 (95% UI 7.00 to 9.96) among both sexes in 2021 (table 1). As shown in online supplemental figure S1, males had much

Table 1 The age-standardised incidence and mortality rates of congenital birth defects and the estimated annual percentage changes (EAPCs) in different regions, 1990–2021

Location	Incidence rate per 100 000			Mortality rate per 100 000		
	1990	2021	EAPC	1990	2021	EAPC
Global	119.51 (103.77 to 138.62)	116.36 (100.28 to 135.08)	−0.13 (−0.15 to −0.11)	15.21 (9.50 to 19.70)	8.21 (7.00 to 9.96)	−1.86 (−1.91 to −1.82)
High SDI	100.57 (88.96 to 114.94)	93.72 (82.54 to 106.40)	−0.23 (−0.27 to −0.19)	7.25 (6.79 to 7.64)	3.12 (2.88 to 3.33)	−2.55 (−2.69 to −2.41)
High-middle SDI	119.77 (102.73 to 140.42)	108.85 (93.93 to 126.74)	−0.33 (−0.37 to −0.28)	15.21 (11.19 to 17.46)	4.43 (3.83 to 5.07)	−4.33 (−4.53 to −4.14)
Middle SDI	113.61 (97.72 to 132.69)	103.56 (89.14 to 120.66)	−0.34 (−0.39 to −0.30)	14.63 (9.69 to 18.98)	6.14 (5.22 to 7.34)	−2.67 (−2.74 to −2.61)
Low-middle SDI	120.61 (104.47 to 138.77)	118.59 (102.00 to 137.52)	−0.09 (−0.10 to −0.08)	15.92 (9.59 to 20.44)	8.74 (7.22 to 10.70)	−1.64 (−1.73 to −1.54)
Low SDI	139.31 (120.90 to 161.02)	134.24 (114.73 to 156.92)	−0.15 (−0.16 to −0.13)	20.26 (9.10 to 30.94)	12.69 (9.82 to 16.83)	−1.30 (−1.38 to −1.22)

SDI, sociodemographic index.

higher mortality rates and death numbers in 0–6 days after birth. For subgroup diseases, global mortality and DALY were presented in online supplemental table S4 and S5. The highest mortality was observed in Afghanistan (28.66 per 100 000, 95% UI 15.98 to 37.91), Tokelau (26.17 per 100 000, 95% UI 21.05 to 36.07) and Yemen (22.35 per 100 000, 95% UI 15.32 to 29.19) (figure 1). Mortality rates were highest in Oceania, Western Sub-Saharan Africa and the Caribbean, while they were lowest in High-income Asia Pacific, Australasia and Western Europe (online supplemental figure S3). In each region, congenital heart anomalies accounted for the majority of the mortality rates.

The global age-standardised incidence rate showed a moderate decreasing trend among both sexes from 1990 to 2021 (figure 2), with an EAPC of −0.13 (95% CI −0.15 to −0.11) (table 1). When stratified by SDI, the most significant decline in incidence rate was observed in middle SDI regions, with an EAPC of −0.34 (95% CI −0.39 to −0.30). When stratified by GBD regions (online supplemental table S6), the greatest decreases were observed in High-income Asia Pacific (−0.68, 95% CI −0.75 to −0.61), East Asia (−0.53, 95% CI −0.64 to −0.41) and Central Europe (−0.51, 95% CI −0.58 to −0.44). However, six regions had positive EAPC values, including Oceania (0.38, 95% CI 0.36 to 0.41), the Caribbean (0.20, 95% CI 0.18 to 0.21), Southern Latin America (0.14, 95% CI 0.09 to 0.20), High-income North America (0.13, 95% CI 0.01 to 0.24), Western Europe (0.09, 95% CI 0.05 to 0.13) and Southern Sub-Saharan Africa (0.07, 95% CI 0.03 to 0.11). More details about the EAPC of incidence and prevalence rate by sex were presented in online supplemental table S1. Besides, the highest and lowest EAPCs of incidence in each GBD region were presented in online supplemental table S10–S14. Notably, although in the same GBD region, Spain had the highest positive EAPC (1.10 95% CI 0.86 to 1.34), while Monaco showed a strong declining trend (−0.80 95% CI −0.86 to −0.74). Moreover, the most significant improvement was observed in Saudi Arabia, with an EAPC of −0.96 (95% CI −1.00 to −0.92). The global age-standardised mortality rate showed significant declining trends from 1990 to 2021 (table 1), with the highest decreasing percentage in the high-middle SDI regions (-4.33 95% CI -4.53 to -4.14) and the lowest in low SDI regions (-1.30, 95% CI -1.38 to -1.22). Stratified by GBD regions, the greatest decreases were observed in East Asia (-5.06, 95% CI -5.34 to -4.78), Central Europe (-4.15, 95% CI -4.28 to -4.02), and Eastern Europe (-4.10, 95% CI -4.51 to -3.69), while the lowest in Oceania (-0.13, 95% CI -0.25 to -0.01), Southern Sub-Saharan Africa (-0.22, 95% CI -0.30 to -0.13), and Central Asia (-0.35, 95% CI -0.67 to -0.04). More details about the EAPC of mortality and DALY rate among different sexes were presented in online supplemental table S10–S13. Besides, the highest and lowest EAPCs of mortality and DALY in each GBD region were presented in online supplemental table S15 and S16. The highest positive EAPC of mortality was observed in Turkmenistan (2.39, 95% CI 1.65 to 3.13),

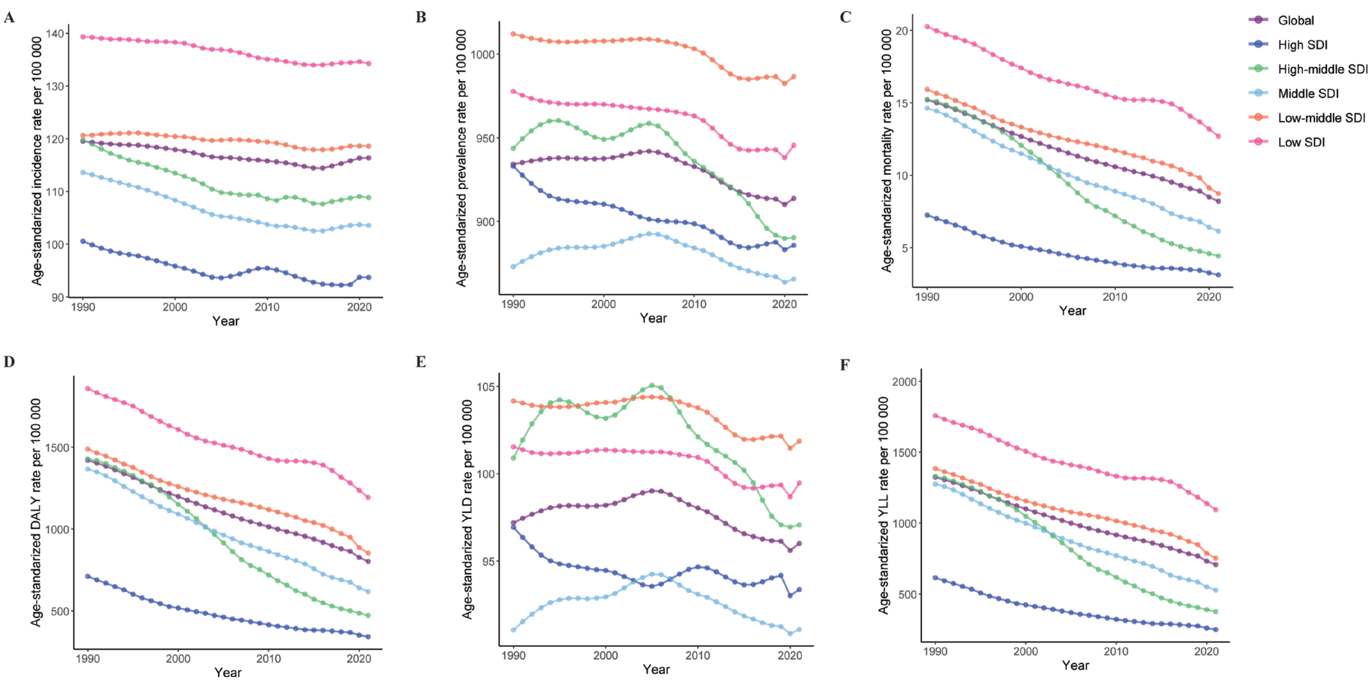

Figure 2 Trends of age-standardised incidence (A), prevalence (B), mortality (C), disability-adjusted life year (DALY) (D), years lived with disability (YLD) (E) and years of life lost (YLL) (F) rates of congenital birth defects among both sexes, 1990–2021.

while the most significant declining trend was observed in Serbia (5.75, 95% CI −6.30 to −5.20).

Composition and temporal trends of DALY

The age-standardised DALY rate declined significantly from 1990 to 2021, with a global EAPC of −1.73 (95% CI −1.77 to −1.69). DALYs caused by congenital birth defects were composed of non-fatal (YLD) and fatal (YLL) burden. Since most deaths caused by congenital birth defects occurred in children under 5 years old, we estimated the proportion of YLD and YLL in the DALY rate in both sexes aged ≥5 years old to assess the contribution of non-fatal burden (figure 3). When stratified by age, it was revealed that the proportion of YLD accounted for over 50% of DALY among the population aged ≥25 years in both 1990 and 2021. Importantly, compared to 1990, the proportion of YLD in 2021 increased in all age groups, particularly among those aged 5–49 years. When stratified by SDI, it was also observed that the YLD proportion increased in all regions from 1990 to 2021, with an increase of over 10% in the high SDI regions.

When stratified by GBD regions, the age-standardised YLD rate among both sexes was highest in High-income Asia Pacific (131.13, 95% UI 92.54 to 179.32), Central Latin America (115.28, 95% UI 81.67 to 155.39) and Eastern Europe (111.32, 95% UI 79.92 to 148.88), while it was lowest in Oceania (75.29, 95% UI 53.30 to 103.19), East Asia (78.67, 95% UI 56.10 to 106.75) and High-income North America (79.10, 95% UI 57.59 to 105.48) (online supplemental figure S4). Unlike the age-standardised YLL rate, the global YLD rate among both sexes did not show a significant change from 1990 to 2021 (figure 2), with an EAPC of −0.06 (95% CI −0.10 to −0.03). The ranking of YLD attributed to subgroup diseases did not change significantly over the years or across regions, with congenital musculoskeletal and limb anomalies, other congenital birth defects, and congenital heart anomalies being the top three causes of YLD (online supplemental figure S5). In contrast, congenital heart anomalies ranked as the first cause of YLL in most regions, except for Southern Sub-Saharan Africa (online supplemental figure S6).

Correlation between the age-standardised burden and HAQ Index

As illustrated in figure 4, the HAQ Index showed a similar distribution to that of SDI, consistent with the previous report.[9] Among both sexes, strong negative correlations were observed between age-standardised incidence (ρ=−0.61, p<0.0001), mortality (ρ=−0.81, p<0.0001) and DALY rates (ρ=−0.8, p<0.0001) and the HAQ Index. However, moderate positive correlations were found between the prevalence rate and the HAQ Index (ρ=0.18, p=0.01). Moreover, the YLL rate among both sexes was negatively correlated with the HAQ Index (ρ=−0.81, p<0.0001), while the YLD rate was positively correlated with the HAQ Index (ρ=0.18, p=0.0095).

DISCUSSION

Significant strides have been made in combating the burden of congenital birth defects from 1990 to 2021, with the most notable decreases in both incidence and mortality observed in Asia. This trend could be attributed to the widespread adoption of prenatal diagnosis for major birth defects in developing countries, particularly like China.[13] However, our study uncovered a concerning trend of incidence rate in North America and

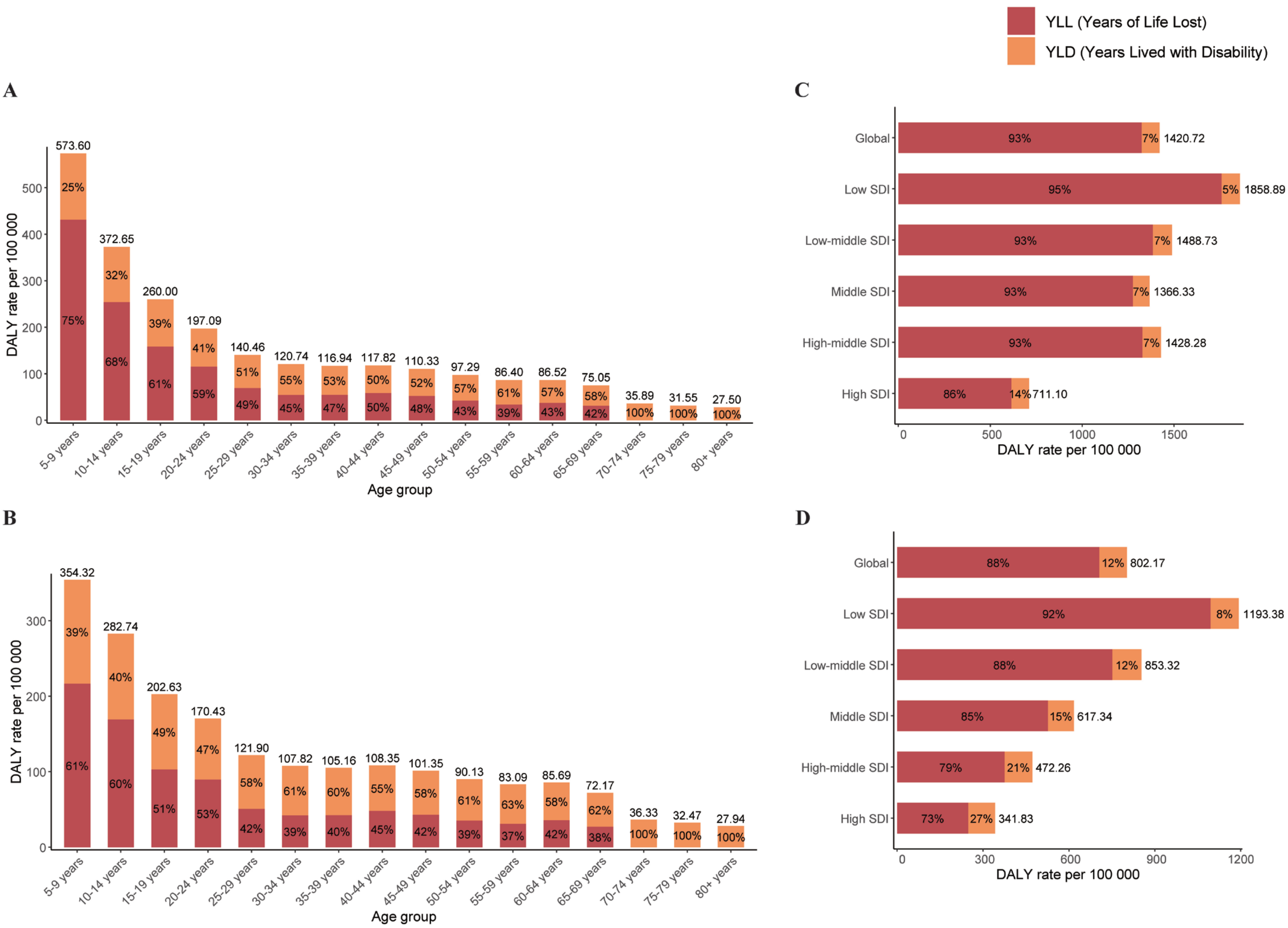

Figure 3 Composition of disability-adjusted life year (DALY) of congenital birth defects among both sexes by age in 1990 (A) and 2021 (B), and by region in 1990 (C) and 2021 (D).

West Europe, likely linked to factors such as advanced maternal age, multiple comorbidities and elevated body mass index among expectant mothers.[14] Of particular concern, Western Sub-Saharan Africa emerged as one of the regions with the highest age-standardised incidence and mortality rate alongside Central Sub-Saharan Africa and Eastern Sub-Saharan Africa. These findings align with previous reports indicating that over 90% incidence and 95% deaths of birth defects occur in low and middle-income countries.[15] The negative correlations observed between the incidence and fatal burden of congenital birth defects and the HAQ Index suggest that deficiencies in a fully equipped medical system and heightened exposure to risk factors during the perinatal period may contribute to high incidence and mortality rates in these underdeveloped regions.

Our findings underscore the critical need for region-specific public health strategies to address disparities in congenital birth defect burden. In low SDI regions (eg, Central Sub-Saharan Africa, Oceania), interventions should prioritise scaling up prenatal screening infrastructure, fortifying maternal nutrition programmes and enhancing access to paediatric surgical care, particularly for congenital heart anomalies, where resource gaps in specialists and postoperative care persist.[16] For instance, Nepal's adoption of systematic birth defect surveillance systems, which prospectively track epidemiological patterns and associated risk factors, has positioned it as a model for low-to-middle-income regions.[17] Middle-income regions with rising incidence trends (eg, Southern Latin America) require targeted health education to mitigate environmental and lifestyle risk factors linked to congenital birth defects.[18 19] For high SDI regions (eg, Western Europe, High-income North America), optimising long-term multidisciplinary care for disability and addressing rising YLD burdens through rehabilitation and psychosocial support systems are essential.[20 21] Globally, harmonising surveillance protocols and fostering cross-border collaborations can standardise data quality and accelerate resource allocation. Policy-makers should leverage insights from frontier analysis to benchmark achievable burden reductions tailored to regional SDI levels, ensuring equitable progress towards global mitigation goals for birth defects.[22]

We estimated that the percentage of non-fatal burden caused by congenital birth defects significantly increased from 1990 to 2021 across all ages, sexes and regions. Among congenital birth defects, congenital

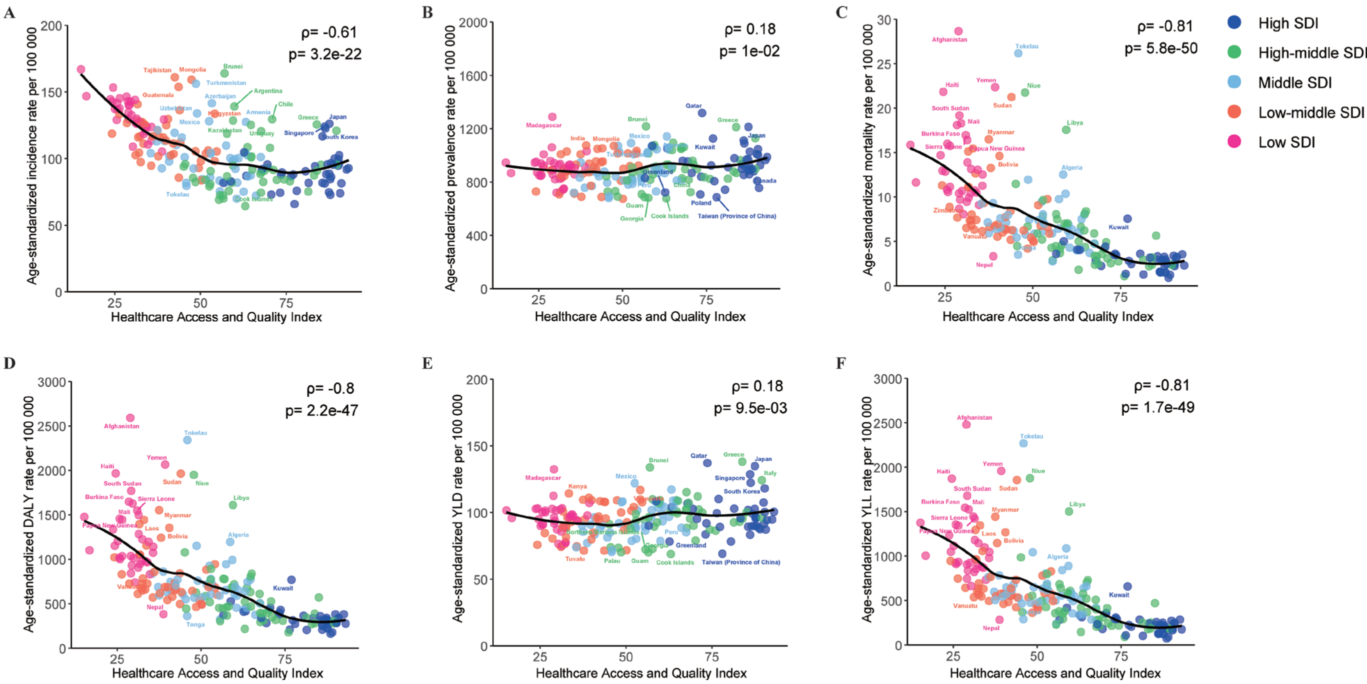

Figure 4 Correlation between age-standardised incidence (A), prevalence (B), mortality (C), disability-adjusted life year (DALY) (D), years lived with disability (E) and years of life lost (YLL) (F) rates of congenital birth defects and Healthcare Access and Quality Index among both sexes.

musculoskeletal and limb anomalies accounted for the majority of incidence and prevalence, ranking as the seventh cause of YLL but the first cause of YLD. CHD, typically seen as the most fatal birth defect, ranked as the third major cause of YLD in 2021. These findings highlighted the urgency of addressing the lifelong disabilities that patients with birth defects often face. The proportion of YLD increased steadily in all regions regardless of SDI, and positive correlations were observed between YLD and the HAQ Index. This suggests that the non-fatal burden of congenital birth defects is prevalent in countries of all income levels and highlights an emerging issue for health expenditure in developed regions with advanced healthcare facilities. In high-income countries, over 90% of infants with CHD can survive into adulthood, a survival rate significantly higher than that in low-income countries.[23] This finding aligns with the negative correlation between age-standardised mortality rate and the HAQ Index. Advances in surgical procedures have improved the survival of CHD patients, but those who survive the first year of life often require ongoing medical care. In low-income countries, the survival rate of CHD remains relatively low. However, paediatric cardiac surgery is becoming more accessible in middle-income countries, leading to a growing population of adolescents and adults living with moderate to severe CHD.[24]

Long-term disability is commonly observed in children and adolescents who have undergone surgical interventions for major birth defects like CHD, including reduced exercise capacity, lower levels of physical activity, diminished self-esteem and a decline in health-related quality of life.[25] Around 2013, the number of adults with CHD surpassed that of children, making a significant achievement in modern medicine.[26] This demographic shift means that more patients with complex CHD are reaching adulthood, necessitating timely and extensive medical management for complications beyond just cardiac care, particularly neurological complications.[27] The ageing process introduces new challenges for this population, including the emergence of geriatric patients with CHD who face typical age-related issues.[28] Addressing the evolving healthcare needs of adult CHD patients requires increased resources and expertise in management, rehabilitation and treatment.[29] Significant healthcare disparities remain, particularly concerning major complications like pulmonary hypertension and the care of pregnant individuals with CHD.[30] Our findings underscore the need for comprehensive, lifelong monitoring and management strategies to improve quality of life for adult patients with congenital birth defects.

Limitations

Our study inherits several constraints inherent to other GBD studies: first, data quality disparities significantly impacted our analysis, particularly in low-resource settings where birth defect surveillance systems are often absent or incomplete. In these regions, we relied on indirect estimation methods using sibling survival histories and survey recall data, which may underrepresent certain congenital anomalies due to diagnostic challenges and cultural stigma surrounding birth defects. Second, the quality of cause-of-death attribution presents additional challenges.[31] Even in settings with medical certification, inconsistent application of International Classification of

Diseases coding standards and variable physician training in death certification may lead to misclassification of birth defect-related mortality. This issue is exacerbated when comorbidities exist, as clinicians may prioritise acute conditions over congenital causes. While GBD's garbage code redistribution algorithms help correct some misattribution, residual errors likely persist—particularly for rare birth defects where clinical recognition may be limited.[7] These data limitations are most pronounced in regions experiencing rapid demographic transitions, where outdated census information fails to capture contemporary risk profiles. The establishment of population-based birth defect surveillance systems and standardised verbal autopsy instruments specifically designed for congenital anomalies would substantially improve future estimates. Besides, although our Spearman correlation analysis identified significant associations between birth defect burden and the HAQ Index, this approach has inherent limitations common to large-scale GBD studies. The ecological nature of GBD data restricts our ability to adjust for potential confounders such as regional variations in genetic predisposition, maternal nutrition, environmental exposures or cultural practices. Although the HAQ Index correlates with healthcare system performance, its association with birth defects may be mediated by unaccounted socioeconomic or public health policy factors.[9]

CONCLUSIONS

Overall, thanks to advances in prenatal screening and neonatal surgery, the global burden of congenital birth defects showed a decreasing trend from 1990 to 2021. However, congenital birth defects remained a fatal threat to newborns in relatively underdeveloped regions. Moreover, the decomposition of DALY indicated a shift from fatal to non-fatal burden among children, adolescents and adults in regions across all income levels. These findings underscore the need for more targeted interventions to address persistent disabilities caused by congenital birth defects in the future.

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Patient consent for publication Not applicable.

Ethics approval Not applicable.

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REFERENCES

1 Simeone RM, Feldkamp ML, Reefhuis J, *et al*. CDC Grand Rounds: Understanding the Causes of Major Birth Defects - Steps to Prevention. *MMWR Morb Mortal Wkly Rep* 2015;64:1104–7.
2 Announcement: World Birth Defects Day - March 3, 2017. *MMWR Morb Mortal Wkly Rep* 2017;66:195.
3 IHME. GBD compare. 2024. Available: https://vizhub.healthdata.org/gbd-compare
4 Wright NJ, Anderson JE, Ozgediz D, *et al*. Addressing paediatric surgical care on World Birth Defects Day. *Lancet* 2018;391.
5 Wang H, Bhutta ZA, Coates MM. Global, regional, national, and selected subnational levels of stillbirths, neonatal, infant, and under-5 mortality, 1980-2015: a systematic analysis for the Global Burden of Disease Study 2015. *Lancet* 2016;388:1725–74.
6 Ferrari AJ, Santomauro DF, Aali A. Global incidence, prevalence, years lived with disability (YLDs), disability-adjusted life-years (DALYs), and healthy life expectancy (HALE) for 371 diseases and injuries in 204 countries and territories and 811 subnational locations, 1990–2021: a systematic analysis for the Global Burden of Disease Study 2021. *Lancet* 2024;403:2133–61.
7 Naghavi M, Ong KL, Aali A. Global burden of 288 causes of death and life expectancy decomposition in 204 countries and territories and 811 subnational locations, 1990-2021: a systematic analysis for the Global Burden of Disease Study 2021. *Lancet* 2024;403:2100–32.
8 Barber RM, Fullman N, Sorensen RJD, *et al*. Healthcare Access and Quality Index based on mortality from causes amenable to personal health care in 195 countries and territories, 1990–2015: a novel analysis from the Global Burden of Disease Study 2015. *Lancet* 2017;390:231–66.
9 Haakenstad A, Yearwood JA, Fullman N, *et al*. Assessing performance of the Healthcare Access and Quality Index, overall and by select age groups, for 204 countries and territories, 1990–2019: a systematic analysis from the Global Burden of Disease Study 2019. *Lancet Glob Health* 2022;10:e1715–43.

10 Cao G, Liu J, Liu M. Global, Regional, and National Incidence and Mortality of Neonatal Preterm Birth, 1990-2019. *JAMA Pediatr* 2022;176:787–96.
11 Li X, Cao X, Guo M, *et al*. Trends and risk factors of mortality and disability adjusted life years for chronic respiratory diseases from 1990 to 2017: systematic analysis for the Global Burden of Disease Study 2017. *BMJ* 2020;368:m234.
12 Golabi P, Paik JM, AlQahtani S, *et al*. Burden of non-alcoholic fatty liver disease in Asia, the Middle East and North Africa: Data from Global Burden of Disease 2009-2019. *J Hepatol* 2021;75:795–809.
13 Zhang Y, Wang J, Zhao J, *et al*. Current status and challenges in prenatal and neonatal screening, diagnosis, and management of congenital heart disease in China. *Lancet Child Adolesc Health* 2023;7:479–89.
14 Shaw D, Guise J-M, Shah N, *et al*. Drivers of maternity care in high-income countries: can health systems support woman-centred care? *Lancet* 2016;388:2282–95.
15 Malherbe HL, Christianson AL, Aldous C. Need for services for the care and prevention of congenital disorders in South Africa as the country's epidemiological transition evolves. *S Afr Med J* 2015;105:186–8.
16 Toobaie A, Yousef Y, Balvardi S, *et al*. Incidence and prevalence of congenital anomalies in low- and middle-income countries: A systematic review. *J Pediatr Surg* 2019;54:1089–93.
17 Paudel P, Sunny AK, Gurung R, *et al*. Burden and consequence of birth defects in Nepal-evidence from prospective cohort study. *BMC Pediatr* 2021;21:81.
18 Wu L, Li N, Liu Y. Association Between Maternal Factors and Risk of Congenital Heart Disease in Offspring: A Systematic Review and Meta-Analysis. *Matern Child Health J* 2023;27:29–48.
19 Akseer N, Mehta S, Wigle J, *et al*. Non-communicable diseases among adolescents: current status, determinants, interventions and policies. *BMC Public Health* 2020;20:1908.
20 Victora CG, Bahl R, Barros AJD, *et al*. Breastfeeding in the 21st century: epidemiology, mechanisms, and lifelong effect. *Lancet* 2016;387:475–90.
21 Kelishadi R, Farajian S. The protective effects of breastfeeding on chronic non-communicable diseases in adulthood: A review of evidence. *Adv Biomed Res* 2014;3:3.
22 Bai Z, Han J, An J, *et al*. The global, regional, and national patterns of change in the burden of congenital birth defects, 1990-2021: an analysis of the global burden of disease study 2021 and forecast to 2040. *EClinicalMedicine* 2024;77:102873.
23 Moons P, Bovijn L, Budts W, *et al*. Temporal trends in survival to adulthood among patients born with congenital heart disease from 1970 to 1992 in Belgium. *Circulation* 2010;122:2264–72.
24 Moons P, Bratt E-L, De Backer J, *et al*. Transition to adulthood and transfer to adult care of adolescents with congenital heart disease: a global consensus statement of the ESC Association of Cardiovascular Nursing and Allied Professions (ACNAP), the ESC Working Group on Adult Congenital Heart Disease (WG ACHD), the Association for European Paediatric and Congenital Cardiology (AEPC), the Pan-African Society of Cardiology (PASCAR), the Asia-Pacific Pediatric Cardiac Society (APPCS), the Inter-American Society of Cardiology (IASC), the Cardiac Society of Australia and New Zealand (CSANZ), the International Society for Adult Congenital Heart Disease (ISACHD), the World Heart Federation (WHF), the European Congenital Heart Disease Organisation (ECHDO), and the Global Alliance for Rheumatic and Congenital Hearts (Global ARCH). *Eur Heart J* 2021;42:4213–23.
25 Dulfer K, Helbing WA, Duppen N, *et al*. Associations between exercise capacity, physical activity, and psychosocial functioning in children with congenital heart disease: a systematic review. *Eur J Prev Cardiol* 2014;21:1200–15.
26 Singh HS, Horlick E, Osten M, *et al*. Interventional cardiology in adults with congenital heart disease. *Nat Rev Cardiol* 2013;10:662–78.
27 Marino BS, Lipkin PH, Newburger JW, *et al*. Neurodevelopmental outcomes in children with congenital heart disease: evaluation and management: a scientific statement from the American Heart Association. *Circulation* 2012;126:1143–72.
28 van der Bom T, Zomer AC, Zwinderman AH, *et al*. The changing epidemiology of congenital heart disease. *Nat Rev Cardiol* 2011;8:50–60.
29 Stuart AG. Changing lesion demographics of the adult with congenital heart disease: an emerging population with complex needs. *Future Cardiol* 2012;8:305–13.
30 Su Z, Zhang Y, Cai X, *et al*. Improving long-term care and outcomes of congenital heart disease: fulfilling the promise of a healthy life. *Lancet Child Adolesc Health* 2023;7:502–18.
31 GBD 2019 Demographics Collaborators. Global age-sex-specific fertility, mortality, healthy life expectancy (HALE), and population estimates in 204 countries and territories, 1950-2019: a comprehensive demographic analysis for the Global Burden of Disease Study 2019. *Lancet* 2020;396:1160–203.