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The burden of cardiovascular disease in children in Asian countries (1990–2021): Systematic analysis and projection of the burden of disease

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ABSTRACT

Background: Cardiovascular disease (CVD) is the leading global cause of death and health loss. The epidemiology and factors influencing CVD in children are unique, making it essential to first evaluate current and future trends to guide interventions and reduce the disease burden.
Objective: To analyze the incidence, mortality, and disability-adjusted life years (DALY) of CVD in children aged 0–14 from 1990 to 2021, and explore global disease burden, risk factors, and trends over the next 30 years. The study focuses on China, Japan, South Korea, India, and Singapore to aid in developing targeted prevention and treatment strategies.
Methods: Using data from the Global Burden of Disease Study (GBD) 1990–2021, we assessed age- and sex-specific morbidity, mortality, and DALY of CVD in Asian children aged 0–14 and computed the EAPC. We analyzed risk factors, specific causes, and projected prevalence trends through 2050 using the Bayesian Age-Period-Cohort (BAPC) model.
Results: From 1990 to 2021, CVD incidence among Asian children aged 0–14 decreased by 8.03 % (95 % UI:13.63 to -4.02). Mortality saw a significant drop of 67.98 % (95 % UI:73.73 to -62.23), with the greatest decline in children aged 2–4, and the highest death rate in those under 1 year. Disability and mortality patterns were similar across gender, age, etiology, and overall trends. In 2021, South Asia had the highest rates of morbidity, mortality, and disability. Rates varied significantly, with Mongolia exhibiting the highest rate and Cyprus the lowest, showing a sixfold difference. Rheumatic heart disease (RHD) and intracerebral hemorrhage were the most critical diseases needed attention. Abnormal temperatures were identified as a risk factor associated with CVD outcomes in children. The burden of CVD is projected to increase in various regions and countries across Asia.
Conclusion: The burden of CVD continues to challenge children aged 0–14 in Asia. Enhancing our understanding of pediatric CVD epidemiology, addressing risk factors, and reinforcing prevention and control measures are essential for reducing this burden.

List of abbreviations

CVD	Cardiovascular disease
DALY	Disability-adjusted life years
GBD	Global Burden of Disease Study
BAPC	Bayesian Age-Period-Cohort
UI	Uncertain interval
CI	Confidence interval
RHD	Rheumatic heart disease

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1. Background

Cardiovascular disease (CVD) is a major contributor to the global burden of disease. In 2022, CVD caused approximately 19.8 million deaths globally, resulting in 396 million years of life lost and 44.9 million years of healthy life lost due to disability (YLD) [1,2]. Despite a 34.9 % decrease in global CVD mortality from 1990 to 2022, significant regional disparities persist. Over 75 % of the global CVD burden is concentrated in low- and middle-income countries, including Oceania, Eastern and Central Europe, sub-Saharan Africa, North Africa, the Middle East, the Caribbean, and East and South Asia, with varying levels of upward trends [1]. However, most existing studies on CVD burden have focused on Africa, South America, the Pacific, the United States, and Mexico [3–10]. A significant gap in public health data on CVD burden remains in Asia [5,11–13]. Asia's vast land area, large population, and complex demographic structure, coupled with diverse cultures, economies, health conditions, and disease prioritization, contribute to the varied and complex CVD epidemiological characteristics across countries and regions. Additionally, most CVD burden studies focus on adults, overlooking children as a distinct group. Children, being physically immature and more susceptible to disease, have a disease spectrum and CVD pathophysiology that differs significantly from adults. Despite medical advances improving survival rates, many children still face long-term consequences, and chronic CVD can persist into adulthood or elevate adult CVD risk [10,14,15]. This study aimed to estimate the burden and prevalence trends of CVD in children aged 0–14 in Asia from 1990 to 2021 using GBD2021 data, examining national, regional, SDI, sex, and age dimensions. It also explored potential risk factors to bridge knowledge gaps and provide a foundation for developing prevention, diagnostic, and management strategies.

2. Methodology

2.1. Data sources

Data were sourced from the Global Burden of Disease (GBD) 2021 database, organized by the Global Health Research Institute to assess and analyze the global and regional impacts of diseases, injuries, and risk factors [15,16]. We utilized the GBD 2021 dataset to collect data on CVD, covering morbidity, mortality, DALY, underlying causes, and influencing factors for children aged 0–14 in Asia from 1990 to 2021. Since this study involved secondary analysis of publicly available data (https://ghdx.healthdata.org/gbd-2021), institutional review board approval and informed consent were not required.

2.2. Sociodemographic index

The Sociodemographic Index (SDI), developed by the GBD study, is a composite indicator that measures a country or region's development status using data on per capita income, average educational attainment, and fertility rate. Each country or region is assigned an SDI value ranging from 0 to 1, with higher values indicating better development. The SDI is crucial for identifying health disparities across socioeconomic contexts and informing targeted interventions [2,11,12,15].

2.3. Age group, Asian region group

In the GBD database, children aged 0–14 were categorized into the following age groups: 0–12 months, 12–24 months, 2–4 years, 5–9 years, and 10–14 years. Asia was divided into six regions: Central Asia, High-income Asia Pacific, South Asia, East Asia, Southeast Asia, North Africa, and the Middle East (see supplementary materials for details).

2.4. Etiology and risk factors of CVD

The etiological analysis included detailed causes from the GBD database, such as intracerebral hemorrhage, endocarditis, ischemic stroke, pulmonary arterial hypertension, myocarditis, subarachnoid hemorrhage, cardiomyopathies, rheumatic heart disease, and other cardiovascular and circulatory diseases [2].

Risk factor analyses encompassed all detailed factors in the Global Burden of Disease (GBD) database, which include Environmental Risks (ambient particulate matter pollution, household air pollution from solid fuels, lead exposure, low temperature, and high temperature); Metabolic Risks (high systolic blood pressure, high LDL cholesterol, high body mass index, high fasting plasma glucose, and kidney dysfunction); and Behavioral Risks (dietary risks, smoking, secondhand smoke, high alcohol consumption, and low physical activity) [2,12,17–20].

2.5. Data analysis

The incidence, mortality, and disability-adjusted life years (DALY), along with their respective rates, serve as the primary indicators of the burden of CVD in children. Each rate is reported per 100,000 population in accordance with the Global Burden of Disease (GBD) algorithm and is accompanied by a 95 % uncertainty interval (UI). The Estimated Annual Percentage Change (EAPC) and its 95 % confidence interval (CI) were calculated using linear modeling to elucidate trends in these changes. A downward trend is indicated if the upper limit of both the EAPC and its 95 % CI is negative; conversely, an upward trend is suggested if the lower limit of both the EAPC and its 95 % CI is positive. The relationships between socio-demographic index (SDI) levels and the incidence rate, mortality rate, DALY rate, and their corresponding EAPC were assessed using Spearman's rank sum correlation test and visualized through locally weighted scatter smoothing curves. Projections of the burden of CVD among children aged 0–14 years in five Asian countries (China, Japan, Korea, India, and Singapore) for the year 2050 were made using Bayesian age-period-cohort (BAPC) models. All statistical analyses were conducted using R Studio (version 4.3.0), and a p-value of <0.05 was deemed statistically significant.

3. Results

3.1. CVD in children: Asia

3.1.1. Morbidity

In 2021, the total number of CVD cases among children aged 0–14 in Asia was 810,283.27 (95 % UI: 582,799.27 to 1094,471.52), yielding an incidence rate of 74.34/100,000 (95 % UI: 53.47 to 100.41). Of these cases, 406,010.06 (95 % UI: 292,452.04 to 544,553.12) were male and 404,273.21 (95 % UI: 288,850.17 to 549,909.38) were female, resulting in a male-to-female-ratio-of approximately 1:1. From 1990 to 2021, the incidence of CVD in children in Asia declined by 8.03 % (95 % UI: −13.63 to −4.02), with an EAPC of 0.05 % (95 % CI: −0.09 to 0.19). The lowest decrease in CVD incidence was observed in children aged 10 to 14 years, with an incidence change of −4.48 % (95 % UI: −10.00 to −1.33) and an EAPC of 0.37 % (95 % CI: 0.18 to 0.56). Conversely, the highest decrease in incidence was noted among children under one year old, with an incidence change of −40.58 % (95 % UI: −44.25 to −36.86) and an EAPC of −1.88 % (95 % CI: −1.99 to −1.77). The incidence rate was slightly lower in boys at 71.34/100,000 (95 % UI: 51.38 to 95.68) compared to girls at 77.62/100,000 (95 % UI: 55.46 to 105.59) (See Table 1 and Supplementary Table 1).

3.1.2. Mortality

In 2021, a total of 22,907.26 (95 % UI: 19,660.75 to 26,390.10) Asian children died due to CVD, resulting in a mortality rate of 2.10/100,000 (95 % UI: 1.80 to 2.42). Among these, there were 12,226.52 (95 % UI: 10,335.93 to 14,240.53) male cases and 10,680.74 (95 % UI: 9091.60 to 12,341.57) female cases. Between 1990 and 2021, the CVD mortality rate among Asian children aged 0–14 years decreased by 67.98 % (95 % UI: −73.73 to −62.23), with an EAPC of −3.30 % (95 %

Table 1
Cardiovascular Disease Burden of Children of Different Ages and Sexes in Asia from 1990 to 2021.

Index	levels	1990		2021		1990–2021	
		Number (95 %UI)	Rate per 100,000 (95 %UI)	Number (95 %UI)	Rate per 100,000 (95 %UI)	Rate change	Rate EAPC (95 %CI)
Incidence	**Asia**	857,364.23 (648,777.55–1,122,154.28)	80.83 (61.17–105.80)	810,283.27 (582,799.27–1,094,471.52)	74.34 (53.47–100.41)	−8.03 (−13.63–4.02)	0.05 (−0.09–0.19)
	Region						
	Central Asia	23,213.82 (16,735.36–31,513.79)	92.89 (66.96–126.10)	26,172.18 (18,654.52–35,791.03)	94.57 (67.40–129.32)	1.81 (−1.60–4.90)	−0.13 (−0.28–0.01)
	East Asia	381,845.53 (293,719.81–491,472.85)	115.77 (89.05–149.01)	234,379.03 (171,543.69–311,139.53)	87.67 (64.16–116.38)	−24.27 (−28.70–20.75)	−0.77 (−0.89–0.64)
	High-income Asia Pacific	10,507.20 (8313.06–13,327.57)	29.85 (23.62–37.86)	6025.49(4670.46–7771.88)	26.87 (20.83–34.66)	−9.99 (−13.58–6.91)	−0.52 (−0.59–0.44)
	North Africa and Middle East	100,523.58 (79,271.48–127,757.01)	71.55 (56.43–90.94)	129,603.07 (96,930.06–169,609.64)	70.70 (52.87–92.52)	−1.20 (−6.81–4.04)	−0.12 (−0.19–0.06)
	South Asia	288,746.73 (205,606.03–389,934.21)	66.63 (47.44–89.98)	372,928.59 (253,625.61–517,464.47)	73.55 (50.02–102.06)	10.39 (4.64–15.31)	1.04 (0.74–1.33)
	Southeast Asia	104,709.38 (82,130.14–130,872.91)	61.32 (48.10–76.65)	105,044.87 (80,757.20–135,034.52)	60.84 (46.77–78.21)	−0.79 (−4.66–2.64)	0.02 (−0.06–0.10)
	Gender						
	Male	433,342.55 (328,155.38–563,656.36)	78.88 (59.73–102.60)	406,010.06 (292,452.04–544,553.12)	71.34 (51.38–95.68)	−9.56 (−14.98–5.56)	−0.02 (−0.15–0.11)
	Female	424,021.68 (318,902.37–558,497.91)	82.93 (62.37–109.23)	404,273.21 (288,850.17–549,909.38)	77.62 (55.46–105.59)	0.04 (−8.55–10.67)	0.12 (−0.03–0.28)
	Age						
	<1 year	31,337.21 (26,604.03–36,753.35)	41.14 (34.93–48.25)	15,419.14 (12,599.47–18,827.60)	24.45 (19.98–29.85)	−40.58 (−44.25–36.86)	−1.88 (−1.99–1.77)
	12–23 months	39,479.40 (33,404.88–46,460.58)	52.75 (44.63–62.07)	24,731.41 (20,191.07–30,224.46)	37.85 (30.91–46.26)	−28.23 (−32.20–24.42)	−1.06 (−1.13–0.98)
	2–4 years	150,200.69 (117,485.52–192,209.83)	67.04 (52.44–85.79)	118,483.86 (89,733.04–156,022.15)	55.41 (41.96–72.96)	−17.35 (−21.44–14.03)	−0.47 (−0.58–0.35)
	5–9 years	300,701.51 (210,731.72–418,962.35)	83.86 (58.77–116.83)	287,366.89 (195,178.57–411,509.71)	76.40 (51.89–109.41)	−8.89 (−12.88–5.87)	0.11 (−0.08–0.30)
	10–14 years	335,645.42 (216,476.50–499,542.84)	102.64 (66.20–152.76)	364,281.97 (224,828.13–549,958.51)	98.04 (60.51–148.01)	−4.48 (−10.00–1.33)	0.37 (0.18–0.56)
Deaths	**Asia**	69,625.15 (60,525.17–82,702.47)	6.56(5.71–7.80)	22,907.26 (19,660.75–26,390.10)	2.10(1.80–2.42)	−67.98 (−73.73–62.23)	−3.30 (−3.44–3.17)
	Region						
	Central Asia	483.81(447.83–526.48)	1.94(1.79–2.11)	252.61(216.16–294.56)	0.91(0.78–1.06)	−52.85 (−59.67–44.45)	−2.25 (−2.55–1.94)
	East Asia	20,490.11 (17,761.00–23,580.08)	6.21(5.38–7.15)	2336.84(1926.27–2748.04)	0.87(0.72–1.03)	−85.93 (−89.20–82.45)	−5.98 (−6.18–5.78)
	High-income Asia Pacific	681.48(610.01–759.66)	1.94(1.73–2.16)	113.89(104.98–121.65)	0.51(0.47–0.54)	−73.77 (−76.50–70.80)	−4.36 (−4.52–4.19)
	North Africa and Middle East	34,760.40 (29,684.32–42,203.61)	24.74 (21.13–30.04)	9616.68(7978.60–11,568.54)	5.25(4.35–6.31)	−78.80 (−83.19–73.96)	−4.39 (−4.58–4.21)
	South Asia	28,855.19 (23,349.76–36,145.23)	6.66(5.39–8.34)	12,569.56 (10,320.27–15,016.94)	2.48(2.04–2.96)	−62.77 (−70.30–53.61)	−2.85 (−3.00–2.70)
	Southeast Asia	9676.19(8317.73–11,814.26)	5.67(4.87–6.92)	3828.65(3263.28–4445.83)	2.22(1.89–2.58)	−60.87 (−69.30–51.93)	−2.80 (−2.86–2.74)
	Gender						
	Male	35,162.74 (30,752.28–40,748.32)	6.40(5.60–7.42)	12,226.52 (10,335.93–14,240.53)	2.15(1.82–2.50)	−66.44 (−72.37–60.09)	−3.17 (−3.31–3.04)
	Female	34,462.41 (29,399.74–42,472.46)	6.74(5.75–8.31)	10,680.74 (9091.60–12,341.57)	2.05(1.75–2.37)	−69.57 (−75.61–63.86)	−3.44 (−3.58–3.30)
	Age						
	<1 year	27,802.80 (24,807.77–33,051.32)	36.50 (32.57–43.39)	8842.59(7195.82–10,534.56)	14.02 (11.41–16.70)	−61.59 (−69.31–53.23)	−2.94 (−3.02–2.86)
	12–23 months	8977.18(7461.77–10,870.90)	11.99(9.97–14.52)	2001.83(1586.37–2428.30)	3.06(2.43–3.72)	−74.45 (−80.29–67.99)	−4.17 (−4.30–4.05)
	2–4 years	12,634.73 (10,235.84–15,860.74)	5.64(4.57–7.08)	2364.05(1841.83–2992.57)	1.11(0.86–1.40)	−80.40 (−85.30–74.88)	−5.16 (−5.30–5.01)
	5–9 years	10,904.02 (9143.54–13,004.52)	3.04(2.55–3.63)	3944.26(3501.31–4459.81)	1.05(0.93–1.19)	−65.51 (−71.27–58.73)	−3.23 (−3.45–3.00)
	10–14 years	9306.42(8104.44–10,756.85)	2.85(2.48–3.29)	5754.53(5142.22–6406.33)	1.55(1.38–1.72)	−45.58 (−52.70–37.45)	−1.74 (−1.90–1.57)
DALY	**Asia**	6,388,747.96 (5,638,326.20–7,494,887.80)	602.33 (531.58–706.62)	2,333,204.27 (2,032,302.83–2,672,328.00)	214.06 (186.46–245.18)	−64.46 (−70.66–58.91)	−3.01 (−3.13–2.90)

(*continued on next page*)

Table 1 (*continued*)

Index	levels	1990		2021		1990–2021	
		Number (95 %UI)	Rate per 100,000 (95 %UI)	Number (95 %UI)	Rate per 100,000 (95 %UI)	Rate change	Rate EAPC (95 %CI)
	Region						
	Central Asia	51,609.32 (47,203.34–57,314.10)	206.51 (188.88–229.34)	32,000.99 (27,281.82–37,801.03)	115.63 (98.58–136.59)	−44.01 (−50.84–36.72)	−1.79 (−2.02–1.57)
	East Asia	1,927,410.41 (1,682,958.90–2,188,361.64)	584.36 (510.24–663.47)	300,387.37 (250,636.83–353,125.42)	112.36 (93.75–132.08)	−80.77 (−84.57–76.88)	−5.16 (−5.27–5.05)
	High-income Asia Pacific	68,439.27 (61,347.77–76,002.13)	194.43 (174.29–215.92)	16,924.27 (14,357.24–19,821.22)	75.47 (64.02–88.39)	−61.19 (−66.38–55.58)	−3.18 (−3.29–3.07)
	North Africa and Middle East	3,103,369.61 (2,668,850.32–3,759,109.05)	2209.03 (1899.73–2675.80)	935,427.57 (791,552.29–1,098,765.98)	510.26 (431.78–599.36)	−76.90 (−81.69–71.92)	−4.17 (−4.33–4.01)
	South Asia	2,602,684.83 (2,126,414.64–3,241,037.88)	600.58 (490.68–747.88)	1,226,609.47 (1,028,499.63–1,444,475.60)	241.92 (202.85–284.89)	−59.72 (−67.43–50.26)	−2.61 (−2.75–2.46)
	Southeast Asia	883,297.15 (766,595.44–1,071,682.92)	517.31 (448.96–627.64)	380,631.95 (332,942.90–437,350.89)	220.46 (192.84–253.31)	−57.38 (−65.60–48.42)	−2.56 (−2.61–2.51)
	Gender						
	Male	3,221,679.36 (2,834,901.45–3,708,731.78)	586.41 (516.01–675.07)	1,234,542.33 (1,068,846.63–1,435,316.28)	216.91 (187.80–252.19)	−63.01 (−69.07–57.00)	−2.90 (−3.02–2.79)
	Female	3,167,068.61 (2,740,540.97–3,851,398.97)	619.44 (536.01–753.28)	1,098,661.94 (951,832.87–1,261,587.28)	210.95 (182.76–242.23)	−65.94 (−72.69–60.21)	−3.13 (−3.25–3.01)
	Age						
	<1 year	2,498,189.60 (2,229,976.70–2,968,165.99)	3279.86 (2927.72–3896.88)	797,387.24 (650,957.04–949,427.25)	1264.26 (1032.10–1505.32)	−61.45 (−69.14–53.13)	−2.93 (−3.01–2.85)
	12–23 months	803,917.20 (669,294.04–971,242.28)	1074.09 (894.23–1297.65)	185,203.39 (149,706.73–222,388.74)	283.48 (229.15–340.40)	−73.61 (−79.48–67.19)	−4.08 (−4.21–3.95)
	2–4 years	1,140,142.05 (930,764.58–1,419,948.45)	508.90 (415.45–633.79)	244,972.20 (199,333.54–303,742.50)	114.56 (93.22–142.04)	−77.49 (−82.76–71.76)	−4.75 (−4.86–4.64)
	5–9 years	1,036,005.97 (878,629.57–1,214,709.84)	288.91 (245.02–338.74)	457,985.40 (401,035.14–526,707.76)	121.76 (106.62–140.03)	−57.85 (−64.52–50.36)	−2.65 (−2.82–2.49)
	10–14 years	910,493.15 (803,999.71–1,045,441.44)	278.42 (245.86–319.69)	647,656.04 (566,956.27–740,137.38)	174.30 (152.58–199.19)	−37.40 (−44.29–30.29)	−1.31 (−1.43–1.19)

EAPC, Estimated Average Percent Change.
Number and Rate are expressed as 95 % Uncertainty Interval (UI); EAPC is expressed as 95 % Confidence Interval (CI).
*If the upper limit of both EAPC and its 95 % CI is negative, its corresponding rate shows a decreasing trend; conversely, if the lower limit of both EAPC and its 95 %CI is positive, its corresponding rate shows an increasing trend.

CI: −3.44 to −3.17). Notably, children aged 2–4 years experienced the most significant reduction in mortality, with a change of −80.40 % (95 % UI: −85.30 to −74.88) and an EAPC of −5.16 % (95 % CI: −5.30 to −5.01). Conversely, children aged 10–14 years had the least reduction, with a mortality change of −45.58 % (95 % UI: −52.70 to −37.45) and an EAPC of −1.74 % (95 % CI: −1.90 to −1.57). Mortality rates and deaths were consistently highest among children under 1 year of age, with 8842.59 (95 % UI: 7195.82 to10,534.56) deaths in 2021 and a mortality rate of 14.02/100,000 (95 % UI: 11.41 to 16.70). The overall mortality rate for both sexes in 2021 was significantly lower than in 1990; however, the male mortality rate of 2.15/100,000 (95 % UI: 1.82 to 2.50) was slightly higher than the female rate of 2.05/100,000 (95 % UI: 1.75 to 2.37) (Table 1, Supplementary Table 1).

3.1.3. DALY

In 2021, the number of DALY among Asian children aged 0–14 years was 2333,204.27 (95 % UI: 2032,302.83 to 2672,328.00), resulting in a DALY rate of 214.06/100,000 (95 % UI: 186.46 to 245.18). This represents a decrease of 64.46 % (95 % UI: −70.66 to −58.91) compared to the DALY rate in 1990, with an EAPC of −3.01 % (95 % CI: −3.13 to −2.90). From 1990 to 2021, the most significant decline in DALY rates occurred in children aged 2–4 years, with a change of −77.49 % (95 % UI: −82.76 to −71.76) and an EAPC of −4.75 % (95 % CI: −4.86 to −4.64). In contrast, the least decline was observed in children aged 10–14 years, with a DALY rate change of −37.40 % (95 % UI: −44.29 to −30.29) and an EAPC of −1.31 % (95 % CI: −1.43 to −1.19), and the highest number of DALY was recorded in children under one year old, amounting to 797,387.24 (95 % UI: 650,957.04 to 949,427.25) cases, which represents approximately 34 % of the total. Consistent with the mortality trend, the DALY rate was slightly higher in males at 216.91/100,000 (95 % UI: 187.80 to 252.19) compared to females at 210.95/100,000 (95 % UI: 182.76 to 242.23) (Table 1, Supplementary Table 1).

3.2. CVD in children: Asian regions

3.2.1. Morbidity

In 2021, Central Asia exhibited the highest incidence rate at 94.57/100,000 (95 % UI: 67.40 to 129.32), while South Asia reported the highest number of cases, totaling 372,928.59 (95 % UI: 253,625.61 to 517,464.47). In contrast, the High-Income Asia Pacific region recorded the lowest number of cases at 6025.49 (95 % UI: 4670.46 to 7771.88) and the lowest incidence rate at 26.87/100,000 (95 % UI: 20.83 to 34.66). East Asia experienced the most significant decline in incidence between 1990 and 2021, with a change of −24.27 % (95 % UI: −28.70 to −20.75) and an EAPC of −0.77 % (95 % CI: −0.89 to −0.64). In contrast, South Asia saw the greatest increase in incidence, with a change of 10.39 % (95 % UI: 4.64 to 15.31) and an EAPC of 1.04 % (95 % CI: 0.74 to 1.33) (Table 1).

3.2.2. Mortality

In 2021, North Africa and the Middle East had the highest mortality rate at 5.25/100,000 (95 % UI: 4.35 to 6.31), while South Asia reported the highest number of deaths, totaling 12,569.56 (95 % UI: 10,320.27 to 15,016.94) cases. The High-Income Asia Pacific region had the lowest mortality rate at 0.51/100,000 (95 % UI: 0.47 to 0.54) and the lowest number of deaths at 113.89 (95 % UI: 104.98 to 121.65). Between 1990 and 2021, all regions exhibited a decreasing trend in mortality rates, with East Asia showing the largest decrease of 85.93 % (95 % UI: −89.20 to −82.45). Central Asia experienced the smallest decline, with a decrease of 52.85 % (95 % UI: −59.67 to −44.45) (Table 1).

3.2.3. DALY

In 2021, the highest rate of DALY was observed in North Africa and the Middle East at 510.26/100,000 (95 % UI: 431.78 to 599.36), while South Asia recorded the highest number of DALY, totaling 1226,609.47 (95 % UI: 1028,499.63 to 1444,475.60) cases; High-income Asia Pacific exhibited the lowest DALY rate at 75.47/100,000 (95 % UI: 64.02 to 88.39) and the lowest total number of DALY, totaling 16,924.27 (95 % UI: 14,357.24 to 19,821.22) cases. From 1990 to 2021, DALY was most prevalent in Asia. Across all regions, the DALY rate demonstrated a decreasing trend during this period, with the most significant decline observed in East Asia, where the DALY rate decreased by 80.77 % (95 % UI: −84.57 to −76.88) and the EAPC was −5.16 % (95 % CI: −5.27 to −5.05). In contrast, Central Asia experienced the smallest reduction, with a DALY rate decrease of 44.01 % (95 % UI: −50.84 to −36.72) and an EAPC of −1.79 % (95 % CI: −2.02 to −1.57) (See Table 1).

3.3. CVD in children: Asian countries

3.3.1. Morbidity

In 2021, Mongolia reported the highest incidence of childhood CVD at 117.66/100,000 (95 % UI: 82.82 to 159.63), while Cyprus had the lowest incidence at 19.42/100,000 (95 % UI: 15.28 to 24.43). The most substantial decrease in incidence rate from 1990 to 2021 occurred in China, with an incidence change of −24.94 % (95 % UI: −29.38 to −21.46) and an EAPC of −0.79 % (95 % CI: −0.91 to −0.66). The Philippines experienced the most pronounced increase in incidence, with a change of 16.21 % (95 % UI: 11.03 to 21.06) and an EAPC of 0.82 % (95 % CI: 0.61 to 1.03) (See Fig. 1, Supplementary Figure 1, Supplementary Tables 2–4).

3.3.2. Mortality

In 2021, Afghanistan had the highest child CVD mortality rate at 8.27/100,000 (95 % UI: 5.99 to 10.94), while India reported the highest number of deaths, totaling 6320.01 (95 % UI: 4963.84 to 7738.71) cases. Israel had the lowest mortality rate at 0.23/100,000 (95 % UI: 0.20 to 0.26), and Cyprus recorded the lowest number of deaths at 0.63 (95 % UI:0.51 to 0.77) cases. The most significant decrease in mortality from 1990 to 2021 was observed in Saudi Arabia, with a mortality change of −91.25 % (95 % UI:−94.60 to −87.53) and an EAPC of −7.58 % (95CI:−7.65 to −7.51). Pakistan recorded the lowest decline in mortality, with a mortality change of −29.09 (95 % UI:−46.17 to −7.52) and an EAPC of −0.15 % (95CI:−0.57 to 0.26). There was no significant difference in the downward trend in mortality between the sexes (Fig. 1, Supplementary figure 1, Supplementary Table 5–7).

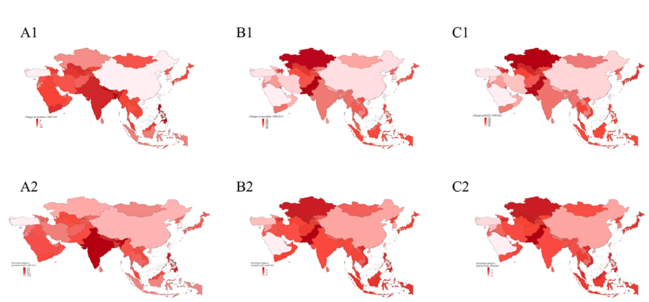

Fig. 1. Changes of children's cardiovascular disease burden in Asian countries or regions from 1990 to 2021.
A1.Changes in incidence,1990–2021; A2.Percentage change in prevalence EAPC,1990–2021; B1.Changes in mortality,1990–2021; B2.Percentage change in mortality EAPC,1990–2021; C1.Changes in DALY,1990–2021; C2.Percentage change in DALY EAPC,1990–2021.

3.3.3. DALY

In 2021, Afghanistan had the highest rate of DALY at 763.68/100,000 (95 % UI: 565.95 to 1002.35), while Israel had the lowest rate at 137.30/100,000 (95 % UI: 31.19 to 45.63). India reported the highest total number of DALY, totaling 650,428.51 cases (95 % UI: 526,269.02 to 788,954.61), whereas the Maldives recorded the lowest number of DALY at 147.07 cases (95 % UI: 121.58 to 177.09). Between 1990 and 2021, the rate of DALY exhibited a decreasing trend across all countries, with Kazakhstan experiencing the least significant decline at −27.31 % (95 % UI:−38.42 to −16.31) and an EAPC of −1.21 % (95 % CI:−1.90 to −0.50). Conversely, Saudi Arabia demonstrated the most substantial decline in the DALY rate at −87.43 % (95 % UI: −91.75 to −82.63), with an EAPC of −6.55 % (95 % CI: −6.64 to −6.46) (Fig. 1, Supplementary figure 1, Supplementary Table 8–10).

3.4. Analysis

The findings from the correlation analysis indicated that the SDI levels in Asian countries were negatively correlated with the incidence ($r = -0.5093$, $p < 0.001$), mortality ($r = -0.5935$, $p < 0.001$), and Disability-Adjusted Life Years (DALYs) rates related to cardiovascular disease (CVD) among children aged 0–14 years ($r = -0.5769$, $p < 0.001$). Additionally, a negative correlation was observed between SDI and the Estimated Annual Percentage Change (EAPC) in incidence ($R = -0.47$, $p = 0.00074$). However, no significant correlations were found regarding the EAPC for mortality and DALYs ($p > 0.05$) (Refer to Fig. 2).

3.5. Risk factor analysis

Abnormal temperatures were associated with CVD mortality, DALY, and CVD outcomes in children. In 2021, the proportion of deaths attributable to high temperatures in Asia was 2.06 %, and the proportion of DALY was 1.75 %. Conversely, the proportion of deaths attributable to low temperatures was 2.65 %, with a corresponding DALY proportion of 2.25 %. Over the 30-year period, the proportion of deaths and DALY attributed to low temperatures in Asia gradually decreased, while the proportions attributed to high temperatures gradually increased. However, throughout this period, the proportions of deaths and DALY attributed to high temperatures remained smaller than those attributed to low temperatures. The proportion of deaths and DALY attributable to non-optimal temperatures decreased with age among Asian children aged 0–14 years. Additionally, there was no significant gender difference in the impact of non-optimal temperatures on CVD (Fig. 3, Supplementary Figure 2).

3.6. Etiological analysis

RHD emerged as the leading cause of CVD among Asian children in 2021, followed by Myocarditis and Ischemic stroke. The incidence of Endocarditis was found to be higher in males than in females, while Pulmonary arterial hypertension was more prevalent in females. The prevalence of RHD was greater among older children, whereas the prevalence of the other causes gradually decreased with age. We selected five countries—namely China, India, South Korea, Japan, and Singapore—for a more detailed analysis of the causes of CVD in Asian children. The results indicated that the primary cause of CVD in China and India was RHD, with its incidence increasing with age. In contrast, Myocarditis was identified as the main cause of CVD in Korea, Japan, and Singapore, with no significant differences observed between males and females (Fig. 4, Supplementary figure 3–4, Supplementary Table 14).

Intracerebral hemorrhage was the leading cause of death from CVD in Asian children in 2021, followed by RHD. The incidence of intracerebral hemorrhage was higher in males than in females, whereas RHD

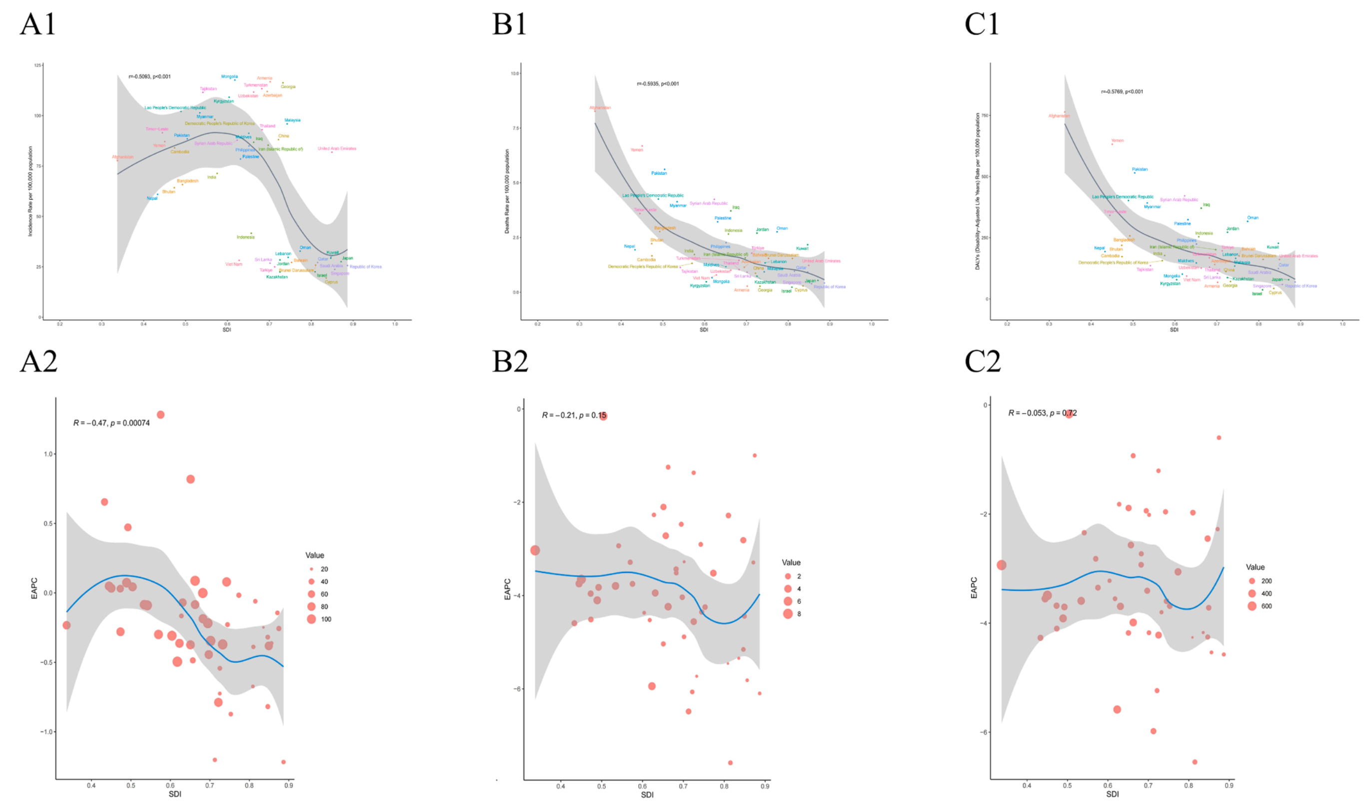

Fig. 2. Correlation analysis of the burden of childhood CVD with SDI in Asian countries or regions.
A1.Correlation between SDI levels and incidence of childhood CVD in Asian countries; A2.Correlation between SDI levels and EAPC of morbidity in Asian countries; B1.Correlation between SDI levels and child CVD mortality in Asian countries; B2.Correlation between SDI levels and EAPC of mortality in Asian countries; C1. Correlation of SDI levels with childhood CVD DALY across Asian countries; C2.Correlation of SDI levels with EAPC of DALY in Asian countries.

was more common in females. The mortality rate associated with RHD was higher among older children. Overall, children under one year of age exhibited the highest mortality rate, primarily due to intracerebral hemorrhage, other cardiomyopathies, and other cardiovascular and circulatory diseases. The leading causes of fatal events in 2021 across China, India, South Korea, Japan, and Singapore, in order of prevalence, were myocarditis, RHD, other cardiomyopathies, and pulmonary arterial hypertension. There were no significant differences in the leading causes between males and females (Fig. 4, Supplementary Figures 3–4, Supplementary Table 14).

In terms of disability, the changes in disability rates, causes, gender differences, and age differences are generally consistent with mortality rates, both across Asia as a whole and within the five countries of China, India, the Republic of Korea, Japan, and Singapore. (Fig. 4, Supplementary figure 3–4, Supplementary Table 14)

3.7. Projections

Asia comprises 48 countries and 6 regions, with a total population of approximately 4.759 billion, accounting for 58 % of the global population. Among this population, China (East Asia, approximately 1.4 billion) and India (South Asia, approximately 1.44 billion) together represent 59 %. The developmental levels, medical conditions, and distribution of health resources across different regions significantly influence the burden of cardiovascular diseases and their development trends. China is recognized as the largest developing country, while India has the highest population. In contrast, Singapore, Japan, and South Korea are classified as high-income countries. Consequently, we selected China, India, Korea, Japan, and Singapore for our study on the future trends of cardiovascular diseases in children. The findings are as follows.

3.7.1. Morbidity

By 2050, the incidence of childhood CVD in China, South Korea, and India is expected to decrease, with the most significant decline occurring in China, where it is projected to decrease by approximately 64.70 % compared to 1990,with the rate at (41.43/100,000 (95 % UI:1.46 to 81.40) in 2025. This decline is more pronounced in males, with a decrease of about 68.25 %, compared to a decrease of approximately 60.44 % in females. In contrast, the projected incidence rates in Singapore, with an incidence rate of 24.27/100,000 (95 % UI: −1.80 to 50.34), indicate an increase of about 3.84 %, while Japan shows an incidence rate of 2828.84/100,000 (95 % UI:9.10 to 48.58), reflecting an increase of about 1.3 % (Supplementary figure 5(A1-A5), Supplementary Table 11).

3.7.2. Mortality and DALY rates

In 2050, both mortality and DALY rates for childhood CVD in the five countries exhibit a declining trend. India experiences the lowest reduction in mortality, with a rate of 0.74/100,000 (95 % UI:−0.68 to 2.17) in 2025, reflecting a decrease of approximately 87.24 % compared to 1990. In contrast, China demonstrates the most significant decline in mortality, with a rate of 0.01/100,000 (95 % UI:−0.02 to 0.05) in 2025, representing a decrease of about 99.84 % from 1990. Furthermore, China shows the greatest reduction in DALY rates, recording a rate of 1.04/100,000 (95 % UI: −1.40 to 3.48) in 2025, which corresponds to a decrease of approximately 99.82 % from 1990. Conversely, India has the smallest decline in DALY rates, with a rate of 62.74/100,000 (95 % UI:−37.68 to 163.16) in 2025, indicating a reduction of about 88.06 % from 1990 (Supplementary figure 5(C1-C5), Supplementary Table 13).

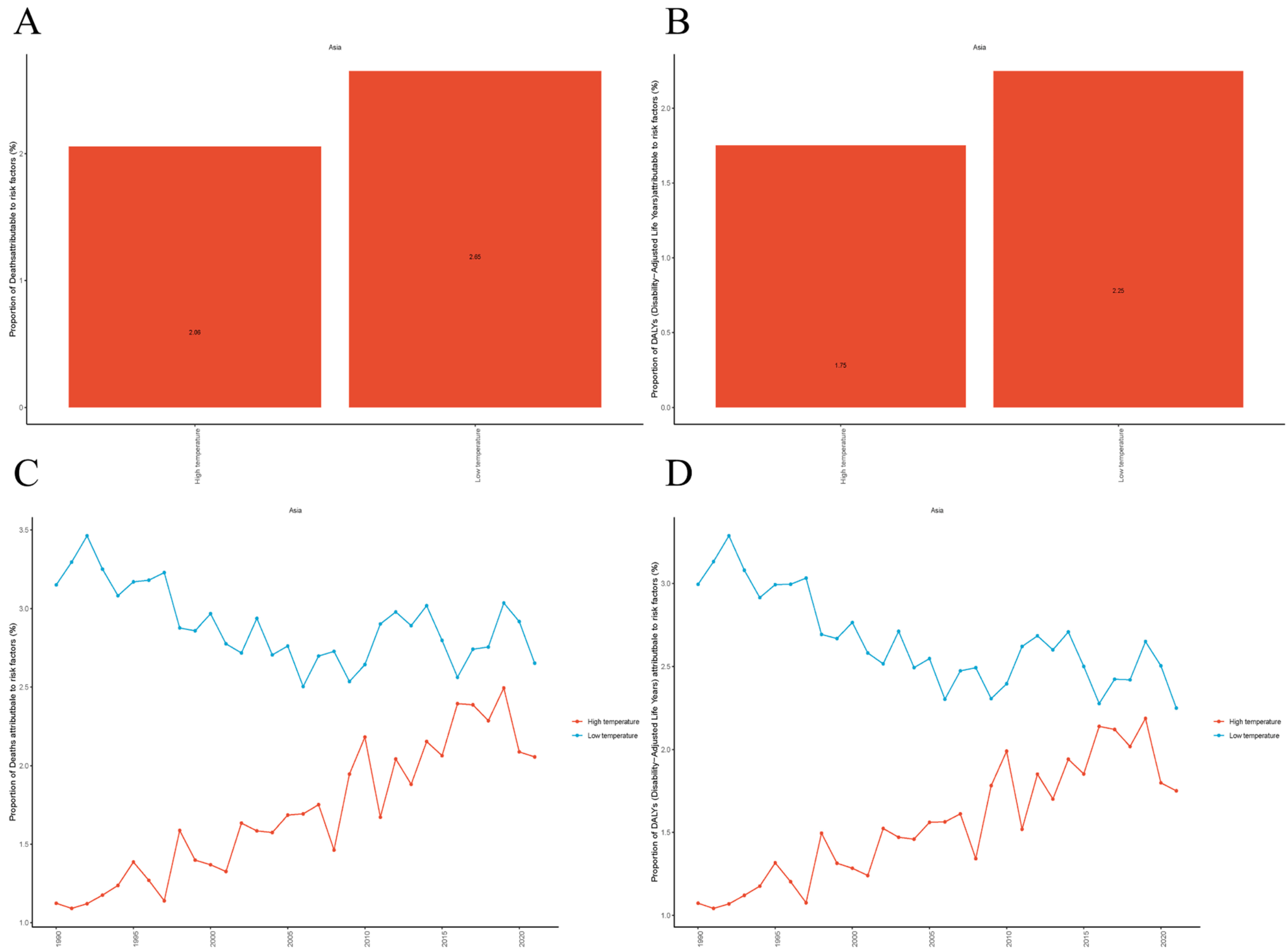

Fig. 3. Risk factor analysis of cardiovascular disease in Asian children.
A. Risk factors for death in 2021; B. Risk factors for DALY in 2021; C. Trends in risk factors for death from 1990 to 2021; D. Trends in risk factors for DALY from 1990 to 2021

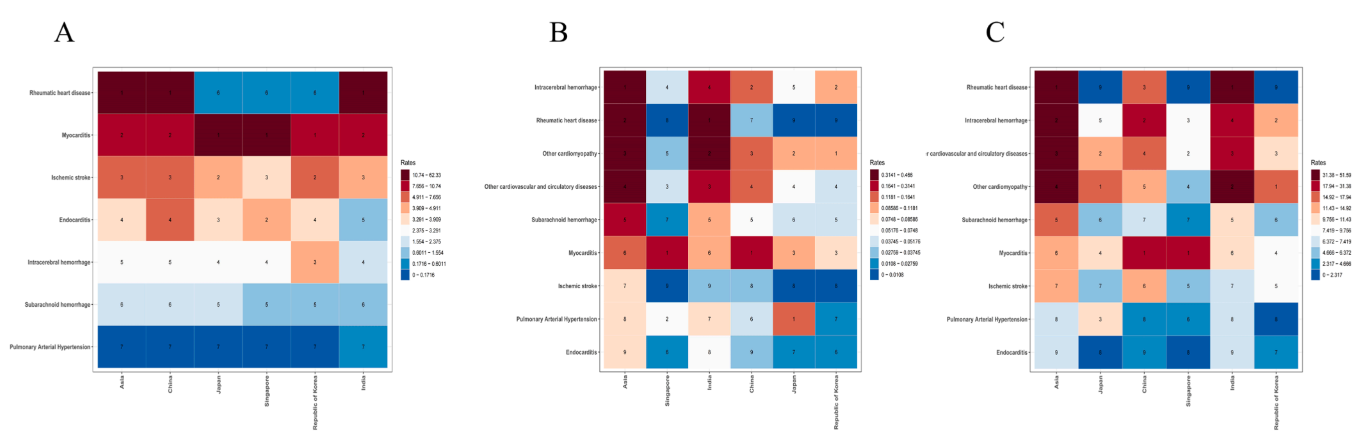

Fig. 4. Causes of Cardiovascular Disease in Children in Asia and China, Japan, Korea, India, Singapore, 2021.
A. Heat map of causes leading to morbidity; B. Heat map of etiological factors leading to deaths; C. Heat map of etiological factors leading to DALY

4. Discussion

This research presents the inaugural comprehensive evaluation of the burden of CVD, its underlying determinants, and anticipated trends among children aged 0–14 years in Asia, utilizing indicators such as morbidity, mortality, DALY, and EAPC. In Asia, the disease burden of CVD in children shows an obvious downward trend.from 1990 to 2021. Nonetheless, the intricate and heterogeneous nature of CVD etiology, coupled with regional and national disparities in economic, cultural, and genetic factors, renders pediatric CVD in Asia a significant public health challenge. Certain nations may even confront the potential risk of an exacerbation of the disease burden. Additionally, the potential influences of children's age, gender, and atypical climatic conditions on cardiovascular health warrant considerable attention. These results not only enhance our comprehension of the epidemiological patterns of CVD in Asian children but also offer critical insights for refining public health strategies and formulating more effective preventive and therapeutic interventions aimed at alleviating the social and economic impacts of the disease.

4.1. Regional differences

The overall decline in mortality and DALY is a global phenomenon [1], reflecting advancements in medical technology and heightened global health awareness. However, substantial regional disparities in CVD incidence persist, attributable to a multitude of complex factors. For instance, China has successfully diminished the incidence of CVD, along with associated mortality and DALY in children, through significant public health investments, medical reforms, and health education initiatives. This success is not solely linked to economic growth and technological advancements in healthcare but is also closely associated with the allocation of public health resources and the ongoing enhancement of the healthcare system [21].

Prior research has indicated that nations with higher levels of economic development tend to exhibit a lower and more rapidly declining burden of CVD, demonstrating a significant negative correlation between the SDI and disease burden. Countries with elevated SDI levels experience a more pronounced reduction in disease burden [3,4,22,23]. However, the increasing incidence of CVD in India appears to contradict this trend. It is posited that a combination of inequitable health resource distribution, insufficient chronic disease management systems, and severe air pollution may have contributed to the persistent rise in CVD incidence in India, highlighting the critical impact of the imbalanced relationship between economic development and public health outcomes.

Similarly, projections for 2050 indicate a potential continued increase in CVD incidence among children in two high-income nations, Singapore and Japan. This trend may be linked to economic, social, environmental, and psychological factors [24]. First of all, rapid economic development has facilitated convenience but has also significantly altered dietary habits and daily activities. Diets characterized by high sugar, fat, and salt content, along with reduced outdoor activity, may contribute to an increased incidence of CVD, particularly among children [25]. Secondly, economic development has been linked to environmental pollution, including ambient particulate matter, household air pollution from solid fuels, lead exposure, and extreme temperature variations, all of which are associated with the onset and progression of CVD [1]. Furthermore, mental health issues are becoming increasingly significant in the context of modernization. Psychological stressors, such as academic pressure, social environment, and familial dynamics, may contribute both directly and indirectly to the emergence and progression of CVD through intricate physiological mechanisms [26].

Consequently, while there exists a negative correlation between economic development and the burden of CVD—indicating that higher levels of economic development are generally associated with a lower burden of CVD [11]—this relationship is not absolute. It is imperative for nations to consider their specific levels of economic development and public health conditions when formulating health policies and implementing interventions. A comprehensive strategy is essential to effectively address the challenges posed by CVD. In less economically developed countries, such as Mongolia and India, public health policies should prioritize the enhancement of medical infrastructure, the strengthening of chronic disease management, and the promotion of health education. Conversely, in countries that have achieved substantial progress, such as China, future policies should aim to deepen health education, enhance individualized disease management, and ensure the sustainability of health outcomes over the long term [6,21,27]. This approach should encompass not only lifestyle modifications, such as dietary changes and increased physical activity, but also the remediation of environmental pollution and the addressing of mental health concerns. Only through a comprehensive and tailored management strategy can the morbidity and mortality associated with CVD in children be significantly reduced, thereby alleviating the overall burden of CVD.

4.2. Etiological differences and age differences

Previous research has indicated that mortality rates among adult CVD patients significantly increase with age, particularly in individuals over 65 years old; however, there has been comparatively less focus on age-related differences in children [2,14]. Our findings reveal an increased incidence of CVD among children aged 10–14 years, a notable number of fatalities in infants under one year, and a high burden of DALY. These observations may be closely linked to the diverse etiologies of CVD, as varying etiological factors contribute to different disease burdens, which in turn lead to disparities in disease impact across age and gender demographics.

In Asia, the incidence of CVD tends to rise with age, a trend that is particularly associated with RHD. RHD is a chronic disease, that is more prevalent among females, typically arises from rheumatic fever, and results in damage to heart valves, thereby impairing normal cardiac function. As time progresses, the cardiovascular implications of this condition become increasingly evident, leading to higher incidence rates among older children and female patients, and potentially resulting in further disability and mortality [27]. Numerous studies have indicated a correlation between poverty and family overcrowding and an elevated incidence of RHD, which poses a significant public health challenge in numerous low-income nations [28–30]. Consequently, RHD represents a critical and preventable contributor to morbidity and mortality among children and young adults in low- and middle-income countries, as well as in specific high-risk populations residing in high-income countries. It is imperative to enhance our comprehension of the disease's prognosis to facilitate timely and appropriate interventions [31].

In infants under one year of age, intracerebral hemorrhage emerges as the primary cause of death and disability. This condition, characterized by a rapid onset during the disease course, significantly contributes to neonatal morbidity and mortality. The neurodevelopmental outcomes for newborns affected by cerebral hemorrhage are contingent upon several factors, including brain maturity, the hemorrhage's location and extent, the presence of specific underlying causes, and other concurrent disorders. The resultant effects on brain function in children are predominantly irreversible [32]. In summary, intracranial hemorrhage constitutes a life-threatening condition, and while intensive care can enhance prognosis, it continues to impose substantial economic and psychological burdens on both the child and their family [33]. Thus, early recognition and prompt treatment are crucial for healthcare practitioners.

Diseases exhibit variability in their intrinsic characteristics and manifestations, leading to significant differences in the distribution and impact of disease burden across gender and age demographics. Understanding and identifying these disparities is essential for the development of effective public health strategies, optimizing resource allocation, and implementing targeted preventive and therapeutic interventions.

4.3. Gender differences

The burden of CVD in children reveals pronounced gender disparities, with male children experiencing higher rates of mortality and DALY compared to their female counterparts, despite a slightly lower prevalence of the disease among males. These discrepancies may be attributed to variations in etiology and metabolic factors. Prior research has documented gender differences in the epidemiology, pathophysiology, clinical management, and outcomes of CVD; however, the underlying pathophysiological mechanisms and social determinants warrant further investigation [12,34–37]. It is important to acknowledge the significant health disparities that exist globally between females and males aged 10 years and older, with only modest progress made in addressing these disparities over the past three decades [38].

There are differences in the disease spectrum between adults and children. At present, there are few studies on gender differences in children, which needs to be actively explored. In addition, Gender differences in health outcomes are influenced not only by biological factors but also by a multitude of social determinants, including cultural norms, educational attainment, economic development, legal frameworks, and national policies. Consequently, a nuanced analysis of gender disparities in health within Asian countries is essential, taking into account each nation's unique context, including disease etiology, policy frameworks, and socio-cultural influences.

4.4. Risk factors

In terms of risk factors for CVD, prior research has predominantly concentrated on adult populations, with evidence suggesting that the elevated global mortality rate associated with CVD is largely attributable to high systolic blood pressure [1]. Furthermore, there has been a growing recognition of the role of metabolic factors, such as obesity, in contributing to CVD risk [2,39–41]. Our findings indicate that non-optimal temperature is a significant risk factor affecting the burden of CVD among children in Asia. While it has been previously established that non-optimal temperature ranks among the top ten global causes of mortality [17], there remains a paucity of studies examining long-term trends in CVD mortality related to non-optimal temperatures across different age groups and genders, as well as a lack of comprehensive analyses regarding the underlying causes of these trends. Recent years have witnessed an increase in the frequency of extreme heat and cold events globally, driven by climate change, which has direct implications for public health through heightened exposure to extreme temperatures. Thus, the impact of abnormal temperature on disease incidence warrants further investigation.

Epidemiological data indicate that both low and high temperatures can elevate mortality risk [17,42,43]. Some studies have suggested that the duration of cold waves typically exceeds that of heat waves, leading to a more pronounced impact of low temperatures, which aligns with our findings [1,44]. Conversely, other researchers argue that regions experiencing high temperatures may encounter significant heat-related health effects that surpass those associated with cold [45]. Currently, the overall rise in ambient temperatures has not been substantial, resulting in a relatively minor burden of heat-related CVD mortality. However, global temperatures have increased by approximately 1.25 °C during the 20th century and are anticipated to surpass 1.5 °C within the next decade [46]. This trend elucidates the growing influence of high temperatures on CVD over the past 30 years and suggests that future global warming may exacerbate the negative health consequences associated with elevated temperatures, thereby increasing the incidence of heat-related diseases. Our risk factor analysis reveals that younger children aged 0–14 years experience a higher proportion of deaths and DALY attributable to abnormal temperature, with low temperatures exerting a more significant impact on CVD than high temperatures.

Younger individuals, whose thermoregulatory centers are comparatively underdeveloped and exhibit limited regulatory capacity, are more vulnerable to extreme weather conditions. This susceptibility may ultimately contribute to an increased burden of CVD. Research indicates that the younger the child, the less developed the thermoregulatory center, resulting in poorer regulatory abilities and increased susceptibility to environmental extremes, which contributes to the worsening of the CVD burden [47,48]. However, there is a paucity of research examining the differential effects of temperature across various age groups, particularly among children. Furthermore, the risk factors associated with 93 % of pediatric cases remain unidentified, necessitating further investigation to elucidate the factors that contribute to disparities in CVD prevalence across different countries, genders, and subtypes, thereby aiding in the reduction of CVD burden.

5. Limitations

Limitations of this study include the inherent constraints associated with the GBD methodology, which may impact the reliability of data sources, the accuracy of analytical methods, and the interpretation of findings [1,12]. Additionally, the GBD study classifies congenital heart disease as a congenital developmental anomaly rather than as a form of CVD, which precludes a discussion of its impact in this article [2,11,12]. Future multicenter clinical studies are warranted to provide a more comprehensive assessment of the CVD burden in children, taking into account economic, familial, and social factors.

6. Conclusion

In conclusion, this study offers a thorough evaluation of the burden of CVD among Asian children aged 0–14 years from 1990 to 2021. While there is a general decline in the incidence, mortality, and DALY associated with CVD in this demographic, significant regional disparities highlight the necessity for tailored public health policies that address the specific needs of different areas. Additionally, the influences of age, gender, and temperature on disease burden warrant further investigation. Future research should aim to explore these factors in greater depth to assist countries in developing more targeted prevention strategies aimed at alleviating the burden of CVD in children and enhancing overall pediatric health.

Findings: From 1990 to 2021, although the incidence, mortality and DALY of cardiovascular diseases among children aged 0–14 in Asia generally declined, the regional differences were very significant. And it is worth noting that this burden has the potential risk of increasing in the future. In addition, the effects of age, sex and temperature on disease burden deserve further study.

Meaning: The study is the first comprehensive assessment of the burden of cardiovascular disease in Asian children aged 0–14 years.

Author statement

We declare that this manuscript is original, has not been published before and is not currently being considered for publication elsewhere.

We confirm that the manuscript has been read and approved by all named authors and that there are no other persons who satisfied the criteria for authorship but are not listed. We further confirm that the order of authors listed in the manuscript has been approved by all of us.

We understand that the Corresponding Author is the sole contact for the Editorial process. He is responsible for communicating with the other authors about progress.submissions of revisions and final approval of proofs.

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CRediT authorship contribution statement

Chenyang Li: Writing – review & editing, Writing – original draft, Investigation, Data curation. **Shiyi Lei:** Investigation, Data curation. **Lingjuan Liu:** Writing – review & editing. **Yuxing Yuan:** Writing – review & editing, Investigation, Data curation, Conceptualization. **Jie Tian:** Writing – review & editing.

Declaration of competing interest

The authors declare the following financial interests/personal relationships which may be considered as potential competing interests:

Jie Tian reports financial support and article publishing charges were provided by Children's Hospital of Chongqing Medical University National Clinical Research Center for Child Health and Disorders. If there are other authors, they declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Supplementary materials

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