Global trends and regional differences in non-transport unintentional injuries mortality among children and adolescents, 1990 to 2019: results from the Global Burden of Disease 2019 study

Yunfei Liu[1], Yanhui Dong[1], Xiaojin Yan[1], Ning Ma[1], Jiajia Dang[1], Jingshu Zhang[1], Panliang Zhong[1], Luo Li[2], Zhiyong Zou[1], Yi Song[1], Jun Ma[1]

[1]Institute of Child and Adolescent Health, School of Public Health, Peking University, Beijing 100191, China;
[2]The University of Melbourne, Melbourne School of Population and Global Health, Parkville, VIC 3010, Australia.

Abstract

Background: Non-transport unintentional injuries (NTUIs) are major public concerns, especially among children and adolescents in low- and middle-income countries. With environmental and cognitive changes, a recent systematic description of global trends and regional differences concerning NTUIs is urgently needed for the global agenda of relevant policy-making and intervention target findings.

Methods: We used mortality, population, and socio-demographic-index (SDI) data from Global Burden of Disease 2019 to analyze the trends of NTUIs mortality. We applied the slope index of inequality (SII) and relative index of inequality (RII) to measure the absolute and relative inequality between countries and territories. The concentration curve and concentration index (CI) were also used to measure the inequality. We conducted a sensitivity analysis to make our findings credible.

Results: In 2019, there were 205,000 deaths due to NTUIs among children and adolescents aged 5 to 24 years, which decreased from 375,000 in 1990. In 2019, the age-standardized mortality rate (ASMR) was 8.13 per 100,000, ranging from the lowest in the Netherlands (0.90 per 100,000) to the highest in the Solomon Islands (29.34 per 100,000). The low-middle SDI group had the highest ASMR of NTUIs, while the low SDI group had the slowest decrease. After excluding the death caused by "exposure to forces of nature" and "other unintentional injuries", drowning accounted for the most deaths in almost every SDI group, gender, and age group, but the major causes of death varied in different subgroups. For example, animal contact was a major cause in low and low-middle SDI groups but less in high SDI groups, while high and high-middle SDI groups had a higher proportion of deaths for foreign body and poisonings. The SII showed a declining trend, but the RII and CI did not, which might indicate that inequality was persistent. Similar results were found in the sensitivity analysis.

Conclusions: Despite the declining trend of the mortality rate and the narrowing gap between countries, there were still a large number of children and adolescents dying from NTUIs, and those experiencing social-economic disadvantages remained at high mortality. Embedding the prevention of NTUIs into sustainable development goals might contribute to the progress of reducing death and inequalities, which ensures that no one is left behind.

Keywords: Children and adolescents; Non-transport unintentional injuries; Socio-demographic-index; Inequality analysis; Foreign body; Poisoning; Global Burden of Disease; Cause of death; Developing countries; Drowning

Introduction

Globally, non-transport unintentional injuries (NTUIs), namely drowning, falls, burns, poisoning, and so on, are major public concerns, accounting for nearly 1.8 million deaths annually in 2019.[1,2] Children and adolescents, especially those in low- and middle-income countries (LMICs), suffered huge losses from them.[3-9] Other than deaths, NTUIs also led to disability, which caused children and adolescents and their families to bear heavy medical burdens as well as physical and mental disorders.[3] The sustainable development goals (SDGs) proposed the goals that aimed to maintain and promote long and healthy lives for all age groups so that no one is left behind.[10] However, NTUIs were relatively ignored because no target focusing on NTUIs was ratified.[10,11]

Even though abundant studies focused on NTUIs worldwide, most of them only analyzed the trend within limited regions or countries across all ages, or they

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Correspondence to: Yi Song, Institute of Child and Adolescent Health, School of Public Health, Peking University, No. 38 Xueyuan Road, Haidian District, Beijing 100191, China
E-Mail: songyi@bjmu.edu.cn;
Zhiyong Zou, Institute of Child and Adolescent Health, School of Public Health, Peking University, No. 38 Xueyuan Road, Haidian District, Beijing 100191, China
E-Mail: harveyzou2002@bjmu.edu.cn

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recognized NTUIs as a part of injuries without detailed analysis.[8,12,13] However, except for age under 5, the most vulnerable group of NTUIs was children and adolescents aged 5 to 24 years, who have been understudied for a long time.[14] To date, no study had systematically explored the global trend and regional difference in NTUIs mortality of children and adolescents aged 5 to 24 years old.

In this study, we hypothesized that the mortality of NTUIs has decreased in recent decades. We additionally hypothesized that inequality existed in different genders, age groups, and regions, which also declined during 1990 to 2019. The purpose of this study was to analyze the trends of NTUIs mortality among children and adolescents aged 5 to 24 years between 1990 and 2019 and find regional differences by using data from Global Burden of Disease (GBD) 2019. In addition to the trend of mortality, our group had a special offer to evaluate the relationship between NTUIs mortality and social development among children and adolescents aged 5 to 24 years. Moreover, we used three representative indexes to evaluate the regional difference and its trend between 1990 and 2019. The results of this study might highlight the focus of intervention and provide insight for future policymaking.

Methods

Data sources

GBD 2019 provided the estimation of the age-specific mortality of 369 diseases and injuries for 204 countries and territories from 1990 to 2019.[15] The diseases and injuries were divided into three level 1 causes—communicable, maternal, neonatal, and nutritional diseases; noncommunicable diseases; and injuries, within which there were 22 level 2 causes, 173 level 3 causes, and 301 level 4 causes.[15] The injuries contained three level 2 causes—transport injuries; unintentional injuries; self-harm and interpersonal violence. In this study, we focused on the level 2 cause—unintentional injuries—and obtained the mortality and population data of children and adolescents aged 5 to 24 years from GBD 2019. The children and adolescents aged 5 to 24 years were divided into four groups by their age (5–9 years, 10–14 years, 15–19 years, 20–24 years). Socio-demographic-index (SDI) data, which combined information from the economy, education, and fertility rate of countries, were also accessed via GBD 2019.[16]

The human development index (HDI), as a substitute for SDI, was also collected from Human Development Reports published by the United Nations Development Programme. The HDI, which is similar to the SDI, is a summary measure of average achievement in three key dimensions of human development — a long and healthy life, being knowledgeable, and having a decent living standard.[17] Both the SDI and HDI are scaled from 0 to 1, and values closer to 1 indicate better development status.

Analysis of mortality rate and death trends

We used the mortality data and global standard population from GBD 2019 to calculate the age-standardized mortality rate (ASMR) between 1990 and 2019. Then, the annual change percentage between 1990 and 2019 was calculated using log-transformed linear regression. We also analyzed the trends of ASMR and the number of deaths in different regions and SDI levels. Considering the instability and incapable of intervening in the death caused by "exposure to forces of nature" and "other unintentional injuries", we also displayed the trends of ASMR and the number of deaths caused by nine other kinds of NTUIs except "exposure to forces of nature" and "other unintentional injuries."

In addition, we utilized the age-period-cohort (APC) model to detect the age effect, period effect, cohort effect for NTUIs except "exposure to forces of nature" and "other unintentional injuries" at each SDI level by using a well-designed web tool (https://analysistools.cancer.gov/apc/) developed by the National Cancer Institute.[18] We also calculated the local drifts and net drifts, which represent the annual change percentage in a specific age group and in a total of four age groups, respectively.

Analysis of the cause of death

We used the cause-specific mortality data of NTUIs except "exposure to forces of nature" and "other unintentional injuries" and calculated the proportion of each cause of death in each gender and age group globally for children and adolescents aged 5 to 24 years in 2019. A similar analysis was conducted at each SDI level.

Panel data regression

To identify the association between mortality and SDI with panel data, we used panel data regression to adjust the cluster effect of countries and territories. In this model, we used countries and territories as the group variable and used year as the time variable, and deaths caused by "exposure to forces of nature" and "other unintentional injuries" were also excluded. Log transformation was used to improve the model fitness. The Hausman test was used to identify what model we should choose, and we chose the fix effect model if the *P* value of the Hausman test was <0.05; otherwise, we chose the random-effect model. Subgroup analysis was used to detect the association by sex, age group, and region.

Inequality analysis

To test the inequality of death caused by NTUIs except "exposure to forces of nature" and "other unintentional injuries" between different countries and territories, we calculated the slope index of inequality (SII) and the relative index of inequality (RII), which could be used to measure the absolute and relative inequality between countries and territories, respectively.[19,20] The SII represents the absolute mortality rate difference between the lowest SDI group and the highest SDI group, and a negative SII value reflects that there were more deaths in the low SDI group. RII represents the relative mortality rate difference, and a 1/RII value greater than 1 reflects that the mortality in the lowest SDI group is several times than that in the highest SDI group. We also plotted the

concentration curve and calculated the concentration index (CI) to describe the regional differences.[19,21] The concentration curve plots the cumulative death percentage and cumulative population percentage, which are ranked by SDI from 0 to 1. CI represents twice the area enclosed by the concentration curve and absolute equality line, and a negative CI reflects that there are more deaths in the low SDI group. Subgroup analysis was also used to confirm the inequality in each gender, age group, and region. In addition, we used available inside-country data from GBD to analyze the trends of SII, RII, and CI to confirm our conclusion.

Sensitivity analysis

To increase the credibility of our results, we also utilized the APC model, panel data regression, and inequality analysis for death caused by all kinds of NTUIs. In addition, we collected data on the HDI from Human Development Reports published by the United Nations Development Programme. We used it as a substitute for SDI and conducted a sensitivity analysis of panel data regression and inequality analysis. APC analysis was conducted in APC web tool (National Cancer Institute, Maryland Bethesda, United States), and the remaining analyses were conducted in R program version 4.0.3 (R Development Core Team, Vienna, Austria).

Results

Global ASMR and death trends by gender and age group

Globally, in 2019, there were 205,000 deaths due to NTUIs among children and adolescents aged 5 to 24 years, which declined from 375,000 in 1990, and the ASMR was 8.13 per 100,000, ranging from the lowest in the Netherlands (0.90 per 100,000) to the highest in the Solomon Islands (29.34 per 100,000) [Supplementary Table 1, http://links.lww.com/CM9/B219]. There were substantial regional differences among 204 countries and territories, and the mortality rate was particularly high in some African and Asian countries. From 1990 to 2019, the global ASMR of NTUIs declined from 17.49 per 100,000 to 8.13 per 100,000 [Supplementary Figure 1, http://links.lww.com/CM9/B219], and the trend in the majority of countries aligned with the overall trend, except for several African countries [Supplementary Table1, http://links.lww.com/CM9/B219]. Males had higher ASMR than females in every single year [Supplementary Figure 2, http://links.lww.com/CM9/B219].

Globally, children aged 5 to 9 years had the highest risk of death (rate ratio was 1.56 [95% CI: 1.50–1.63] for males and 1.81 [95% CI: 1.73–1.89] for females *vs.* children aged 10–14 years) [Figure 2A]. The risk of death declined with the period and cohort. Children and adolescents in the 1990 to 1994 period had the highest risk of death (rate ratio was 1.35 [95% CI: 1.28–1.42] for males and 1.30 [95% CI: 1.23–1.37] for females *vs.* children and adolescents in 2000–2004), while children and adolescents in the 2015 to 2019 period had the lowest (rate ratio was 0.67 [95% CI: 0.64–0.72] for males and 0.71 [95% CI: 0.66–0.75] for females *vs.* children and adolescents in 2000–2004) [Figure 2B]. Children and adolescents born in 1970 had higher risk of dying from NTUIs compared with those born in 1990 (rate ratio was 1.38 [95%CI:1.26–1.51] for males and 1.30 [95%CI:1.17–1.44] for females), while children and adolescents born in 2010 had lower risk (rate ratio was 0.42 [95% CI: 0.38–0.47] for males and 0.43 [95% CI: 0.39–0.48] for females) [Figure 2C]. The net drifts were −2.78% (95% CI: −2.95% to −2.60%) for males and −2.58% (95% CI: −2.77% to −2.40%) for females globally, and the annual percentage change decreased with age in both males and females [Figure 2D].

Global ASMR and death trends by SDI group

The trend of each SDI level was also consistent with the overall trend [Figure 1]. The ASMR of NTUIs dropped fastest in the high SDI group (for nearly 63%) and dropped slowest in the low SDI group (almost 42%) during the past decades. The low–middle SDI group had the highest ASMR of NTUIs (10.46 per 100,000) among the five SDI groups in 2019, while the high SDI group had the lowest (2.59 per 100,000). The number of deaths decreased in each SDI group except the low SDI group, where the number of deaths increased from 38,000 to 47,000 [Figure 1].

Unlike the overall, for males in the high SDI group, adolescents aged 20 to 24 years were most vulnerable (rate ratio was 2.03 [95% CI: 1.96–2.11] *vs.* children aged 10–14 years), while in other SDI groups, children aged 5 to 9 years had the highest risk of death for NTUIs [Figure 2A]. The changes in risk of deaths for different periods and cohorts in each SDI level were basically consistent with the global results [Figures 2B, C]. In the high SDI group and high–middle SDI group, the mortality rate of males declined faster than that of females, which was consistent with the global situation, but the situation in the remaining three groups was reversed [Figure 2D].

Global main causes of death by sex and age group

Globally, we found that drowning had the highest proportion of deaths in all subgroups except for females aged 20 to 24 years. Males' proportions fell from 49.12% to 30.28%, while females' proportions fell from 33.63% to 15.56% as they grew older. Falls and exposure to mechanical forces were also leading causes of death for children and adolescents aged 5 to 24 years, with older adolescents, particularly males, suffering the most. The proportion of death in male adolescents aged 20 to 24 years was 22.27% and 18.32%, while the proportion in male children aged 5 to 9 years was 14.17% and 7.07%, respectively. The burden of fire, heat, and hot substances increased with age in females, changing from 9.72% to 24.16%. Furthermore, we discovered that death due to animal contact was more severe in females, especially in children aged 5 to 14 years [Figure 3, Supplementary Table 2, http://links.lww.com/CM9/B219].

Global main causes of death by SDI group

We also discovered that drowning, falls, exposure to mechanical forces were leading causes in every SDI group,

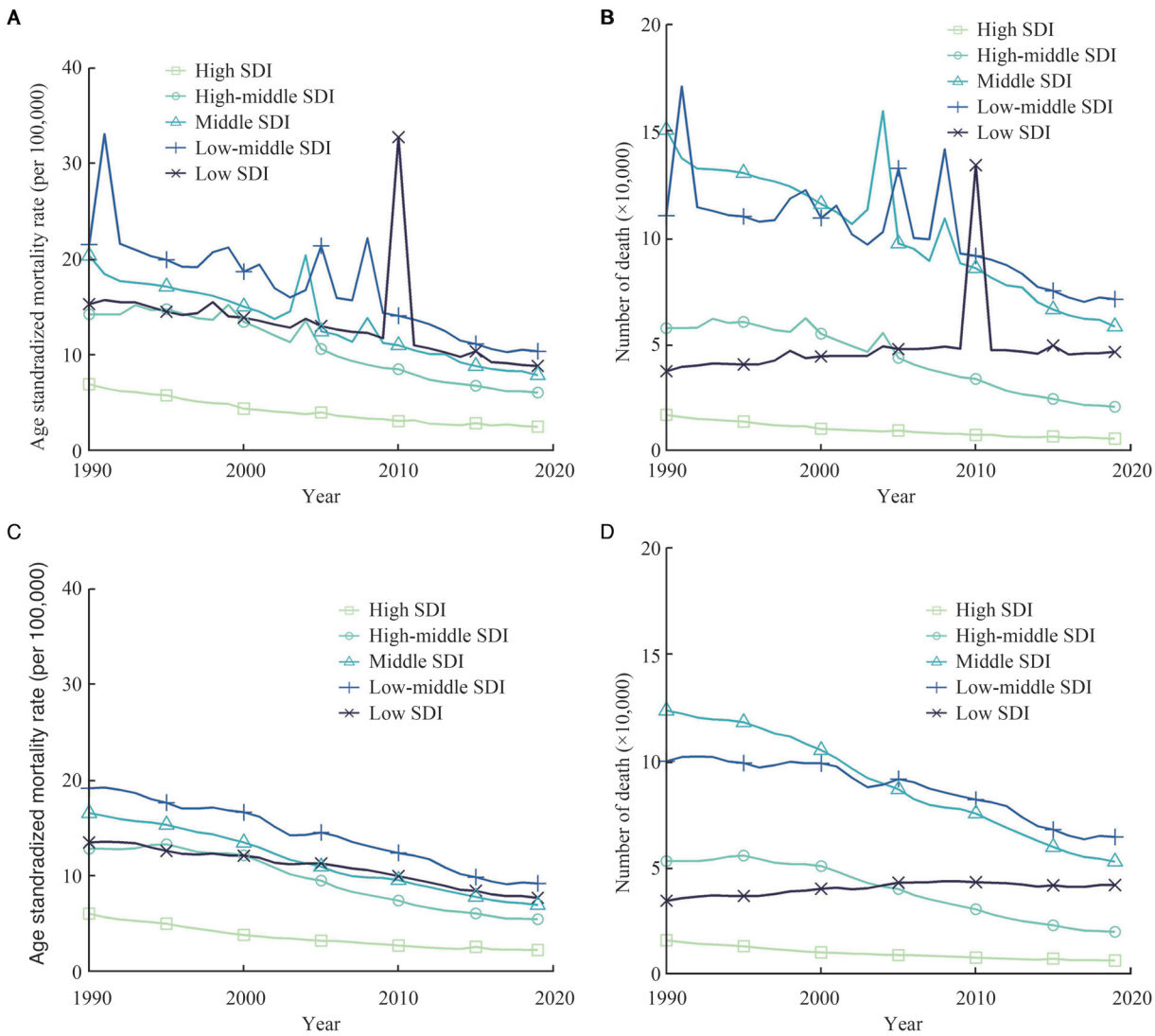

Figure 1: Global age-standardized mortality rate and number of deaths for NTUIs among children and adolescents aged 5 to 24 years, by SDI levels, 1990 to 2019. (A) Age-standardized mortality for NTUIs. (B) Number of deaths for NTUIs. (C) Age-standardized mortality for NTUIs excluded the death caused by "exposure to forces of nature" and "other unintentional injuries." (D) Number of deaths for NTUIs excluded the death caused by "exposure to forces of nature" and "other unintentional injuries." NTUIs: Non-transport unintentional injuries; SDI: Socio-demographic index.

and the distribution in each subgroup was largely consistent with the overall distribution. However, the children and adolescents in low and low–middle SDI groups suffered many times higher than those in high and high–middle SDI groups. Drowning claimed the lives of 11,000 and 23,000 deaths in low and low–middle SDI groups, respectively, while it claimed the lives of 2000 and 8000 deaths in high and high–middle SDI groups, respectively, despite the fact that the proportion was similar across all five SDI groups. Besides that, animal contact was a leading cause in low (the proportion ranging from 9.92% to 20.13% in each subgroup) and low–middle SDI groups (ranging from 10.97% to 23.37%), but less in high SDI groups (ranging from 0.29% to 1.77%). The proportion of deaths for foreign body and poisonings in high (ranging from 6.30% to 13.73% and from 3.22% to 11.50%, respectively) and high–middle SDI groups (ranging from 4.99% to 8.31% and from 5.24% to 15.47%, respectively) were higher than those in low (ranging from 4.73% to 8.03% and from 5.91% to 8.85%, respectively) and low–middle groups (ranging from 2.60% to 5.71% and from 3.64% to 7.54%, respectively) [Figure 3, Supplementary Table 2, http://links.lww.com/CM9/B219].

Association between ASMR and SDI

Globally, we found that for every 0.1 increase in SDI, the ASMR of NTUIs decreased by approximately 29%. We discovered that the mortality rate of children aged 5 to 9 years was the group most affected by SDI, the mortality rate decreased by nearly 37% for every 0.1 increase in SDI, and the effect declined with age [Table 1]. The results analyzed by region showed that the declining percentage in mortality of children and adolescents in Europe and Central Asia would drop fastest for the improving of the economy, education, and fertility rate of these countries. We also found that NTUIs ASMRs drop fast when the SDI

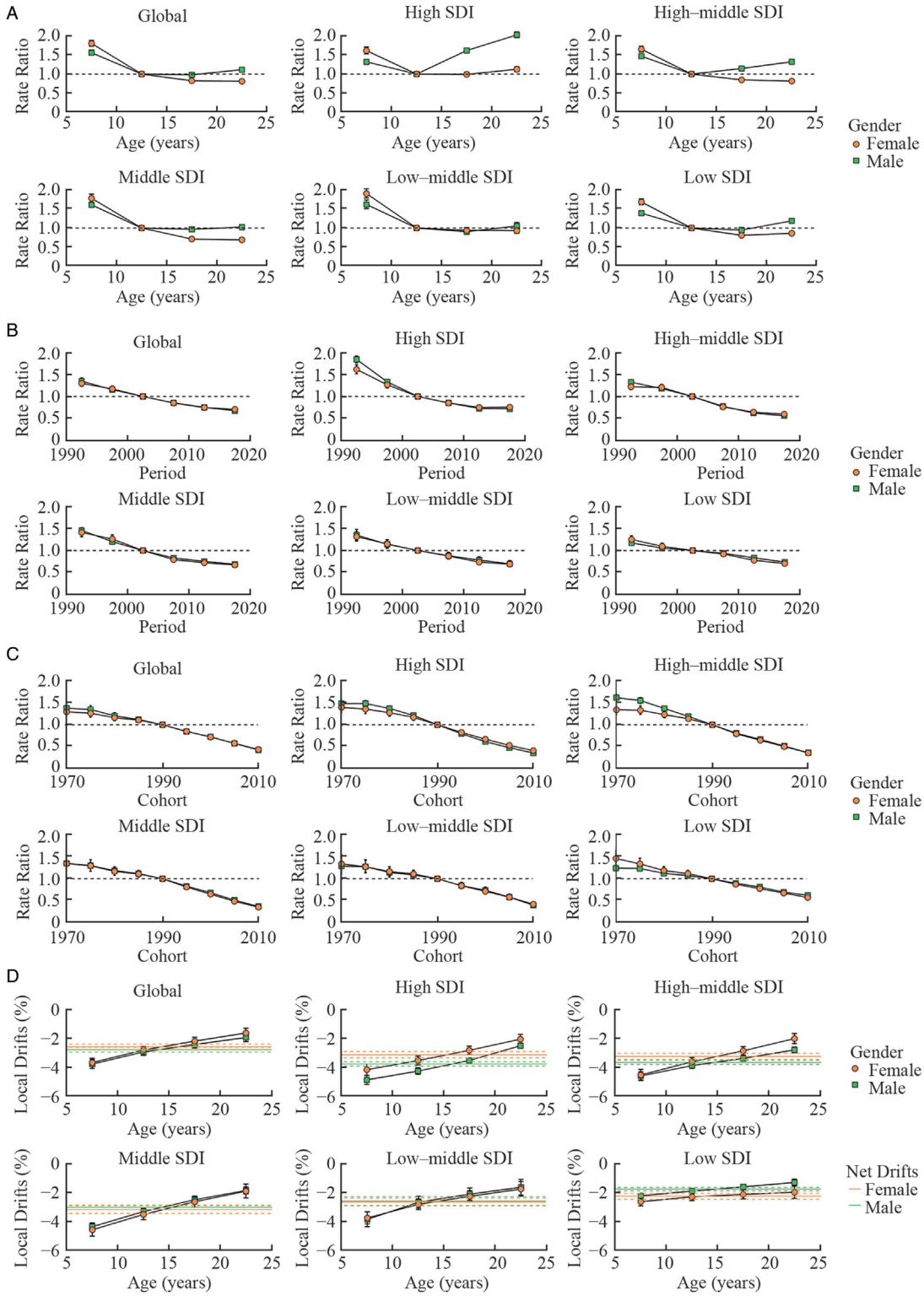

Figure 2: Trends in NTUIs mortality by SDI quintiles, 1990 to 2019. (A) Age rate ratio of NTUIs in 1990 cohort by SDI levels, adjusted for period effect. (B) Mortality rate ratio of NTUIs by SDI levels and period from 1990 to 2020. (C) Mortality rate ratio of NTUIs by SDI levels and birth cohort from 1970 to 2010. (D) Age-specific annual percent change of NTUIs mortality rate by SDI levels, 1990 to 2019. Death due to "exposure to forces of nature" and "other unintentional injuries" was excluded. NTUIs: Non-transport unintentional injuries; SDI: Socio-demographic Index.

improves in countries and territories with low SDI levels, such as the countries and territories in Latin America and the Caribbean, Sub-Saharan Africa, and South Asia [Table 1, Figure 4].

Inequality analysis

For both males and females, the SII was negative, meaning that children and adolescents in countries with lower SDI had higher ASMR. The female group (9.63 per 100,000)

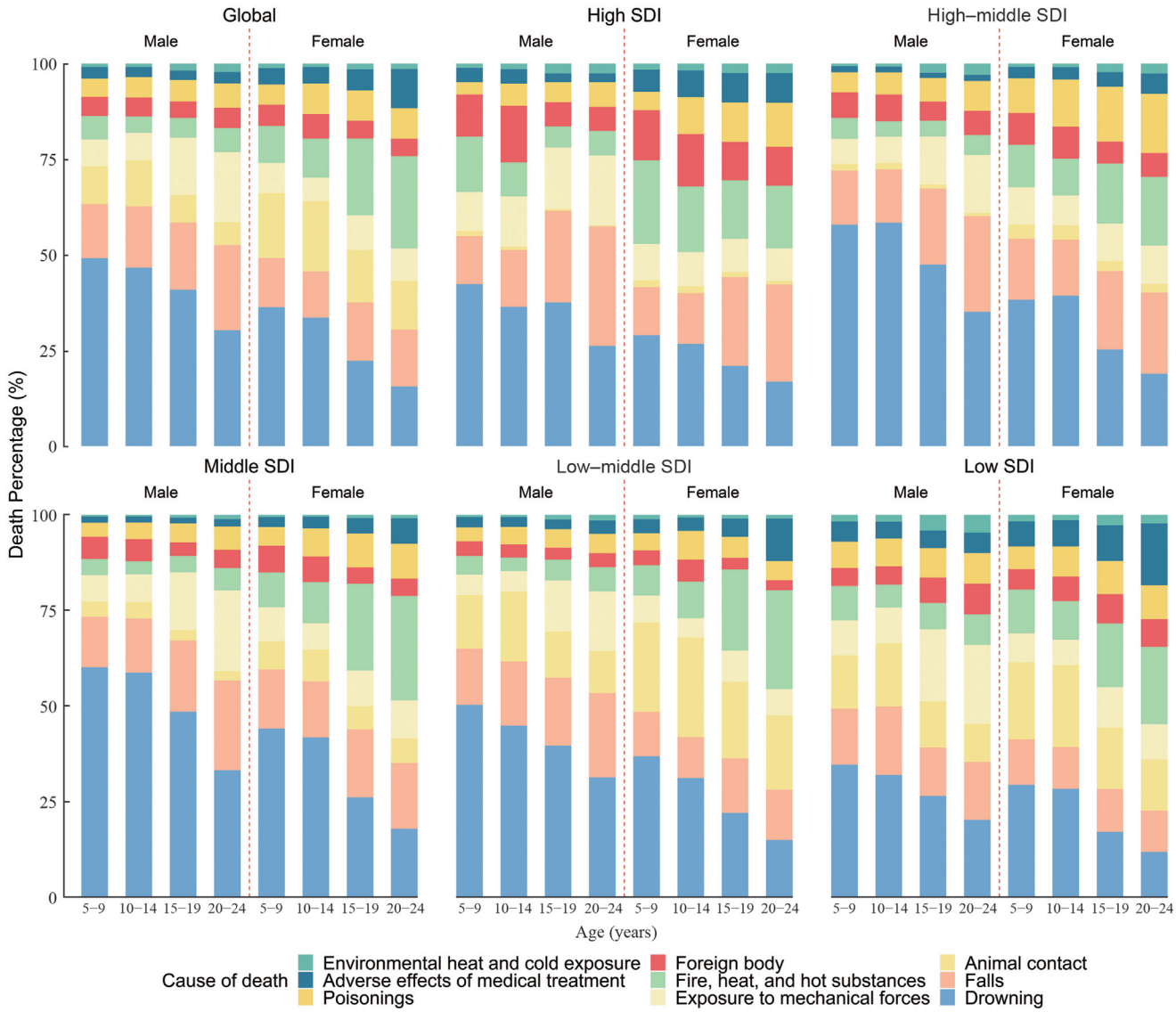

Figure 3: Cause-specific proportion in each gender and age group by SDI quintiles in 2019. Death due to "exposure to forces of nature" and "other unintentional injuries" was excluded. SDI: Socio-demographic index.

had a higher "−SII" than the male group (5.97 per 100,000) in 1990, which indicated that female mortality was more relevant to SDI than male mortality, and the gap narrowed in 2019. The degree of inequality rose with age and decreased in 2019. The overall trend of "−SII" declined from 7.77 (95% CI: 4.61–10.93) per 100,000 to 3.61 (95% CI: 2.29–4.93) per 100,000, and the obvious downward trend was consistent in all subgroups except Latin America and Caribbean and Sub-Saharan Africa. However, as we observed in "1/RII," CI was not as optimistic as SII. The "1/RII" and CI were relatively stable in global trends and all subgroups [Table 2, Supplementary Figure 3, http://links.lww.com/CM9/B219]. Inside-country analysis showed similar trends [Supplementary Figure 4, http://links.lww.com/CM9/B219].

Sensitivity analysis

When we used all kinds of NTUIs in the APC model, panel data regression, and inequality analysis, the results were similar [Supplementary Figures 5–7, http://links.lww.com/CM9/B219, Supplementary Tables 3 and 4, http://links.lww.com/CM9/B219]. After we used HDI as a substitute for SDI, we found that the result was also consistent with previous results. The degree of inequality showed a declining trend when we used the SII as the judging criterion and the RII and CI did not [Supplementary Tables 5, http://links.lww.com/CM9/B219, and 6, http://links.lww.com/CM9/B219, Supplementary Figure 8, http://links.lww.com/CM9/B219].

Discussion

Our study reported the trends of NTUIs mortality globally and the regional differences across countries by using data from the GBD 2019 study. An over 50% reduction in ASMR of NTUIs among children and adolescents aged 5 to 24 years was found during the past decades. The degree of absolute inequality also declined by over 50% during the past decades. However, the situation among children

Table 1: The association between NTUIs mortality rate and SDI, by gender, age group, and region.

Group (*n*)	β-coefficient (95% CI)	SE	*P* value
Global (6120)	−3.49 (−3.58 to −3.41)	0.043	<0.001
Male (6120)	−3.53 (−3.61 to −3.44)	0.044	<0.001
Female (6120)	−3.49 (−3.57 to −3.40)	0.042	<0.001
Age			
5–9 years (6120)	−4.65 (−4.76 to −4.55)	0.053	<0.001
10–14 years (6120)	−3.75 (−3.84 to −3.66)	0.047	<0.001
15–19 years (6120)	−3.12 (−3.21 to −3.03)	0.047	<0.001
20–24 years (6120)	−2.86 (−2.95 to −2.77)	0.045	<0.001
Regions			
East Asia and Pacific* (1110)	−3.88 (−4.07 to −3.69)	0.097	<0.001
Europe and Central Asia* (1560)	−7.26 (−7.47 to −7.04)	0.109	<0.001
Latin America and Caribbean (1050)	−3.66 (−3.87 to −3.45)	0.106	<0.001
Middle East and North Africa* (630)	−2.72 (−2.85 to −2.60)	0.064	<0.001
North America* (90)	−6.76 (−7.41 to −6.11)	0.331	<0.001
South Asia (240)	−3.05 (−3.26 to −2.84)	0.109	<0.001
Sub-Saharan Africa (1440)	−1.88 (−1.98 to −1.77)	0.054	<0.001

N indicates sample size of association analysis. Death due to "exposure to forces of nature" and "other unintentional injuries" was excluded. The β-coefficient represents that the ASMR will decline for $(1 - e^{0.1 \times \beta\text{-coefficient}}) \times 100\%$ for every 0.1 increase in SDI. * In East Asia and Pacific, Europe and Central Asia, Middle East and North Africa, and North America, we chose the random-effect model because the *P* value of the Hausman test >0.05, while in all remain group we chose the fix effect model. ASMR: Age-standardized mortality rate; CI: Concentration index; NTUIs: Non-transport unintentional injuries; SDI: Socio-demographic index; SE: Standard error.

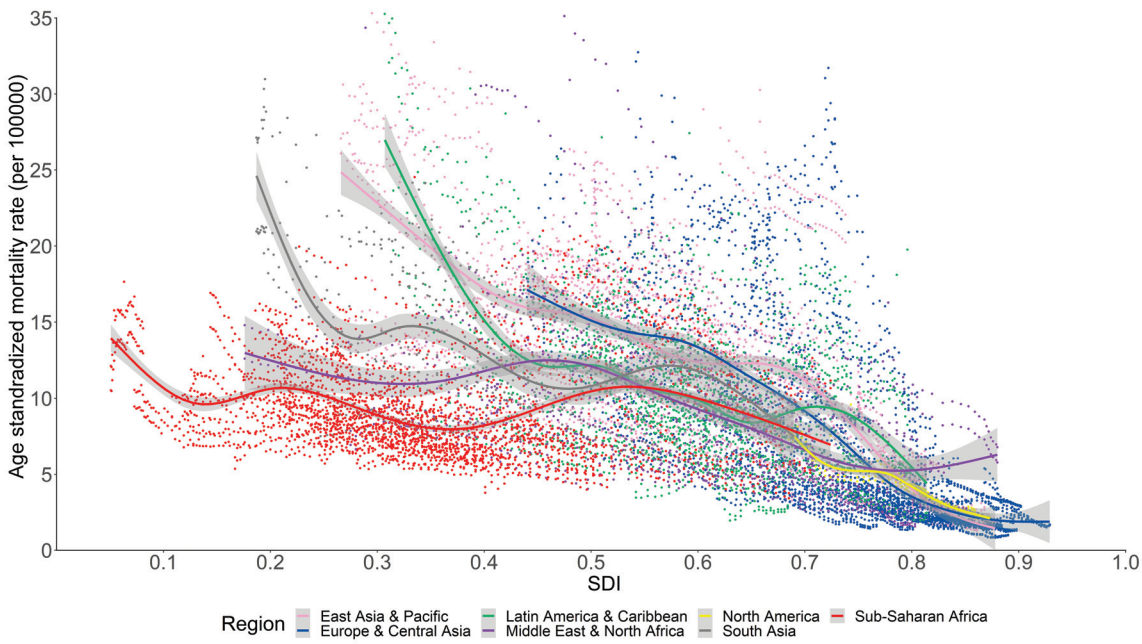

Figure 4: Country-level association between ASMRs of NTUIs and SDI in 1990–2019, by region. Death due to "exposure to forces of nature" and "other unintentional injuries" was excluded. Only one point which represents Tuvalu in 2000, with ASMR 115.48 per 100,000, was not shown in the figure. ASMR: Age-standardized mortality rate; NTUIs: Non-transport unintentional injuries; SDI: Socio-demographic index.

and adolescents living in low and low–middle SDI countries was not optimistic for the huge loss from NTUIs. In addition, the degree of relative inequality remained stable during the past 30 years, which indicated that we should still take intervention measures for those suffering social-economic disadvantages.

Globally, the ASMR of NTUIs among children and adolescents aged 5 to 24 years showed declining trends with fluctuation, which was consistent in each SDI group and almost every country. The significant increase in ASMR in 1991, 2004, 2008, and 2010 might correspond to several severe natural disasters, such as cyclone, earthquake, and tsunami.[22-25] When we excluded the death caused by "exposure to forces of nature" and "other unintentional injuries," we found a steady downtrend in each SDI group, which indicated a great achievement in injury prevention worldwide.

Table 2: The changes of SII, RII, and CI, by gender, age group, and region, in 1990 and 2019.

Group	1990			2019		
	−SII (95% CI) (1/100,000)	1/RII	CI	−SII (95% CI) (1/100,000)	1/RII	CI*
Total	7.77 (4.61–10.93)	1.69	−0.09	3.61 (2.29–4.93)	1.67	−0.08
Male	5.97 (1.54–10.40)	1.33	−0.05	3.52 (1.75–5.28)	1.45	−0.06
Female	9.63 (7.23–12.03)	3.11	−0.18	3.96 (2.75–5.18)	2.46	−0.14
Age						
5–9 years	12.52 (7.03–18.01)	1.92	−0.10	5.33 (3.89–6.76)	2.21	−0.12
10–14 years	6.27 (3.44–9.09)	1.68	−0.08	4.03 (2.81–5.25)	2.02	−0.11
15–19 years	5.32 (2.67–7.97)	1.51	−0.07	2.24 (0.88–3.61)	1.39	−0.05
20–24 years	5.79 (2.65–8.93)	1.50	−0.06	3.32 (1.40–5.23)	1.45	−0.06
Regions						
East Asia and Pacific	17.06 (12.23–21.90)	2.86	−0.12	3.95 (0.94–6.96)	1.73	−0.08
Europe and Central Asia	8.91 (2.44–15.37)	2.48	−0.14	6.57 (3.44–9.70)	5.71	−0.23
Latin America and Caribbean	4.19 (−0.30–8.68)	1.39	−0.05	4.94 (1.76–8.12)	2.34	−0.13
Middle East and North Africa	−2.82 (−12.32–6.68)	0.82	0.03	−1.30 (−5.85–3.25)	0.82	0.04
North America	2.13 (1.57–2.68)	1.45	−0.02	0.82 (−0.05–1.70)	1.40	−0.01
South Asia	−12.07 (−26.25–2.11)	0.52	0.06	−2.71 (−7.07–1.66)	0.75	0.03
Sub-Saharan Africa	3.32 (−0.07–6.72)	1.43	−0.06	2.97 (1.45–4.49)	1.62	−0.08

SII represents the absolute mortality rate difference between the lowest SDI group and the highest SDI group, RII and CI represent relative mortality rate difference. Death due to "exposure to forces of nature" and "other unintentional injuries" was excluded. CI: Concentration index; RII: Relative index of inequality; SDI: Socio-demographic index; SII: Slope index of inequality.

In our study, males had a higher ASMR of NTUIs than females, which was consistent with most previous studies.[1,26-28] We also discovered that males had a higher proportion of drowning, falls, and exposure to mechanical forces than females, while females were more vulnerable to fire, heat, and hot substances. The prefrontal cortex immaturity was the basis for the rise in risk-taking behavior, which was a product of an imbalance between biologically driven increases in novelty and immature self-regulation.[29] Compared with males, females tended to be more anxious and risk-averse when faced with stress.[30] It could be the reason that males are more likely to develop risk-taking behaviors than females. Moreover, males could be more impulsive and easier to expose to hazards within occupations than females, which might be the reason for the difference between genders.[4,6,26] Safe living environment and working environment should be provided according to the occurrence of NTUIs for children and adolescents of different genders.

Globally, we found that children aged 5 to 9 years had the highest mortality rate and highest annual change percent of mortality rate, and they both decreased with age. We also found that the mortality of children aged 5 to 9 years was most affected by SDI. They were the most vulnerable group among the four age groups,[14] but they would obtain the largest gains if some measures preventing NTUIs were taken, which could be an explanation of the phenomenon we found in this study.

Most of the previous studies indicated that children and adolescents in LMICs suffered huge losses from NTUIs.[3-9] In this study, we obtained a similar result: children and adolescents from low and low–middle SDI countries and territories suffered greater losses than those from high and high–middle SDI countries and territories. In addition, we further discovered that children and adolescents from the low–middle SDI group instead of the low SDI group had the highest ASMR of NTUIs, but the estimates dropped rapidly, while the low SDI group had the second highest ASMR and the lowest annual change percent of ASMR during the past decades. In addition, the number of deaths in the low SDI group showed an increasing trend in the past three decades. There were multifactorial reasons for these interesting phenomena. The six of the top ten causes of death in low-income countries were communicable diseases, and neonatal conditions,[31] indicating that these countries were suffering more from communicable diseases instead of injuries, which could be the explanation for the result that children and adolescents in the low SDI countries and territories had lower ASMR and annual change percent of NTUIs than those in low–middle SDI countries and territories. A reduction in death would be the result of measures preventing injuries and better access to medical care after an injury. However, the increasing number of deaths reminded us that we should pay more attention to children and adolescents in low SDI countries and territories and take action to minimize the likelihood that they would suffer larger losses from NTUIs with social development and the decline in communicable diseases.[32]

In comparison to the high and high–middle groups, although the low and low–middle groups had the similar proportions of drowning, falls, and exposure to mechanical forces, they undertook substantially greater death burden, which might be attributable to precarious living and working conditions, inadequate adult supervision, limited first aid awareness, insufficient safety equipment, and inadequate health service.[3] Additionally, some causes of death, that was, animal contact, had a low proportion in the high and high–middle groups, but a large proportion in low and low–middle groups, meanwhile foreign body and poisonings occupied a higher proportion

in the high and high–middle SDI group. Therefore, we should provide safer living and working conditions to those in low and low–middle groups, as well as provide easier access to quality emergency trauma care, animal vaccination, and vaccine stockpile.[3,33] In the meantime, health education for children and adolescents and their guardians was required in all SDI groups, which would promote the awareness of injury prevention and reduce the occurrence of NTUIs, such as foreign body and poisonings.

The relative inequality has persisted for the past decades, although most countries and territories had made great achievements in regard to the prevention of NTUIs in children and adolescents, and thus the absolute gap between different countries and territories has narrowed. The ASMR of children and adolescents was negatively correlated with the SDI because a higher SDI value represented a stronger national economy and a higher average educational level, which has been proven to be related to the decline in mortality by existing research.[34-36] Social development could also be an explanation for the decline in absolute inequality during the past decades. However, persistent relative inequality reminded people to pay more attention to low, low–middle SDI countries and territories, especially to countries with large numbers of children and adolescents, such as China and India. A significant improvement in the global average health level could be observed if we take more actions to decrease the NTUIs among those from low and low–middle SDI regions.

Previous studies have indicated the precaution we should take to reduce death, and there are different interventions for each type of NTUIs.[28,37] In this study, we found the target groups that need our attention. Despite the declining trend of the mortality rate and the decreasing degree of absolute inequality in the past 30 years, relative inequality between countries had almost no improvement. The mortality rate remained high among people who experienced social-economic disadvantages in 2019, which indicated that there would be a necessity to improve the social-economic conditions of those experiencing social-economic disadvantages. We should especially focus on children and adolescents from low SDI countries and territories to prevent the rebound of mortality. Moreover, males suffered more from NTUIs than females, while children aged 5 to 9 years suffered the most, and the ASMR was most affected by the SDI in the four age groups, which reminded us that it might be effective to reduce the overall NTUIs mortality rate and further promote the whole health status of children and adolescents if we could pay more attention to these children and adolescents.

To the best of our knowledge, our study provided the first descriptions of NTUIs mortality trends globally and regional differences across countries, focusing on children and adolescents aged 5 to 24 years old. We used the data from GBD 2019, which estimated the mortality data for 204 countries and territories from 1990 to 2019, so we could explore the trend of mortality and inequality across countries. An additional strength was that we used several statistical models, which could prove each other and increase the credibility of our results.

This study had several limitations. First, we used the data of NTUIs from GBD 2019, and previous studies proposed that the injury data from LMICs were inaccurate because of the low or absent coverage of vital registration.[1,15,27,38] However, GBD used the largest data collection and statistical models to estimate it with uncertainty intervals.[1] Second, although we estimated the cohort effects using the APC model, our results were based on multiple cross-sectional data rather than cohort data. Third, we used country-level data to analyze the inequality between countries, and inequality within the country was only conducted in seven countries for sensitivity analysis due to the lack of data. Fourth, considering that many other factors were related to the ASMR of NTUIs among children and adolescents, we only used SDI, a complex index combined with information on the economy, education, and fertility rate, to explore whether it is associated with the mortality rate. HDI was used for the sensitivity analysis, which showed consistent results with SDI. More relevant social determinants should be included to explore the specific and overall profiles in future research.

In conclusion, despite the declining trend of the mortality rate and the narrowing gap between countries, there were still a large number of children and adolescents dying from NTUIs, and those experiencing social-economic disadvantages remained at high mortality, which indicated that inequality still existed. We should pay more attention to those who suffer huge losses from NTUIs, such as males, children aged 5 to 9 years, and children and adolescents in low and low–middle SDI countries. We should especially focus on the low SDI group. Although they had a lower ASMR than the low–middle SDI group, they might have a higher ASMR for NTUIs when the burden of other diseases dropped. A global research agenda on injury prevention, such as embedding injury prevention into the SDGs, might contribute to the efforts and implementation of NTUIs in countries with low and low–middle SDI, which would be beneficial to reducing the overall NTUIs mortality, promoting a safe and healthy life among children and adolescents, and further reducing inequalities to ensure that no one is left behind.

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Conflicts of interest

None.

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